Pursuing Mass Personalisation:An Identification of Strategic Management Drivers

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To my loving mother, thank you for your sacrifice.

To Jennifer for her love and support throughout this journey.

To Ade and Haymond for their support and encouragement.

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other University. This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration, except where specifically indicated in the text. This dissertation contains fewer than 60,000 words including appendices, bibliography, footnotes, tables and equations and has less than 40 figures.

Kevin Fasusi

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Abstract

This thesis explores the research gaps identified from a systematic literature review on the topic of mass personalisation, an emerging field of the enquiry. This research examines the strategic considerations Companies make when pursuing mass personalisation, using a case study methodology and semi structured interviews.

This thesis contributes to the theoretical boundary of mass customisation (MC) and mass personalisation (MPer) positioning the contingent supply chain components from Cooper et al. (1997) and Lampel et al. (1996) in a synthesised framework. This research also contributes a taxonomy of the literature and a conceptual model. Practical contributions include the understanding of strategic supply chain management and mass personalisation, through an empirical case study of four organisation. Large corporations with infrastructure that already support MC do indeed make different strategic considerations relating to the technical competency of the workforce, product architecture, and acquisition of advanced manufacturing technology when their stated aim is personalisation. The research finds that the pursuit of personalisation is markedly different from the individualisation promised by mass customisation. Large organisations that are seeking to personalise products from a mass customisation background, retain the economies of scale associated with MC. These Companies leverage their infrastructure for personalised products, however, this does not have to be the case, and in fact, the organisation's size before pursuing MPer and their product complexity are critical factors for the organisation's reliance on MC economies of scale. Typically these companies are the first foray into MPer and are considered risky ventures.

The research concluded that mass personalisation, distinct from the individualisation found in MC literature, is in its infancy and as such may look very different in the near-future. The conclusions of this thesis support the possibility for further empirical validation of the role organisation size and current product variety play in the type of MPer pursued.

Keywords: Mass Personalisation, Mass Customisation, Engineer-to-Order, Systematic Literature Review, Bayesian Classifier

Publications Arising From Thesis

Sharif, A.M. and Fasusi, K. (2016). "Strategic enterprise imperatives for Industry 4.0 : the Mass Personalisation revolution". Submitted to *Journal of Enterprise Information Management*

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Glossary of Terms

Acronyms / Abbreviations

ATO Assemble-to-Order

BOM Bill of Materials

BTB Business-to-Business

BTC Business-to-Customer

CAD Computer Aided Design

CAPP Computed Process Planning

CODP Customer Order Decoupling Point

DFM Design For Manufacture

EDI Electronic Data Intergchange

ERP Enterprise Resource Planning

ETO Engineer-to-Order

FGI Finished Goods Inventory

FP Form-postponement

IS Information Systems

JIT Just-in-Time

MC Mass Customisation

MP Mass Production

MPer Mass Personalisation

MRP Material Requirements Planning

MRPII Material Resource Planning

MS Manufacturing Strategy

MTF Make to Forecast

MTO Make-to-Order

MTS Make-to-Stock

OEM Original Equipment Manufacturer

OSI Open System Interconnection

PCA Printed Circuit Assemblies

S&OP Sales and Operations Planning

SCO Supply Chain Optimisation

SME Small to Medium Enterprises

UoA Unit of Analysis

WIP Work in Progress

1. Introduction

This chapter introduces Mass Personalisation as a field of enquiry, describing Mass Customisation and the dichotomy between product variety with low production volumes and product affordability. The case for Mass Personalisation is introduced, contrasting Mass Customisation with pure customisation . Chapter 1 also states the aims of the research and the thesis structure, as well as the background theory, data theory and focal theory.

Mechanised manufacturing and continued technological advancements have enabled the high volume production, of affordable products. Mass producers can manufacture products with either long lead times or low-cost products with short lead times (Duray, 2002). However, the marketplace has become typified by dynamism and competition (Kotha, 1996). The market of today is notoriously varied and has resulted in the shortening of product life cycles and the proliferation of product variants (Kotha, 2007).

Continuous improvements in manufacturing techniques and technologies have established a high standard for quality, consequently shifting competition towards time and customisation (Christopher, 2005; Wikner and Rudberg, 2005). Critically customers now expect customisation at an affordable price, as a standard offering where applicable. The customisation of the product to fulfil the intended use and taste of an individual consumer is a more coveted in today's marketplace. Christopher (2005), stated:

> "*Not only do customers want shorter lead times, but they are also looking for flexibility and increasingly customised solutions.*"
>
> Christopher (2005, pp.38)

Organisations have, therefore, become focused on satisfying consumers' increasingly short lead-time expectations reliably (Christopher, 2005). Servicing the current demand of the market requires an alignment between the means of production and the operations strategy. The misalignment of a mode of production and operations strategy causes problems for the efficient production and distribution of products (Reichhart and Holweg, 2007). Reichhart and Holweg (2007) commented on the impracticality of Mass Production (MP) practices and the prevailing trend of increased product differentiation stating:

> "*The former development creates severe operational problems for traditional make-to-forecast or push strategies, as firms require large amounts of finished goods inventories to ensure customers find the specification they are looking for*"
>
> Reichhart and Holweg (2007, pp.3)

MP's reliance on the warehousing of finished goods inventory (FGI) is impractical when dealing with combinatorially large numbers of product configurations. The impracticality of stocking thousands or even millions of product variants to meet forecasted demand stems from the requirement for vast warehousing space and significant capital expenditure. The inefficiency is increased further by the associated risk of forecast error and the *bullwhip effect*. The *bullwhip effect* is the propagation of supply chain inefficiencies along the distribution channel in response to shifts in customer demands. It is clear that the production of low-volume and high-variety (i.e., customisable) affordable products presents a challenge. MP is categorically not a strategic fit for resolving the dichotomy between affordability and low productions runs; Mass Customisation (MC) has therefore shown promise. Unfortunately, Mass Customisation focuses less on *pure customisation* and the provision of personalised products; instead MC is more focused on the delivery of a greater combination of features to increase variety. There seems to be a conundrum; MC has not delivered truly individualised products, and the provision of variety is complex and costly, yet the marketplace seems determined to achieve the personalisation of goods and services. Advancements in manufacturing technology such as additive manufacturing continue to reduce the cost and lead time of products and challenge convention. Concurrently technological progress in communications technology is increasing collaboration between supply chain tiers and customers, lowering the cost of customer collaboration and customer co-creation. Cloud computing The synergy of advancements in manufacturing and communication technology is reducing the barriers to providing personalised products, with mass produced prices and lead-times (Kumar, 2007a,b). The extant literature extensively covers MP and MC, while Personalisation literature is scant. This doctoral research and thesis, attempts to investigate Mass Personalisation as a empirical phenomenon, describe the 'state of the art' and explore the implications for strategic supply chain management.

1.1 Defining Mass Customisation and Mass Personalisation

Davis (1987, cited in Piller 2007) defines MC as delivering:

> "*individualised product to each customer quickly and affordably as a result of integrating flexible and agile processes*"
>
> Davis (1987, cited in Piller 2007, p631)

MC is the provision of product variety, based on the augmentation of a core product. Although customisation is part of the product offering, MC remains affordable for the end customer and economical for the producer Jiao and Tseng (2004). MC shares similar mass production efficiencies to standardised non-differentiated products (Ahlstrom and Westbrook (1999); Silveira *et al.* (2001); **?**).

Mass personalisation (MPer) is defined by Kumar (2007a) as:

> "*...a limiting case of Mass Customisation. Whereas both of these strategies are guided by the criterion of product affordability consistent with Mass Production efficiencies, the former aims at a market segment of one*."
>
> (Kumar, 2007a, 536)

MPer is similar to MC in that it too seeks to provide a variety of affordable products to the end customer. However, MPer differs from MC in regards to the focus on individual customer requirements instead of a market segment. In Section 1.2 we further explore the importance of this distinction and make a case for MPer as distinct from MC.

1.2 The Case for Mass Personalisation

Fordism is often cited as contributing to the critical success of MP and credited is with popularising the modern mass production system (Pine and Gilmore, 2011). The production efficiencies resulting from the efficient production operations, lead to economies of

scale and low-cost products. The logic has been simple, where standardised product design, production and distribution are seen as a conceptual whole (Lampel and Mintzberg, 1996).

The economies of scale were derived from the adherence to highly standardised practices and processes, resulting in highly regulated products. Forecast-driven products made-to-stock (MTS) as a mode of order fulfilment, is central to MP.expectation of customers

According to MP any mode of production not guided by the principle of standardisation eroded these efficiency gains. Wikner and Rudberg (2005) have indicated that individualisation became antithetical to mass production and was much derided at the time (Lampel and Mintzberg, 1996). In summary, MP produces highly standardised products at low cost with high efficiency. MP is facilitated by strong statistical control and in its purest form:

1. Reduces the impact of demand variability;

2. Simplifies and streamlines businesses interaction with consumers.

The stability of product and process leads to a reduction in variability while cost reductions are accrued from the learning curve and subsequent reduction of wastes (time, materials, etc.) (Vollmann *et al.*, 2005). Building standardisation into products and their supply chains remained an important enabler of achieving economies of scale.

Excellence in production introduced quality as an important differentiator, affecting how the customer valued the product; artisanal products catered to this market. However, the commoditisation of the product allowed the price to become the focus of competition and standardisation provided little differentiation.

Product variety is, now, in many cases mandatory for customers to take a product offering into consideration. In essence, the provision of variety has become what is known as an 'order-qualifier' (Christopher, 2005; Harrison and van Hoek, 2005; Mason-Jones *et al.*, 2000). An order qualifier being defined as a market factor regarded as an 'entry ticket'(Harrison and van Hoek, 2005). As mentioned previously in the introduction, increasingly stocking large quantities of various SKU's can become impractical. Managing the provision of a large variety of SKU, so as to avoid the impracticality mentioned earlier, creates complexity. An increase in the difficulty of predicting customer demand is a well-

documented complication that occurs in the supply chain. An inability to make accurate forecasts causes production planning difficulties (Fisher, 1997). Postponing the final configuration of goods, known as form postponement (FP) , has become a necessary method for delivering customised products within the lead-time expectation of customers (Forza *et al.*, 2008). To manufacture a widget when a client has placed an order is an ideal proposition. A production and engineering lead time greater than total expected lead time of the customer, according to traditional operations theory should be made to stock (MTS) especially if availability is an order qualifier for this product (Dekkers, 2011; Slack and Lewis, 2002; Vollmann *et al.*, 2005). As Wikner and Rudberg (2005) highlighted the choice of the manufacturing process is intimately related to the point of order entry by a customer (Selldin and Olhager, 2007). Despite the importance of the alignment of operations strategy, supply chain typology and manufacturing techniques and technology, there is little literature that systematically explores their relationship in the pursuit of personalisation.

In contrast to standardisation, personalising products require that each process is seen as an individual transaction (Kumar, 2007b). This disaggregation of product, process and distribution, diverges from the norm of a tightly specified and consistent product, manufactured and produced in the same way, over successive production runs and retailed via the same singular channel. Increasing product variety complicates the supply chain (Christopher, 2005). Empirical evidence of the state of the art in the strategic focus of organisations satisfy varying levels of product personalisation, while minimising the effect on the supply chain, is an exciting area of research with a paucity of literature. Understanding whether the strategic decisions at senior management level are similar to MC or indeed different when pursuing personalisation of products, is a fundamental aim of this thesis.

The provision of variety, either through augmenting a standard product or acquiring the capability to produce different products every time, makes traditional MTS impractical. The large quantity of finished goods required to satisfy demand would require substantial amounts of working capital, storage space and increase an organisations exposure to the risk of obsolescence. Reichhart and Holweg (2007) cited the case of Mercedes Benz E Class Salon car, available in more than three septillion variations. The impracticality of

stocking such a quantity of physical stock keeping units (SKU) highlights the intuitiveness of pursuing form postponement and differentiation of products closer to customer order entry. Reichhart and Holweg (2007) commented on the impracticality of Mass production, regarding the prevailing trend of increased product differentiation stating:

> *"The former development creates severe operational problems for traditional make-to-forecast or push strategies, as firms require large amounts of finished goods inventories to ensure customers find the specification they are looking for"*
>
> Reichhart and Holweg (2007, pp.7)

Due to the impracticality of holding large quantities of finished goods inventory (FGI), many industries do not view product, process and delivery as one standard transaction. Figure 1.1 illustrates the conceptualisation of product, process and distribution as a kernel or basic unit of consideration.

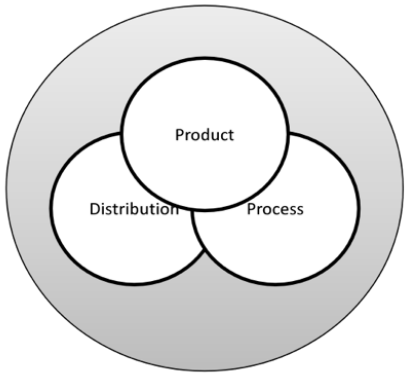

Figure 1.1: Standardised Product and Process (adapted from Lampel and Mintzberg (1996))

Decisions made by senior managers with a view of product, process and distribution as one issue to contend with, will invariably miss opportunities to augment either product, process or distribution to support increased product variety. Successfully supporting an extensive product range in a supply chain requires that organisations treat product, process and distribution as individual transactions with scope for modification as illustrated in Figure 1.2.

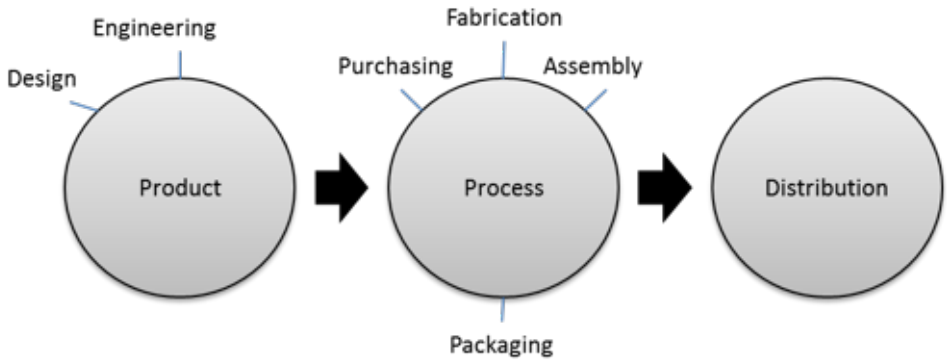

Figure 1.2: Dissagregation of Standardised Product and Process (adapted from Lampel and Mintzberg (1996))

In Figure 1.2 product, process and distribution are disaggregated. In the view of the product, process and distribution illustrated by Figure 1.2, separate considerations can be made for each step. Products are designed in such a way as to meet specific process requirements, like delayed assembly until receipt of a customer order. In this context, the products are said to be postponed. Form Postponement a strategy discussed later in section 2.6.1 that helps customise products.

Often the products have a substantial amount of input from the customer, as such the tailoring process reduces the possibility for resale in the open market; often specific functionality has been designed or configured into the resulting product Poulin *et al.* (2006). Internal process is set up to provide affordable product, for example, batch manufacturing, purchasing of sub-assemblies for just-in-time (JIT) assembly.

The personalisation of products and services, from a supply chain perspective, has its roots in Mass Customisation (MC) literature (Ahlstrom and Westbrook, 1999; Davis, 1987; Haug *et al.*, 2009; Kumar, 2007a,b; Pine and Davis, 1999). Ahlstrom and Westbrook (1999); Gilmore and Pine (1997); Hart (1995); Piller (2007); Silveira *et al.* (2001), acknowledged the customisation of products and related services, as a means of providing product variety. However, the extant literature lacks a consensus on the extent to which MC is a strategy for providing *individualised* products (Gosling and Naim, 2009; Holweg, 2005; Kumar, 2007a,b; Wikner and Rudberg, 2005).

Achieving MC requires Form postponement (Fp). Fp is the deliberate delaying of a products assembly at different stages of production (Forza *et al.*, 2008). The postponement of the assembly of goods affords the organisation the ability to minimise final inventory of finished products. Customer orders will be fulfilled based on a demand signal. Understanding this process informs the manufacturing strategy, allowing organisations to assemble-to-order (ATO), make-to-order (MTO), build-to-order (BTO) efficiently (Hill, 1993; Hilletofth, 2009). Theoretically, these typologies are rooted in contingency theory, discussed further in Section 2.2, and the supply chain model presented by Cooper *et al.* (1997) and have informed much of the discussion around the alignment of manufacturing strategy and supply chain design. An empirical study into the effects of strategic decisions required to pursue MPer is of significance because it challenges some of the traditional views of supply chain structures, manufacturing strategy specifically the application of form postponement and the alignment of supply chain design and manufacturing strategy.

1.3 Aim

A Framework that captures the nuance of strategic decision making, as it pertains to the pursuit of personalised products, is a difficult proposition. Strategic decisions respond to a variety of variable, impacting the choices made. However in their continued pursuit of ways to reduce cost, shorten product development times and manage risk (Hicks and McGovern, 2009; Hicks *et al.*, 2000), core tenet may exist that inform the decision-making process and are unique strategic considerations for personalisation that differs from customisation.

The aim of this research is to study the efficacy of mass personalised products and services, using a semi-structured interview protocol. The study seeks to explore and describe the state of the art in supply chain management (SCM) strategy when product personalisation is a stated goal by an organisation.

1.3.1 Research Objectives

Four objectives, embrace the aim of this thesis. The goals listed have provided guidance in the execution of this research project. The primary aims are to:

- Identify and describe Mass Personalisation as separate fields of inquiry from Mass Customisation and delimit its scope in an SCM context, through a systematic literature review;
- Explain the decisions and considerations in supply chain management necessary when pursuing Mass Personalisation of products and services, through an analysis of in-depth case studies;
- Critically examine and evaluate the emerging themes from industry and compare the state of the art and emergent themes with current topics in the literature using a thematic framework with conjectures and propositions;
- Develop and evaluate the contingent strategic requirements for pursuing personalisation in supply chain management, through a thematic framework based on empirical data.

The aforementioned research objectives, align with the questions posed at the end of section 1.2. The following paragraphs will briefly describe how each issue raised at the end of section 1.2, aligns with the aforementioned objectives.

The first question posed at the end of section 1.2, seeks to identify whether practitioners acknowledge a critical difference between MPer and MC. The corresponding research objective aims to detect and describe Mass Personalisation as a field of inquiry. The objective assists in answering the first question posed at the end section 1.2, by providing a definition of the phenomenon of MPer from a systematic review of the literature. The definition of MPer is applied to empirical data from the case study respondents, to delimit the scope of Mass Personalisation in an SCM context.

The second questions at the end of section 1.2 seek to understand the strategic implications for supply chain and the manufacturing function when pursuing Mass Personalisation.

The corresponding objective aims to describe the decisions and considerations in supply chain management when seeking Mass Personalisation. Analysing the respondents from a case study methodology provides a primary source from which to investigate the strategic implications and subsequently critically examine and evaluate the emerging themes.

1.4 Research Questions

In a positivist study good research questions, make explicit the relationship between variables, remove ambiguity and can be tested empirically (Collis and Hussey, 2013). In an interpretivist study research questions can take the form of a *"grand tour"* question, these are single research question posed in a general way (Collis and Hussey, 2013). This thesis is an interpretivist study using a case study research strategy, outlined in section 4.3; therefore, a general question is posed and broken down into descriptive and analytical questions. Creswell (1994) advocates no more than two *"grand tour"* questions, followed by no more than five to seven subsidiary questions (Collis and Hussey, 2013). In emerging areas of research such as Mass Personalisation, a general question affords the research the opportunity to be refined through the course of the study (Collis et al., 2013). The aim of the research question should be to focus the research on a particular phenomenon, in this case, Mass Personalisation.

This thesis asks *"What are the strategic considerations for senior management when pursuing Mass Personalisation?"*. The question can be further broken down into the following descriptive and analytical questions:

- What differentiates Mass Personalisation and Mass Customisation in theory and practice?
- What are the strategic managerial considerations for supply chain management when pursuing Mass Personalisation?
- What are the effects of Mass Personalisation on supply chain design and operation?

1.4.1 What differentiates Mass Personalisation and Mass Customisation in theory and practice?

Mass Customisation and Mass Personalisation share a common goal (Kumar, 2007a,b). Mass Personalisation (MPer) is a theory that is defined by Kumar (2007b) as an extension of MC, retaining essential features such as product affordability and lead-times in keeping with MC as opposed to those found in bespoke engineer-to-order (ETO) products (Kumar, 2007a,b). It is unclear from the literature whether MC is MPer, or if MPer is a seperate phenomenon. MPer is less developed and a younger field of inquiry. Many questions remain unanswered.

1. Do practitioners acknowledge a critical difference between pursuing MPer and MC?

2. What are the strategic implications for the supply chain and manufacturing function when pursuing MPer?

The two questions raised above, also inform the development of research questions in section 1.4.

The first question is important because Mass Customisation, as coined by Davis (1987) includes the concept of product *individualisation*. The scope of definition proffered by Davis (1987), gives rise to the possibility that MPer and MC are similar, or even the same field of enquiry and the terminology is a problem of semantics. Acknowledging whether or not practitioners view the two as separate is an important question because it provides more reason to research MPer as a field of study. As mentioned earlier in this section MPer is a theory that is defined by Kumar (2007b) as an extension of MC. Some overlapping themes and concepts are to be expected. Traditional MC relies on modularity and some process standardisation (Pine, 1993b). If MPer is more akin to ETO, then expectation regarding modularity and standardisation of product and process may be wrong.

1.4.2 What are the strategic managerial considerations for supply chain management when pursuing Mass Personalisation?

The alignment of the manufacturing function with the product's process of production and distribution is critical if that product is to be managed and distributed efficiently (Wikner and Rudberg, 2005). The alignment of MC with assemble-to-order and build-to-order modes of order fulfilment is well documented in the literature (Poulin *et al.*, 2006). The subsequent importance of modular product architecture and form postponement are also well documented and discussed further in subsection 2.6.1. Understanding this relationship for MPer is important as it will help coordinate decisions through its inclusion in a framework.

1.4.3 What are the effects of Mass Personalisation on supply chain design and operation?

The choices made in the pursuit of a strategy to provide personalised products will have implications for the design of the supply chain (Balasubramanian, 2001). MPer supply chain design and operation may be similar to MC or align more with engineer-to-order supply chains. If the latter is the case, then many questions arise regarding how this supply chain achieves the stated requirement of affordability as indicated by Kumar (2007a). Other problems also become pertinent, such as:

- Is process modularity important?
- Is supply chain collaboration important?

These questions do not currently have practical answers when considering MPer (Kumar, 2007a,b).

1.5 Thesis Structure

The chapters that follow support the overall approach proposed by Phillips and Pugh (2010), explaining the background theory, focal theory and data theory.

1.5.1 Background Theory

The background theory covers the identification and analysis of the problem domain. The aim of the background theory is to demonstrate a command of the area under investigation, specifically the key developments, controversial viewpoints and limitations. A literature review, presented in Chapter 2, covers the background theory from a review of literature intersecting four core topics: Manufacturing, Supply Chain Design, Mass Customisation and Product Design. Mass Personalisation (MPer) is the focus of this research. MPer is classified as after a foundational paper by Kumar (2007a). In Chapter 2 MC and MPer are defined and disambiguated. Chapter 2 reviews the literature for supply chain structures supporting personalisation and the implications for models of order fulfilment. Therefore, the background theory in this thesis is described as literature on MPer focusing on the strategic implications for supply chain management. The literature review examines MPer as an extension of MC and engineer-to-order order fulfilment, disambiguating the definition of MC and MPer and identifying the framework through which low-volume high-variety production is feasible. This review concludes with a taxonomy of the literature in Table 3.2.

1.5.2 Focal Theory

This research gains objectivity from the systematic literature review and seeks to develop a conceptual model. Chapter 3, narrows remit of the research and clarifies conjectures and propositions for latter support by data. Hence, in Chapter 3 the importance of strategic decisions for achieving MPer are stressed. The need to reconcile product and process and supply chain capabilities is also identified, through a list of contingent factors required for MPer based on rationalising the extant literature.

From the systematic literature review, key themes are used to create a taxonomy of the literature in Chapter 3. The themes from the taxonomy are group into higher level themes from the literature that typically cover the granular themes. An automatic classification system was used, to discern between which literature to include or exclude, for the systematic review and subsequent taxonomy, The classification system uses supervised machine

learning and Naive Bayes classification to classify the literature, Appendix C describes the classifier in detail. The use of this method continued the systematic method for conducting the literature review.

1.5.3 Data Theory

The third part of a doctoral dissertation is related to the data theory. The data theory justifies the relevance and validity of the of the supporting material. In Chapter 4, conditions affecting the choice of research strategy are explored, an epistemological stance is taken and justified developing the research method. Justifications for using a multiple case study approach in Chapter 4. The core constructs of the data theory inform the research design, data collection method and a thematic analysis of the cases under study. Chapter 4 contains the empirical evidence testing and analysis.

1.6 Participant Organisations and Case Context

A key component in delivering a comprehensive piece of research is the explicit declaration of the methodology and research design. This thesis uses case studies with semi-structured interviews, culminating in a thematic analysis of data and comparison with the extant literature and synthesised framework. From an epistemological perspective, this approach uses both positivism in the collection of and interpretivism in its framing of the data.

As mentioned earlier, this research uses a case study methodology. The selection criteria for participants is important both in contextualising the research and also for making generalisations later in the conclusion. A brief word on the organisation that participated in this research. The application of MC and MPer varies across industries and organisations, this research therefore sought out organisation promoted their ability to personalise products in their literature, marketing and product offerings. The participants were selected based on their stated aim of persuing the personlisation of a specific aspect of a product, and the availability of a Director with sufficient knowledge of the organisations strategy. The incumbent was responsible for to communicating strategic requirements for tacitical and operational

execution.

1.7 Summary

Mass production has been successful at utilising mechanised manufacturing to produce quality standardised goods. However, product variety has superseded quality as the main criteria for customers considering the purchase of goods (Harrison and van Hoek, 2005). Mass customisation has supported the efficient distribution of increased product variety, through the use of Form Postponement, modular product architecture and delayed assembly of finished goods. Although MC has been successful in industry and the topic is well covered in the extant literature, the push for Personalisation of products and services has lead to the theory of mass personalisation. Mass personalisation seeks to provide product variety beyond the capabilities of MC, at an affordable price for mass consumption. The pursuit of Mass Personalisation as a proposition has several implications for the supply chain management, which extend from the constraints of Mass Customisation. Mass Customisation reduced the reliance on finished goods inventory, through the use of lean processes. Lean production is rooted in the just-in-time production systems popularised by Toyota Motor Company of Japan (Harrison and van Hoek, 2005). Lean production is a paradigm shift, as stated by Harrison and van Hoek (2005):

> "*Lean production sought to describe a radically different approach to running the business from the traditional mass production*"
>
> Harrison and van Hoek (2005, pp.155)

The lean principles taken from the automotive industry have been applied in other sectors to, reduce cost, or to increase variety, or a combination of both (Harrison and van Hoek, 2005). Mass personalisation seeks to move beyond this level of product variety, to provide bespoke products at affordable prices (Kumar, 2007b).

2. Literature Review

Chapter 2 explores the literature for the fields of enquiry that converge on Mass Personalisation. Mass Personalisation is viewed through the lens of a continuum of operational activities related to Mass Production and Mass Customisation. The chapter begins by defining the scope of the review triangulating Mass Personalisation as a field of enquiry converged on by Product Design, Supply Chain Design, Mass Customisation and Manufacturing. The disambiguation of the definitions for Mass Personalisation is provided, situating it on a continuum with Mass Production and Mass customisation. The Chapter concludes with a taxonomy of the literature based on the thematic analysis and contributions from the extant literature.

This review chapter explores the extant literature for the fields of interest that converge on MPer, as illustrated in Figure 2.1.

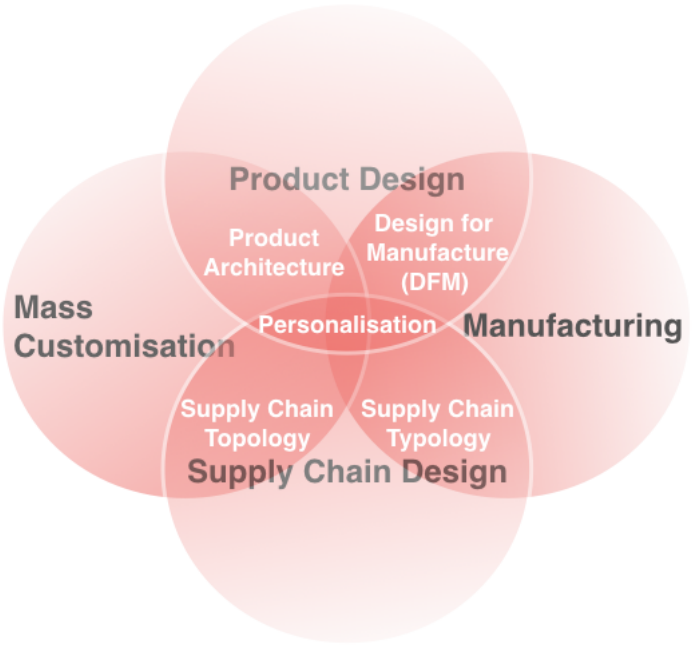

Figure 2.1: Venn Diagram: Literature Review Scope

This chapter will progress with a review of supply chain strategy, Mass Customisation, Mass Personalisation and Product Architecture. MP traditionally offers less product variety than MC, and ETO offers more variety than MC. There are two common perspectives in the literature for MC are explored. The two favoured paths are MP to MC, the movement from low to high product variety and ETO to MC the reduction of the product range to a large but ultimately combinatorially finite subset. MPer in the literature is a continuation of MC (Punch, 2000; Rahim and Baksh, 2003; Rao *et al.*, 1983; Reyes and Raisinghani, 2002) and MPer as a continuation of ETO (Kumar, 2007b). This Chapter culminates in a taxonomy of the literature.

Figure 2.1 illustrates the intersection of fields of inquiry and their convergence on the central topic, the personalisation of products in the supply chain. Other peripheral topics pertinent to the discussion will contribute to the literature review.

This literature review is predominantly concerned with:

1. The taxonomy of personalisation in the literature;
2. The theorised and practical of implications of personalisation for product, process and supply chain design;
3. The delineation, if any, between mass customisation and mass personalisation.

In the pursuit of delimiting the scope of MPer and defining its relationship with MC literature, topics found at the convergence of multiple areas of study are reviewed and synthesised. The literature review aims to:

- identify, define, critically appraise and summarise the strategic supply chain considerations and competencies required for MPer;
- Summarise the research gaps in the literature covering these topics, for the formulation of comprehensive framework and research conjectures and propositions.

This chapter will progress with a review of the extant literature for each theme identified as critical to the study. Each section will proceed with a definition, followed by a critique of relevant research and ending with a conclusion.

2.1 Literature Review Method

The research started by reviewing the literature, deducing consequence and asserting connection in the form of a conceptual model (Guest *et al.*, 2011). After a systematic review of the extant literature and comprehensive appreciation of the research, domain is required, the research need can be made explicit. Chapter3's proposed framework, propositions and conjectures are the culmination of the systematic review. The multiple case study can then test the theory through the validation, verification and triangulation of the phenomenon encoded in the thematic analysis. Figure 2.2 provides an overview of the literature review process .

Figure 2.2: Overview of literature review method Source: Authour

The research design was operationalised into a protocol and used as a tool to solicit responses and capture data to satisfy the aims of this literature. Semi-structure interviews were conducted with the aim of retrieving sensitive information regarding the strategic decisions made in the pursuit of personalisation. These insights are induced by open-ended questions affording more elaborate and roving responses where appropriate. The content of the replies is likely to divulge competitive advantages based on implementation and execution of prior strategic considerations.

The use of an interview agenda formalised the interaction between the respondent and interviewer, ensuring some consistency across all respondents. However, sufficient freedom to deviate from the agenda is also necessary, as exploratory research need to be able to deal with the new ideas and themes. Additional evidence is recovered through company specific documentation and published reports.

A systematic literature review protocol was followed to collect, exclude and synthesise a corpus of relevant academic literature. A systematic literature review differs from traditional narrative or structured literature reviews by:

> "...adopting a replicable scientific and transparent process...that aims to minimise bias through exhaustive literature searches of published and unpublished studies and to provide an audit trail of the reviewer's decisions, procedures and conclusions."(Tranfield *et al.*, 2003, pp.208)

The following is a detailed description of the literature review methodology including the bespoke tools used herein. A full explanation is provided for the use and design of the bespoke tool, instead of the use of off the available shelf alternatives, where such existed.

The systematic literature review needs to be a logical process (Tranfield *et al.*, 2003). To aid in that goal several key steps where taken:

1. Keywords - The selection of keywords was used to specify terms for construction search strings to use in interrogating the databases;

2. Search Strings - The construction of search strings were used to narrow the scope and limit the response from the databases;

3. Searching Database - A search of databases containing the journal articles;

4. Exclusion Criteria - The exclusion criteria were used for the first database, then documents sorted into relevant irrelevant and used to train the supervised document classifier for each search string;

5. Supervised Document classification - Using a bespoke program to sort literature;

6. Argument analysis - discuss database application;

7. Theme analysis - A bespoke database was used to tag sections of text based on the theme and part of argument analysis.

2.1.1 Keywords

Keywords limit the articles returned when used to search for literature in journal databases. A strict set of keywords can reduce the quantity of returned publications, to a subset focused on a topic. Personalisation is an emerging theme in supply chain literature. To explore related topics, appropriate keywords are selected.

Initial themes were selected from a cursory exploration of the interrelated fields of enquiry, indicated by well cited and established concepts, theories and practices in current supply chain literature. The keywords were necessary for later defining search terms and constructing search strings and are tabulated in Table 2.1.

The focus of this thesis were on the implications for supply chain strategy when seeking to provide Mper products. The state of the art in engineer-to-order (ETO) supply chains seemed a logical place to start looking.

The search terms are synonyms or acronyms, used to compile search strings. Also, a wildcard character is used to instruct the database provide all variants of a word. The wildcard is an asterisk symbol (‘*’) and is employed in this research to ensure that articles with the keyword’s specified root and various suffix are captured.

The specified search strings, instructs the search engine to find papers which include the alternative terms. Retrieving articles from the academic databases in this manner increases

Keyword	Search Term
Engineer-to-Order	(Engineer-to-order) OR (ETO)
Mass Customisation	(mass customi*) OR (customer co-design*) OR (customer co-creation*)
Mass Personalisation	(mass personali*)
Supply Chain Design	(supply chain design*) OR (supply chain strate*) OR (supply chain architectur*) OR (supply chain manage*) OR (supply chain plan*) OR (SCM) OR (SCS) OR (supply chain manag*) OR (supply chain typolog*) OR (supply chain classi*) OR (Supply chain taxonom*)
Product Design	(product develop*) OR (product design*) OR (product engineer*) OR (product architecture*)
Flexible Manufacturing	(flexible manufacture*)

Table 2.1: Search Strings

the expansiveness of the search, while simultaneously narrowing the possible results of articles meeting the constraints.

Approaching the literature search with explicitly specified keywords and search terms ensures that the research compiling the corpus reviewed in the subsequent chapter is capable of being audited. Any research replicating the method outlined and using the databases, search terms specified and exclusion criteria discussed in Subsection 2.1.4, will be capable of retrieving the same articles. A brief explanation for the choice of each initial Keyword follows.

2.1.2 Search Strings

The identified keywords were used to create the search strings used to query the journal databases. Different variations of the keyword are captured with the operand 'OR' and used to create the search terms as strings in Table. These variants are synonyms and acronyms and instruct the search engine to find papers that include the alternative terms. To increase the expansiveness of the search, the wildcard represented by '*' is used. The wildcard when placed correctly, for example in place of a common suffix, will retrieve every permutation of that word from the database. The search terms are then combined to form search strings

Database	Description
Proquest	ProQuest is a leading name in the collection, publication and dissemination of information. The database provides a comprehensive list of titles and in-depth coverage of business publications.
Science Direct	Science Direct is a database archive for scientific journal puplications. The database provides coverage for over 2,500 journals and 26,000 books.
Google Scholar	Google Schlolar is a search engine curated by google which includes pubulications from major publishers as well as conference papers, white papers and uncited works.

Table 2.2: Journal Databases Source: Author

that can be used in successive searches in several databases. The search strings can be found in Appendix F.

2.1.3 Selection Strategy

A comprehensive, reproducible and unbiased search for literature requires an explicit strategy. The process followed in this thesis is detailed below. The search strategy outlines the systematic approach to the literature review process. The study was conducted using searches in digital libraries and search engines. The databases used for this study were detailed below in Table 2.2.

There are limitations to using such a strategy that should be taken into consideation. Articles published in these sources often take several rounds of editing and review, adding months to the submission process. The contents is also based on research conducted over an extended period of time before the first submission. The lead time for publication in these sources are significant for exploratory research and has, therefore, informed the types of research included and excluded from this review. The following section will detail the exclusion criteria used in this thesis.

2.1.4 Exclusion Criteria

The selection criteria specify which literature is within the scope of this research and that which is beyond its perview. Objectively filtering is an important part of the systematic literature review. While the selection of the keywords and combination of search strings will have confined the research to a particular body of knowledge, the literature that will ultimately compose the corpus of literature that is reviewed in Chapter 2, requires the application of the selection criteria. The selection criteria include; context, coverage, time frame, quality of the journal, peer review and language.

Peer review articles were included in the literature review, as they have been read and assessed by other academics and appraised for the veracity of the arguments, claims and conclusions made. However, due to the exploratory nature of the research, only focusing on such material would be restrictive. Journal articles often go through several rounds of review and editing before being published. The implication here is that the research may have been conducted much earlier. For this reason other sources of literature such as PhD thesis and conference proceedings will also be included.

The coverage of the literature describes the fields of research the literature must have some affiliation. In this research, all the articles have some element of supply chain design and customisation at the centre of their focus. Any papers that do not cover an aspect of supply chain design issues are omitted, from the review process.

The criterion of language is a common one. Due to the limits of the researcher all publications in another language, apart from English, have been omitted from the study. A vast majority of publications are published in English journals; it is necessary for a systematic review that this is made explicit. Therefore, a warning can be expressed, that this research does not know of contributions made outside of the specification in this criterion.

The time frame this research acknowledges is from 1987 onwards. The year 1987 pertinent to the topic of mass personalisation because this was when the term mass customisation was coined by Davis (1987). One of the objectives of this study is to delimit the scope of customisation about personalisation beyond mere semantics. Also, mass personalisation

seems a derivation of mass customisation. As such literature before mass, customisation is not deemed necessary to the study.

The quality of the journals included is based on the ABS guide which ranks journals with a star rating based on their quality (The Chartered Association of Business Schools, 2015). Although quality is not the only factor ranked in the ABS Guide, an alternative being impact factor, it is considered the most indicative. Journals ranked with two stars, or higher are included in the selection criteria. Traditionally 3 and 4-star journals are considered the publishers of the most critical literature. This research opens the floor to 2-star publications due to the exploratory nature of the area of study. Any publication that is without ranking in the ABS will be excluded unless heavily cited in important works.

The number of citations is an arbitrary criterion in some respects as a lack of citations does not imply a lesser publications and the opposite is also true. However, it is still deemed a viable heuristic. As a criterion on its own specifying, an explicit inclusion criterion is difficult. As stated before publication that is heavily cited (above 20 citations in 3 or 4-star publications) then it will be included.

2.1.5 Abstract Screening

Abstract screening forms another part of the selection criteria. After interrogating the databases and retrieving relevant articles, their abstract is read. Using those above 'hard' selection criteria the articles are further filtered based on the abstract. Once this has been completed the remaining articles are read thoroughly, and final exclusion is based on coverage. At this point, the method for storing and extracting information from these articles becomes a consideration. The whole process up until this point can be summarised in the flow diagram illustrated in Figure 2.3.

2.1.6 Data Extraction

The consistent appraisal and analysis of the literature in a systematic review requires some method of consistently recording and storing key elements.

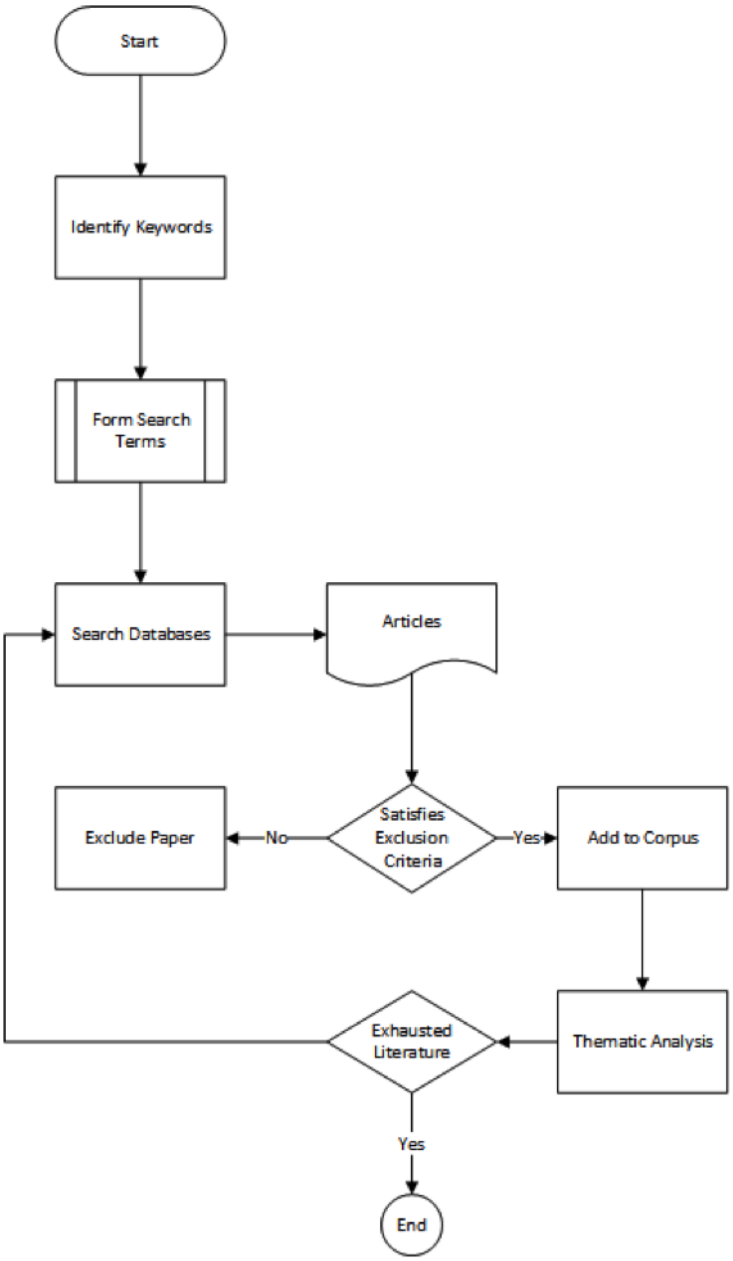

Figure 2.3: Flow Diagram for Literature Review Process Source: Author

The fields that are independent of article that should be captured are the:

- Rationale - The reason the paper has been written is stated and an explanation of the issues that the journal hopes to address;
- Arguments - The coverage of the paper is categorised and condensed in using an explicit method e.g. applied thematic analysis as in the case of this thesis;
- Context - An indication of the contextual information that is pertinent to the article that may indirectly bias the article or limit any indiscriminate inference or comparability. Contextual factors include, but are not limited to, the: sector, geography, size of the sample, the size of the company, etc;
- Research method - What method was used in the study;

Traditionally a flat file system would be used to collate this information during the gathering of the relevant literature. However due to the proliferation of computer technology and the myriad of application, both off the shelve and bespoke, academics are seeking new ways of compiling this information. It is becoming common place to use Nvivo even at the literature review stage.

Existing software, such as Nvivo, was deemed inappropriate because of the inherent lack of flexibility when choosing how to maintain relationships across the whole structured literature review and beyond into field work. Moreover, using a relational database design method affords the opportunity to relate coded text and investigate queries using a formal language in a systematic and auditable way. Information regarding the articles citation can often be managed online using 3rd party software such as reworks, which is proprietary, or Zotero, which is an open source solution. Some of the more comprehensive databases offer a save function, to store searches and citations for later export as a bibliography. However, noting key features of an article and analysing its content was not a supported feature in any of the off the shelf software as of the start of this thesis. During the course of this research, software such as Qiqqa has become available. Unfortunately, switching platforms at such a late date was unfeasible.

Objectivity and audibility of the coded content, discussed in the literature, is maintained by a relational database. Relational database design is based on set theory and predicate logic and is, therefore, a formal and mathematically exact method for enforcing some referential integrity. Allowing a database architecture to enforce such referential integrity allows the content tagged with emerging codes from the literature to be related to the content tagged with emerging codes from field data.

2.1.7 Argument Analysis

Arguments contain a structure and internal logic that can be viewed as field invariant Toulmin (2003). An argument is composed of claims, data and warrants and backing Toulmin (2003). Figure 2.4 illustrates the components of an argument. About this research, the journal articles are the data; the arguments put forward within the literature can be reduced to specific types of claims within the context of the discussion.

To make sense of the arguments as they were being constructed, a system was employed to code the literature using a method of content analysis. Argument analysis and theme analysis are used to code the literature reviewed by new topics and invariant arguments. These two approaches are useful for exploratory research. The convention followed for the invariant arguments was based on Toulmin (2003) method of argument analysis depicted in Figure 2.4.

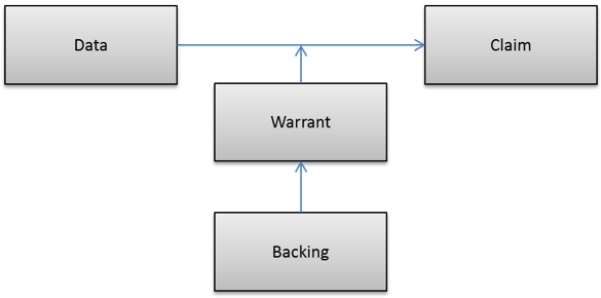

Figure 2.4: Toulmin Argument Model (Toulmin, 2003)

Toulmin (2003) explained that all arguments contain a structure and internal logic that is field invariant. A criticism of the Toulmin (2003) model of argument analysis is that it is not

Claim Type	Description
Claim of Fact	Statements that can be proven true or false.
Claim of Policy	Normative statements about what ought to be done rather than what is done.
Claim of Value	Statements that cannot be proven true or false: they are judgements about the worth of something.
Claim of Concept	Statements defining or advocating a recognisable perspective on the language used.
Claim of Interpretation	Proposals on how some data or evidence are to be used or evidence are to be understood.

Table 2.3: Types of claims in field-invariant arguments Source: Toulmin (2003)

so useful for dynamic arguments being made in real time and is instead most practically applied to understanding historic arguments. This research, therefore, played to the strengths of argument analysis by using it to categorise written arguments and not arguments made in real time. The field-invariant claims which are classified into five types as listed in Table 2.3. Claims made in the retrieved journals were listed by using these 'claim' types, making particular note of individual claims made within each paper and not attributed to another author or other authors. Each claim was coded by emergent themes. The emergent themes and arguments were used as methods for content analysis. Theme and argument analysis, are two useful methods for exploratory research. Table 2.3 describes the tags used to code emergent themes by invariant arguments.

2.1.8 Thematic Analysis of Literature

These claims were coded by emergent themes from the literature. The emergent themes were used as methods for content analysis. These two methods are useful for exploratory research (Guest *et al.*, 2011). The structure of the argument analysis used is depicted in authors was built. These claims were coded by emergent themes and invariant argument. Thematic analysis assists in identifying and describing (Guest *et al.*, 2011).

Thematic analysis is a qualitative research method used to analyses the concepts and themes. The concepts and themes are instrumental in reducing the data to key ideas. Thematic analysis involves more than counting explicit words and instead focuses on explaining

implicit and explicit ideas within the data (Guest *et al.*, 2011). To encapsulate the specific ideas in the data, text from the literature and field data are summarised as codes for later analysis. The codes behave as markers agglomorating similar text, therefore implicit in the categorisation of both literature and field data is a reference point.

2.1.9 Coding The literature

A systematic literature review was undertaken to retrieve and review the literture in this chapter. The review identified the arguments surrounding the topics of interest, higlighted at the beginning of this Chapter. During the course of this research, hundreds of articles were read. An articles' inclusion or exclusion was based on the criteria outlined in Section 2.1.4. Keeping track of the developing arguments, established theories and general discussion surrounding the topics, required a logical method for collating and coding the research. This research used both a thematic and argument based coding system to document the topics their associated arguments as discussed in Sections 2.1.8 and 2.1.7.

A database was used to collect and collate themes from the literature. The full explanation of the mechanics of the database can be viewed in Appendix G. However, since the focus of this thesis is not computer science, this section will not concentrate on the mechanics, but rather the process followed.

Collecting the themes discussed in the literature required coding article excerpts by topic. Each excerpt which received a code was a sentence or paragraph that contributed to the argument presented in this thesis. The general theme and type of evidence the extract adds to is recorded. A theme is typically a word or phrase which summarises the contribution made by the author and captured in the excerpt, while the type of argument indicates what type of claim the extract is making. Argument analysis and claims invariant to a field are explained further in subsection 2.1.7.

Table 2.4 shows an example extract from a journal publication and Appendix A.

Theme	Claim Type	Claim	Journal Author	Journal Publication Date
Lead-Time ETO Mass-Customisation	Claim of Value	... The importance of time compression is highlighted in Towill's (2003) conclusion that 40% reduction in project time can lead to a 25% reduction in total work undertaken and cost. Thus, for mass producers, mass customization can be achieved by minor product design changes, such as allowing that some components can be interchanged with others (e.g. the same component in different colours) or by offering addable components. ...	GOSLING J. and NAIM M.	2009

Table 2.4: Coding Literature

2.2 Contingency Theory and Supply Chain Design

The traditional view of a supply chain as illustrated in many models is one based on contingency theory (Cooper *et al.*, 1997; Lampel and Mintzberg, 1996). Contingency theory states that there is no single best way to achieve an optimal organisation. Instead, optimal operation is dependent (or *contingent*) on the external and internal factors. This perspective has informed many strategies and operations methodologies seeking to align separate functions for optimal performance. The coordination effort has become particularly difficult during the last half-century where time-based supply chain management strategies have become key to competition (Stonebraker and Afifi, 2004). Stonebraker and Afifi (2004) put forward a model describing four phases of supply chain technological development and uses it as the foundation of a contingency model. The model looks at intergative technologies and that trend towards more flexibility and agility. Mass personalisation is inkeeping with the general trend outlined by Stonebraker and Afifi (2004) and focuses on the efficient integration of processes and functions through the utilisation of new technologies such as additive manufacturing. Stonebraker and Afifi (2004) highlighed that technology can force differentiation and integration:

> "*For executives, the implication of this study is that the more evolved the technology, the greater the differentiation, and consequently the greater the amount of integration effort required.*"
>
> (Stonebraker and Afifi, 2004, pp.1142)

Designing and organising supply chains around contingency theory has emphasised the importance of aligning and integrating separate function and processes. Manufacturing strategy, discussed in Section 2.3 is a prime example.

2.3 Manufacturing Strategy

A manufacturing strategy is necessary for the pursuit of efficient provision of product variety. This section will discuss supply chain and manufacturing strategy (MS) in the extant

literature and relates the importance of this topic to the pursuit of personalisation and MPer.

The importance of MS can be traced back to the industrial revolution between 1820 - 1840, followed by the early twentieth-century assembly lines of Ford Motor Co. to the late twentieth-century production systems of Toyota (Spear and Bowen, 1999). Since the growth in popularity of explicit manufacturing strategies, global competition has complicated the value proposition of production. The manufacturers have experienced considerable global economic pressure to off-shore itself, due to low-cost regions affording cheaper labour forces (Christopher *et al.*, 2006). However, the labour force of developing countries is experiencing a rise in wages and improved living standards, reducing the advantages off-shore manufacturing. Simultaneously there is an increase in the advancement of manufacturing technology, changing how the function delivers a competitive advantage. Agile manufacturing has been proposed as an answer to the economic pressures facing the manufacturing function of organisation based in developed countries (Thomas *et al.*, 2012).

Organisations pursuing personalised products will require a congruent manufacturing strategy, as part of an overall business strategy. Companies across all sectors are likely seeking ways to reduce cost, shorten product development times and manage risk (Hicks *et al.*, 2000). Against the pressures of increasing business costs, manufacturers need to be able to design systems that allow for rapid and consistent delivery of new products (Thomas *et al.*, 2012). A manufacturing strategy complementing the product offerings and the market will also help avoid inefficiencies (Fisher, 1997). It is argued that the new business models are necessary to maintain a competitive advantage and that manufacturers should provide complimentary services (Thomas *et al.*, 2012).

A manufacturing strategy can be summarised as a consistent pattern of decision making that aligns the capabilities of the manufacturing function, with the business plan (Chan, 2005; Christopher, 2005; Hayes and Wheelwright, 1984). Hayes and Wheelwright (1984) separated manufacturing strategic decisions into two groupings, structural and infrastructural and formalised competing priorities of a manufacturing function. The structural arrangements include capacity, facility, technology and vertical integration. According to Hill (1993), these priorities should be separated into *order winning* and *order qualifying* criteria.

The shift in many business' strategic foci from quality to product variety in the 1970s, emphasised the importance of the manufacturing function for corporate strategy. A manufacturing strategy that supports either cost or quality will differ in implementation, and confer different implications to the supply chain strategy (Hill, 1993). As previously mentioned cost conscious manufacturers are more predisposed to seeking the economic advantages of low-cost geographical regions.

Chan (2005) discussed positioning strategy as a term denoting how a product and process are linked together. These positioning strategies are similar to the concept of the customer order decoupling point (CODP) discussed in Sub-Section 2.6. Chen *et al.* (2003) identify the fundamental positioning strategies as:

- Make-to-Stock (MTS) - Products are produced to stock as finished goods, in expectation of orders being placed.
- Assemble-to-Order (ATO) - A Product's sub-assemblies are kept in stock, awaiting a customer order before they are finally assembled-to-order.
- Make-to-Order (MTO) - A product is built from the ground up, from a standard product specification, after a customer makes a purchase.

Each of the positions is discussed later in Sub-Section 2.6. Managing the trade-off inherent in prioritising variety is important, and the alignment of the manufacturing function processes with the way product and process are linked is critical in achieving this goal Chen *et al.* (2003). The Chan (2005) conceptual framework, focuses on the positioning strategy and the importance of aligning product and process. The importance of this is a strong theme through supply chain literature. The research indicates that efficient provision of product variety, without adhering to the need for this alignment is unlikely.

Manufacturing strategy in MC is often in line with an ATO modes of order fulfilment, where products are assembled to the requirements of the customer (Forza *et al.*, 2008; Kumar, 2007b). Though the competitive landscape has resulted in manufacturers pursuing non-MTS strategies such as engineer-to-order (ETO) (Saisse and Wilding, 1997). It is unclear to what extent the manufacturing strategy differs from traditional MC. Saisse and Wilding

(1997) used the concept of turbulence from fluid dynamics, to describe the complexity of moving to more product customisation. Turbulence is classified in five categories; design, volume, mix, schedule and process (Saisse and Wilding, 1997). This conceptualisation is theoretical and did not gain as much traction in the literature as other frameworks describing the adoption of non-MTS strategies.

The supply chain literature points to three main supply chain strategies lean, agile and a *hybrid* of the two. Lean supply chains focus on reducing cost and eliminating waste. An agile approach focuses on responsiveness. Agility is often preferable in highly configured, customised and specified products.

Kumar (2007b) acknowledged the possibility of high costs being a barrier to the pursuit of Mper. Although flexible manufacturing practices and agile manufacturing systems have served effectively to produce new products at high speed and low-cost personalisation is still not the norm. A supply chain strategy with personalisation aforethought is expected to display an "agile" or "leagile" strategic focus. A lean focus is counter-intuitive, focusing on product rationalisation instead of satisfying several markets (Mason-Jones *et al.*, 2000).

Manufacturing strategy is an important consideration for pursuing Mass Customisation. It is likely that any method of production that seeks to meet growing product variety will require a carefully considered manufacturing approach. The requirements for MPer in regards to manufacturing strategy are currently unknown.

2.3.1 Affordability and Personalisation: A Manufacturing Dichotomy and Constraint

MC attempts to retain the criterion of affordability associated with mass production (Kumar, 2007a,b). There is a dichotomy inherent in the pursuit of affordable customised products. Several authors have acknowledged this dichotomy. Ahlstrom and Westbrook (1999) described mass customisation as providing customer chosen variations without significant lead-time or cost penalties. Since larger product variety increases demand uncertainty, the challenge for the supply chain and manufacturing function is to make provision for high product variety, with low operational costs and within acceptable lead-times. Previously

volume and throughput were primarily responsible for economies of scale and affordability. Manufacturers, therefore, must overcome the trade-off between flexibility and cost efficiency (Meyer *et al.*, 1989).

MC has highlighted some of the capabilities necessary for personalisation. While MC itself has not fulfilled the criteria of individualisation contingent factors such as:

- Modular product architecture - Product architecture can be defined by the degree to which components can be separated or integrated. Modular products are said to have a one-to-one relationship with architecture while integral products possess a one-to-many. The most prominent types of modularity are, slot, bus and sectional as defined by Ulrich (1995). For slot modularity, each of the various components in a slot architecture is of a different type from the other and therefore cannot be interchanged (Ulrich, 1995). An example of slot modularity is an aircraft engine. Each component fits in a specific place in a specific way and is not interchangeable. For bus modularity, all physical components connect through a standard interface (Ulrich, 1995). An example of bus modularity is the USB interface, through which a variety of different products can connect using the same interface. For sectional interfaces, the interfaces have the exact some interface and can be assembled by connecting the components to each other in one way (Ulrich, 1995). An example of a sectional modular interface is a modern sofa.

- Product configuration tool for the customers - Product configuration tools are applications that facilitate the assembly of the final product from components. Car manufacturers and sports footwear companies are typical examples of organisations that employ online applications for the configuration of goods.

Figure 2.5, provides an illustrative overview of the dimensions the different manufacturing function and process types. The dimensions include volume, variety, and process task and flow. The implication of this illustration is the satisfying individual consumer requirements with products carrying mass-produced prices problematic.

Project and jobbing manufacturing operations are very different to that found in con-

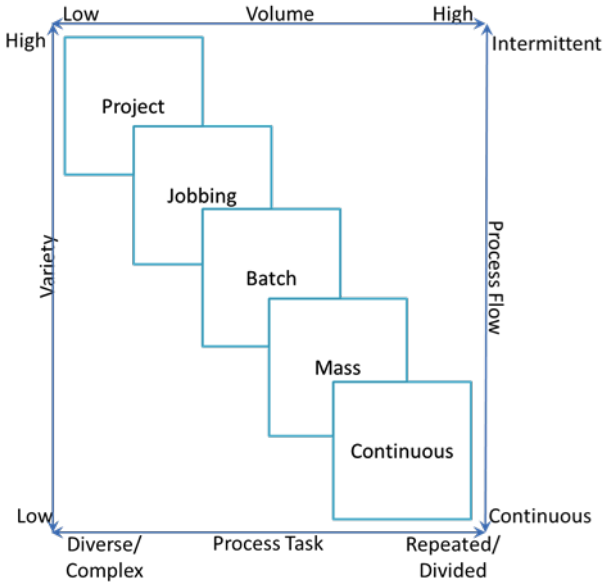

Figure 2.5: Process Types in Manufacturing Operations (adapted from Slack and Lewis (2002))

tinuous and mass production. The section labelled 'continuous' in Figure 2.5, is reliant on the forecast driven production of a narrow range of products and components (Slack and Lewis, 2002). The section labelled 'mass', is representative of the order driven production of a broader range of finished products. The last section marked 'Prjoect'is antithetical to 'continuous'; all production and engineering activity are on demand. It is likely that personalisation is in any of these process types albeit to varying degrees.

Critical to exploring the possibility of providing low-volume high-variety production through a supply chain, is supply chain design. There is a significant correlation between the point of customer interaction and the focus of the manufacturing and production function (Haug, 2013; Slack and Lewis, 2002; Wikner and Rudberg, 2005). Due to this relationship exploring the possibility of MPer also requires an exploration of the structure of the supply chain, including point of customer interaction and implications for the manufacturing and production function. Supply chain typology and topology are important fields of enquiry to cover the topics above.

2.4 Mass Customisation

Davis (1987) coined the term "*Mass Customisation*," describing the phenomenon of producing and distributing individually customised goods. MC represents the prevailing trend in the late 90's towards the production and distribution of individualised products and services. To what extent MC can be credited with providing individualised products, is a contentious issue. Table 2.5 tabulates the prevailing definitions within the literature.

Author	Definition	Defines solution space	Defines Market size	Defines Lead Time	Defines Price
Ahlstrom and Westbrook (1999, pp.263)	"*... numerous customer chosen variations on every order with little lead-time or cost penalty*"		✓	✓	✓
Hart (1995, pp.36)	"*...the ability to provide your customer with anything they want profitably, any time they want it anywhere, any way they want it.*"			✓	
Jiao and Tseng (2004, pp.745)	"*... Mass customization aims at best satisfying individual customer needs with near mass product efficiency*"	✓	✓	✓	
Piller *et al.* (2004, pp.438)	" *To distinguish mass customization from (craft) customization, we emphasize the possible extent of the additional willingness to pay only if the premiums asked for the customized solution do not lead to a change of market segments compared to providing the product in a mass production system we will refer to mass customization. Mass customization implies that the same large number of customers can be reached as in mass markets of the industrial economy, and simultaneously they can be treated individually....*"	✓	✓	✓	✓
Silveira *et al.* (2001, pp.2)	"*..... the ability to provide individually designed products and services to every customer through high process agility, exibility and integration. MC systems may thus reach customers as in the mass market economy but treat them individually as in the pre-industrial economies.*"		✓		✓

Table 2.5: Defining Mass Customisation (adapted from Haug *et al.* (2009))

Table2.5 indicates which definitions, define or acknowledge a solution space, market size, lead time or price. The components solution space, market size, lead time and price of customised products, are important in defining Mass Customisation. The *solution space* is typically finite, meaning that a product has a maximum number of variations created from its modular parts. A combinatorial upper limit is a typical constraint in MC, where the focus is to provide variety for a segment of the market. An example of this is seen in the automotive industry, where car specifications are tweaked to the preference of the consumer through the substitution of various components. The *market size* refers to the size of the market the product range aims to caters for, considering all the product variants. MC by definition aims to satisfy individuals. However, there is often a one-to-many relationship with customised product offerings. Acknowledging the market size is a key differentiator between Mass Customisation and Mass Personalisation, as Mass Personalisation aims to satisfy a market size of one (Kumar, 2007b). The *lead time* dimension is an essential part of the definition because it separates Mass Customisation and Mass Personalisation from ETO, which is synonymous with long lead times on an industrial scale. Theoretically, if given a longer lead time, a product can be customised or personalised to any specification. However, the final component of the definition *price* further constrains the definition of Mass Customisation. MC is synonymous with product affordability, typically implying that a customised variant does not differ in price substantially from a base model unless the additional customisations are materially different.

On one side the mass strategies inform an organisation how they will deal with product variety. In mass production's case, product type is treated in a standardised and rigid way. MC, on the other hand, aims for flexibility and responsiveness to consumer demand. Conceptually this is often presented in the literature as a continuum as shown in Figure 2.6.

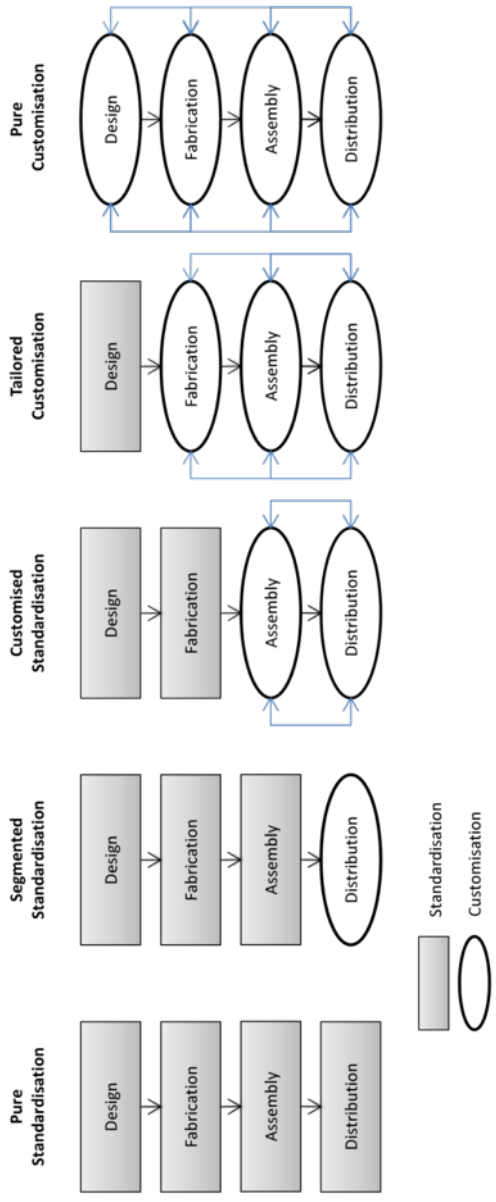

Figure 2.6: Continuum of Customisation (Lampel and Mintzberg, 1996)

The descriptions of MC tend to differ between those who attribute individualised *pure customisation* to MC, and those who attribute the milder *customised standardisation*. Most do not discuss the nuance of product, market, or scale and the implications for the type of customisation possible as part of the definition. Instead, the definitions attempt to define the concept entirely. It is possible personalisation exists in the extant literature, as a way of describing the extreme case of customisation.

What is clear from the definitions presented in 2.5 is that MC has some definitions in the extant literature. From the literature, it is clear that many authors and practitioners, defining the pursuit of providing high product variety using MC, believe it to encompass individualisation of personalisation.

The definition favoured in the existing literature, is one that moves from mass-produced products to the provision of more product variety (Haug *et al.*, 2009). The transition from individualised products, specifically those that are engineered-to-order (ETO), to MC has had little attention (Gosling and Naim, 2009). Arguably the manufacturing dichotomy received in sub-section 2.3.1, where increased variety implies lower volumes and higher costs, is likely to have a resolution (Gosling and Naim, 2009). What this means for ETO, is the need for companies to rationalise their product range capabilities into more standardised product ranges. This viewpoint is at odds with the concept of personalisation which is not bound by a configuration solution space (Jiao and Tseng, 2004; Kumar, 2007a; Piller, 2007; Riemer and Totz, 2003).

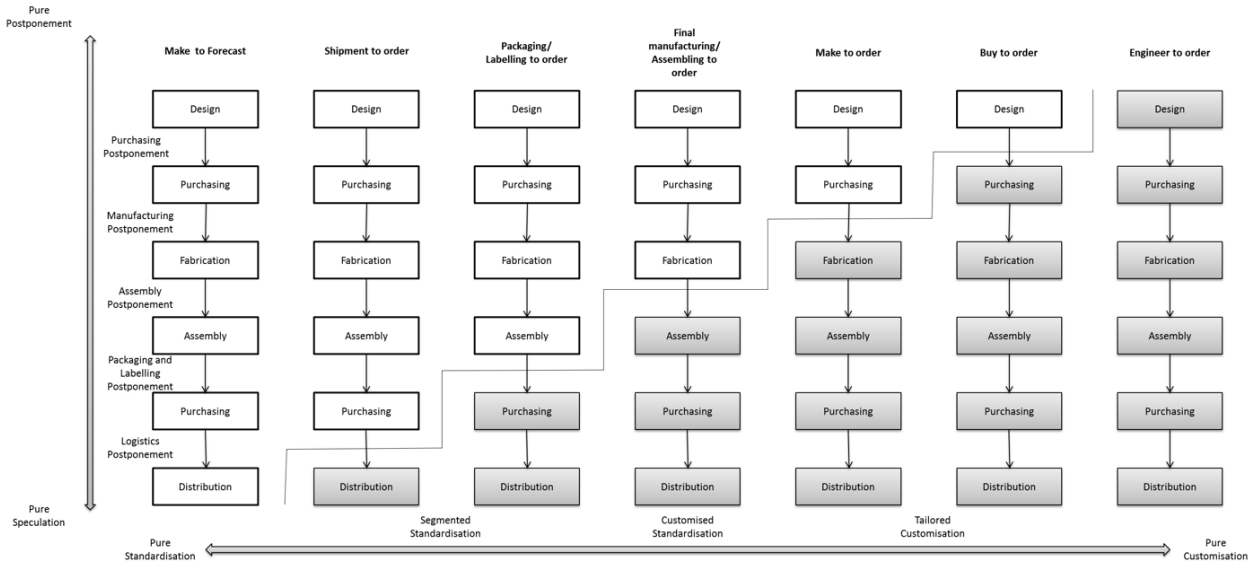

Figure 2.7: The Two Prevailing Trajectories of Mass Personalisation (adapted from Wikner and Rudberg (2005); Yang *et al.* (2004))

Most of the descriptions share the focus on individualisation and to some extent affordability, critically a difference between customisation and personalisation is emerging.

Wikner and Rudberg (2005) described MC as a compromise between the requirement to contract time and the necessity to customise a product; they state that the aim of MC is to shorten lead time and provide customer value by way of unique products. To give value through unique products, while reducing lead-time requires that both the supply chain and method of order fulfilment be conducive for differentiating products promptly (Wikner and Rudberg, 2005). Aligning the supply chain, mode of order fulfilment and product design has significant implications for manufacturing function (Holweg, 2005).

Products may at least be differentiated based on a market segment, offering customers a significantly large combinatorial configuration of product specification (Piller *et al.*, 2004). Ultimately MC constrained by a finite solution space Piller *et al.* (2004).

Conventionally the characteristics of companies are determined by their production system, products, business processes and markets. Therefore, an organisation wishing to disseminate personalised products efficiently must align strategic aims with operational and tactical activities.

Wikner and Rudberg (2005) and Yang *et al.* (2004) extended this continuum to include postponement, indicating postponement in different modes of customisation. The application of postponement in customisation, however, is not a clear as indicated in their diagram Forza *et al.* (2008).

MC has highlighted some of the capabilities necessary for personalisation. While MC itself has not fulfilled the criteria of individualisation contingent factors such as:

- Modular product architecture; and
- Product configuration tool for the customer.

Have been established as necessary for the pursuit of personalisation.

Haug *et al.* (2009) argued this proliferation may lead to "Mass Confusion", yet organisations are compelled to acquire the capability to provide any product at any time (Yang *et al.*, 2004). Gilmore and Pine (1997) argue that the MC was adopted too brazenly by some in

the industry and resulted in unnecessary costs and complexity. The acknowledgement of the need to implement MC appropriately and in some cases constrain its application, support the assertion that Gilmore and Pine (1997) were also advocates of a 'solution-space'.

There are also some industries and products that do not necessarily lend themselves towards being customised. Pine (1993b) stated:

"*Not all markets are appropriate for mass customization. Customers of commodity products like oil, gas, and wheat, for example, do not demand differentiation*"

Pine (1993b, pp.111)

To summarise many authors have contributed to the definition of the term customisation, key descriptors centre around defining the mass customised products architectural dimensions, market size and configuration. This study is interested in how the authors describe the dimension of the product solution space and market size. The solution product space is a reference to the combinatorial possibility of the product. For example, as previously mentioned the case of Mercedes E class, available in more than three septillion variations (Reichhart and Holweg, 2007). Some authours indicate that customisation is akin to individualisation/personalisation and as such an aspect of the product offering is infinitely configurable with no such combinatorial boundary. In practice, this may be an exaggeration and the extent literature biases towards the careful application of MC.

2.5 Mass Personalisation

Mass Personalisation as defined by Kumar (2007b), is:

"*Mass personalization is a limiting case of mass customization. Whereas both of these strategies are guided by the criterion of product affordability consistent with mass production efficiencies, the former (mass personalization) aims at a market segment of one while the latter (mass customization) at a market segment of few.*"

Kumar (2007b, pp.536)

According to Sunikka and Bragge (2012), authors who differentiate between customisation and personalisation do in one of three instances; in company driven processes, when

marketing and in internet environments. For some authors, the differentiation between customisation and personalisation is not significant (Sunikka and Bragge, 2012). Sunikka and Bragge (2012) conceptualisation of personalisation positions MPer as personalisation directed at several people. Table 2.6 shows the conceptual framework by Sunikka and Bragge (2012).

<table>
<tr><td colspan="4">Personalisation</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Intangibles (web context, service)</td><td>Tangibles (Products)</td></tr>
<tr><td>Individual</td><td>Group</td><td>Individual and Group</td></tr>
<tr><td>system initiated</td><td>One-to-One Personalisation</td><td>Mass Personalisation</td><td rowspan="2">Mass Customisation</td></tr>
<tr><td>user initiated</td><td>(Web) customisation</td><td>Collaborative Customisation</td></tr>
</table>

Table 2.6: Framework for personalisation, customisation and mass customisation Source: Sunikka and Bragge (2012)

MPer, therefore, aims to:

- Be affordable, benefiting from the economies of scale consistent with mass production Kumar (2007b);
- Serve a market of one (Gilmore and Pine, 1997; Kumar, 2007b; Pine and Gilmore, 2011; Riemer and Totz, 2003);
- Remove the commoditisation of the product (Gilmore and Pine, 1997; Kumar, 2007b; Pine and Gilmore, 2011; Riemer and Totz, 2003); and
- Have a time to market that is consistent with traditional consumer expectations (Gilmore and Pine, 1997; Holweg, 2005; Kumar, 2007b; Riemer and Totz, 2003).

In MPer Kumar (2007b) acknowledged the dichotomy associated with personalised products and affordability discussed further in Section 2.3.1.

MPer, as defined, is the provision of individualised products on a one-to-one basis (Kumar, 2007a,b). For Kumar (2007b) the application of *mass* is based on the implicit asso-

ciation of personalisation with MC literature. The relationship described aligns with the previous section (Section 2.4), where Personalisation and individualisation are a stated aim of MC. Kumar (2007b) reinstating the word *mass* to maintain the implicit affordability of the end product. A big question, therefore, is whether MPer and MC are in fact different strategies along with a continuum?

Few papers discuss *Mass Personalisation* as a particular strategy. Zhou *et al.* (2013a) define MPer by attempting to address what they consider are the key dimensions of personalisation. Zhou *et al.* (2013a) defines MPer as:

> "*... a strategy of producing goods and services to satisfy individual customer's latent needs with values outperforming costs for both customers and producers*." Zhou *et al.* (2013a, pp.1047)

A market-of-one, mass efficiency, customer co-creation and user experience are the main dimensions used to define Mper. While some aspects of the definition are consistent with Kumar (2007b), personalisation is often used interchangeably between product, platform and supply chain. In some instances it is unclear which of the three Zhou *et al.* (2013a) is referring to or indeed the relationship between the types, for example when discussing Amazon.com:

> " *... Amazon.com can personalize customers' preferences based on their profile and purchase histories*."
>
> Zhou *et al.* (2013a, pp.1048)

This statement aligns MPer to recommendation engines found in online marketplaces that require membership and solicit your preferences through your interactions and purchase. A clear distinction in the literature for personalisation, as relates to MPer, is the distinction of *hard* and *soft* personalisation (Tseng *et al.*, 2010). In support Tseng *et al.* (2010) stated that personalisation in supply chains will exhibit both *hard* and *soft* characteristics. For Tseng *et al.* (2010) *hard* related to deep product architectural characteristics such as componentry, while *soft* features were related to superficial characteristics such as color. Zhou *et al.* (2013a) discussed recommendation engines as a form of soft personalisation; however an

explicit definition that separates MPer from MC is missing in the article. The view that personalisation is indeed *soft* is consistent with some of the literature, where a clear distinction exist between personalisation based on reconfigurability of a product and personalisation of the experience and other intangible often via a web-based platform (Sunikka and Bragge, 2012; Tseng *et al.*, 2010).

Zhou *et al.* (2013a) acknowledged the distinction between three types of personalisation citing a *system-centered* approach, a *business-orientated* approach and a *customer-centered* account. The research context may explain the lack in a hard definition for MPer about supply chain management and or supply chain design but curiously not product architecture. Although an explanation may be that this paper views personalisation as only a *soft* characteristic. The main focus of this paper is the mapping of personalisation features to customer needs that specifically relate to cognition Zhou *et al.* (2013a), this may also account for the perspective the paper takes on MPer. It is also unclear whether Zhou *et al.* (2013a) considered the difference between business-to-business (B2B) and business-to-customer (B2C) when discussing mass personalisation. In this context the assertion that:

> "*In a paradigm of mass production, products are standardised by designers without any involvement from customers*."
>
> Zhou *et al.* (2013a, pp.1050)

The disambiguation of MPer requires a clear distinction between the roles and processes encompassed by MP, MC and MPer. Kumar (2007a,b) and most of the MC literature has agreed that personalisation or individualisation of products goes beyond focusing on the soft aspects. A key attribute for MPer is the requirement to expand the product architecture or solution space to near infinite possibilities (Kumar, 2007a,b; Riemer and Totz, 2003). The 'solution space' describes a finite number of configurations possible for a given product Piller *et al.* (2004). A finite number of configuration for a product is an important distinction that is made many times throughout the MC literature. MC is, therefore, synonymous with configuring a product within a set number of possibilities. The number was maybe so large that the possibilities seem infinite, but a maximum number of combinations does exist.

As mentioned the characteristics critical dimension in the definition of personalisation is market size. Previously in the descriptions of MC, customising a product for the market segment was an acceptable explanation. A look at the definitions of personalisation reveals that authors equate personalisation to individuals and a market of one, rather than a market segment. Definitions specific to supply chain management and logistics or operations management are very few in comparison to those from other disciplines. The lack of empiricism is a gap in the literature defining and describing MPer. A framework and empirical study of self-proclaimed product personalised, in supply chain management, would be a genuine contribution.

By definition, personalisation is the customisation of some feature (*hard* or *soft*) of a product. The aim of personalisation in the literature is to afford the customers more convenience, lower cost or some other benefit (Kumar, 2007b; Sunikka and Bragge, 2012). Personalisation, in this context, is initiated by the customer or the firm. For Peppers *et al.* (1999) Personalisation (or individualisation which is synonymous) in general means matching on objects nature with one subject's needs.

Sunikka and Bragge (2012)'s tabulation of definitions also highlights the lack of contribution made by supply chain management. One criticism of the definition listed by Sunikka and Bragge (2012) is not explicitly stating why these definitions are chosen over others, or how the review was conducted. In particular, the search criteria or exclusion criteria used is not explicit. A statement on what is in scope and what is not would have been beneficial in directing the discussion. Instead, text mining literature related to customisation and personalisation is presented with little exposition. The paper was published in a journal relating to IS and which explains the bias towards information systems.

MPer is often contrasted with MC when describing the ability to reach a market segment or a market of one Tseng *et al.* (2010). The academic interest in Mper is increasing as the successful implementation of servicing a market of one may signify a transformation in the global economy (Tseng *et al.*, 2010).

Several authors point to eliciting customer interactions to achieve the personalisation (Piller, 2007; Poulin *et al.*, 2006; Riemer and Totz, 2001, 2003; Sunikka and Bragge, 2012;

Tseng *et al.*, 2010; Tseng and Piller, 2003; Vesanen, 2007). It is therefore not unsurprising that Mper is discussed in the literature about web technologies and customer centric design. Examples like Amazon have commonly cited examples of organisations, personalising an aspect of a product or service. These examples in keeping with the soft personalisation described by Tseng *et al.* (2010). Soft personalisation in this instance is aligned with customer centric and solution spaces and web-based tools, and hard personalisation relates to engineer to order and 3d printing and product architecture

There seem to be two schools of thought regarding MPer; one is the nascent possibility of manufacturing any widget with personalised features, and the other is the augmentation of a core product with some ancillary personalised feature.

The Personalisation literature relating to products has its developmental roots in MC literature. Customisation and personalisation have been used synonymously in supply chain management, operations management and marketing research. However, some authors have also sought to delimit the scope. The categorisation of the research is explored during the review. Many definitions of personalisation exist in the literature and like customisation, the definitions span many disciplines; therefore, a table of definitions and the related field of enquiry is provided.

Personalisation of products and services is synonymous with individualisation, a view supported in the literature (Lampel and Mintzberg, 1996; Peppers *et al.*, 1999; Riemer and Totz, 2003). Peppers *et al.* (1999) in their monograph 'the one-to-one future' described personalisation as customising some feature of a product or service so that customers enjoy more convenience, lower cost or some other benefit. Personalisation can be initiated by the customer or the firm.

Peppers *et al.* (1999) focused on customising some feature of the product acknowledges that personalisation does not have to occur in every facet of a product. The depth of the personalisation i.e. whether it affects the product architecture and functionality of the base unit is, in this case, a degree of personalisation. Kumar (2007b) described personalisation as a limiting case of MC. Kumar (2007b) also acknowledged personalisation's focus on an individual or "a market of one" as well as the difference between soft and hard. Montgomery

and Smith (2009) interestingly, defined personalisation as the adaptation of product and services by the producer stipulating that personalisation is "automated" on the customer's behalf as opposed to at the request of the client. This definition has more implication for personalisation in information systems (IS) and hints at consumer websites featuring recommendation engines such as Amazon (an online retailer) and eBay (an online auction platform). Separating customisation and personalisation in this context is unique in its more restrictive scope, specifying that personalisation or customisation is determined by who performs the configuration activity. How prevalent this view is in the industry is not mentioned but would be an interesting empirical observation, further defining what personalisation is considered to be in the industry. While the consensus is that personalisation can occur at any part of the marketing mix, this study focuses on the product and the ancillary services around the product which augments and personalise the product.

Table 2.7 summarises the prevailing distinction between MP, MC and MPer.

Strategy	Market Size	Product Configuration/ Solution Space	Aim	Author
Mass Production	∞	1	The high volume production of affordable standardised products. Low cost consistent quality Long product development cycles	Kumar (2007a,b); Reichhart and Holweg (2007); Slack and Lewis (2002); Wikner and Rudberg (2005)
Mass Customisation	Market Segment	finite combination	Affordable, high quality and customisable goods and services Short product cycles	Holweg (2005); Piller *et al.* (2004)
Mass Personalisation	1	∞	Affordable individualised products, with comprable lead-time and cost to mass customisation	Jiao and Tseng (2004); Kumar (2007a,b); Peppers *et al.* (1999); Tseng and Piller (2003)

Table 2.7: Table Summarising Contributions by Authors Defining Personalisation Source: Author

IS based Personalisation is an online reality for literature in marketing and Information Systems (Sunikka and Bragge, 2012). Consumer online behaviour is used to recommend products; often research focuses on how personalisation of the consumer's online activity drives purchasing intention and the conduct of the user (Sunikka and Bragge, 2012).

Sunikka and Bragge (2012) cite many authors that view personalisation as a process that can occur anywhere in the value chain; an example being One-to-one marketing. One-to-one marketing was deemed personalionalised marketing by Peppers *et al.* (1999). A modern understanding of personalisation in the service context is one in which, instead of changing, assembling or modifying product or service components information objects (i.e. data as a product) are provided to the consumer (Kumar, 2007b; Sunikka and Bragge, 2012). The rise of "Big Data", expansion of data storage capacity and an increase in computer processing power has popularised the idea of data as a product. The development of processing technologies like Hadoop, Mongo DB and other noSQL database have allowed the scalable processing of the vast amount of information entering petabytes. Leveraging these technologies has allowed companies to personalise product experiences.

The definitions for MC in the literature also use the term *individualisation* synonymously. However, there is at least in the literature, a clear distinction between individualisation/personalisation and customisation and therefore warranting its own "space" as a field of enquiry. Figure 2.8 illustrates the emerging relationship mass personalisation has with the market size using Kumar (2007a,b) conceptualisation. The diagram represents the contraction in the size of market size and complimentary production volume, while also showing the retention of core aspects of related strategies. The diagram may be viewed as a representation of the holonic nature of the strategies. Holonic refers to something that is simultaneously a whole and a part of a structure (Van Brussel *et al.*, 1998).

Although personalisation seeks to individualise products, the role scale and product architecture play have not been explored. MPer may extend to specifying deep changes in product architecture, or functionality. MPer may instead be more superficial and seek to change cosmetic aspects of the product. The role of scale may be different when comparing business to customer relationships and business to business relationships.

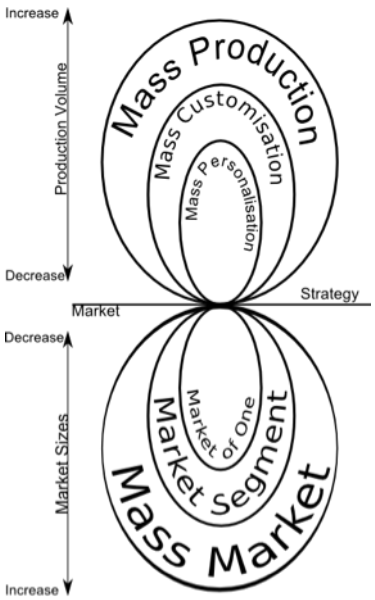

Figure 2.8: Relationship between *mass* strategy and market size Source: Author

This conclusion is consistent with the findings of Sunikka and Bragge (2012) in which they present finding that show there is no overlap in publications by authors in the top ten for personalisation and customisation. Coupled with the predominance of personalisation literature arising from IS, while customisation literature is the remit of manufacturing and operations management type publications, more credence can be given to personalisation as being distinct from customisation.

Very few frameworks exist, in operations and supply chain management that view personalisation of products as a significant departure from customisation. Poulin *et al.* (2006) developed a model that classifies personalisation of goods and services based on their characteristics. These personalisation options were mapped onto an illustration of the order fulfilment capabilities and their traditional decoupling point in Figure 2.9.

"*. . . core range of products that can be accessorised.*"

Poulin *et al.* (2006, pp.998)

'parametering' involves the selection of key components and seems akin to traditional customisation as seen in the consumer electronics industry specifically personal computing. Tailoring allows customers to design products within the capabilities of the firm. Poulin

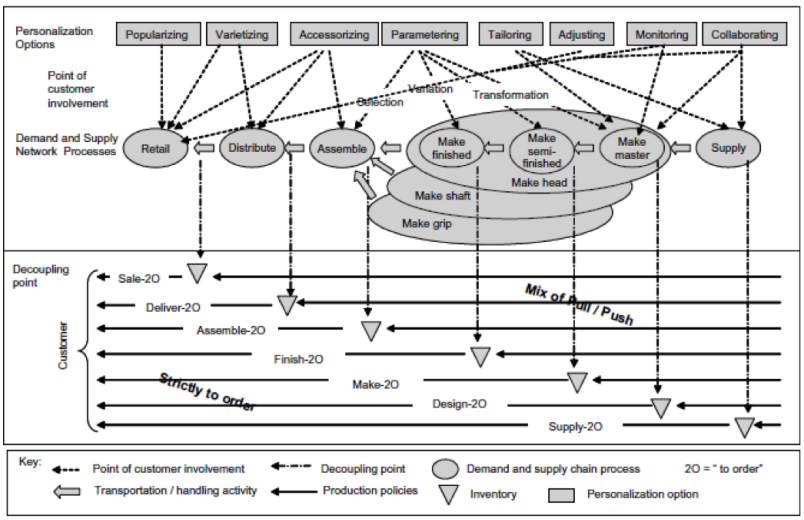

Figure 2.9: Point of Customer Involvement and Decoupling point of Personalised Offers (Poulin *et al.*, 2006, p1007)

et al. (2006) states of the last three that they:

> "*...refer to customer offers breaking away from the single-sale-event mind frame, taking a lifecycle approach.*"
>
> Poulin *et al.* (2006, pp.998)

Figure 2.9 shows the implementation of Poulin *et al.* (2006) framework in a conceptual model linking the personalization options to the customer order decoupling point.

Poulin *et al.* (2006) is not the only author to indicate types of customisation and personalisation and relate them to a supply chain type and order fulfilment capability. Wikner and Rudberg (2005), Yang *et al.* (2004), Lampel and Mintzberg (1996) and Hilletofth (2009) to mention a few also map personalisation, customisation against order fulfilment capabilities, postponement, decoupling point and sequential processes required to provide a product to the customer. This practice is consistent with contingency theory and the Lambert and Cooper model that so much of supply chain discourse is arranged around.

MPer in literature is a distinct field of enquiry. There are significant overlaps between MC and MPer to warrant the claim that MPer is linked to MC. There is a paucity of empirical research covering the strategic decisions required for persuing MPer. The paper in which Kumar (2007b) defined MPer was largely theoretical in nature and provided the impetus for

future research. Poulin *et al.* (2006) provided a framework linked to empirical research and definitively discusses personalisation as an operations and supply chain issue.

A worthwhile distinction to make regarding personalisation is the difference between strategic personalisation and personalisation as a necessary function of the product offering. Strategic personalisation for product differentiation or to enter a market might look different from personalisation as a necessity. Credit cards are an example of a product that requires personalisation as a default requirement and is heavily regulated.The implications for the strategic management of a supply chain supporting the production a product requiring personalisation by default, may be different from one personalised based on strategic priorities.

2.5.1 Servitisation and Personalisation

Servitisation is a topic related to Personalisation in regards to the provision of services to augment or personalise a product. First defined by Vandermerwe and Rada (1988), servitization is the intergation of:

> "*...goods and services to integrated "bundles" or systems, as they are sometimes reffered to, with services in the lead role.*"
>
> Vandermerwe and Rada (1988, pp.314)

Servitisation is also defined by Baines *et al.* (2009) as:

> " *... the process of creating value by adding services to products*"
>
> Baines *et al.* (2009, pp.547)

Traditionally, organisations may have avoided the provision of ancillary services with their product offerings (Vandermerwe and Rada, 1988). However, since the late 1980s the pursuit of servitisation as a competitive manufacturing strategy has been studied by a range of authors(Baines *et al.*, 2009; Vandermerwe and Rada, 1988). Personalisation and Servisation share common ground, for example Tseng *et al.* (2010) conceptualisation of *soft* personalisation includes the intangible aspects of services supporting (Vandermerwe and Rada, 1988) assertion that:

> "*...services are performed rather than poduced and are essentially intangible.*"
>
> Vandermerwe and Rada (1988, pp.315)

Both agree that a significant amount of the product offering and added value to the customer can come from services. Both acknowledge that consumer demand for more customisation is phenomenon pushing custom- tailored goods (Vandermerwe and Rada, 1988). Presciently, Vandermerwe and Rada (1988) also acknowledged the discernable trend of manufacturers positioning themselves further and further down the distribution chain and seeking the end user to provide products and services. Vandermerwe and Rada (1988) offered three reasons why manufacturing organisations pursue servitisation

- competitive advantage;
- customers lock in; and
- product differentiation.

ETO organisations positioning themselves in this way is a common theme in the literature. The increase in operational capability offered data collection and information processing technology, has increased the perceived viability of servitisation (Baines *et al.*, 2009). Advancements in technology has also been an enabler of both peronsalisation of products and services seeking to provide a bespoke product to a customer. While personalisation and servitisation share many concepts, they are not synonymous. Mass personalisation is more aligned with the manufacturers product configuration (Kumar, 2007a,b). Vandermerwe and Rada (1988) acknowledged servitisation as being a paradigmn in which:

> "*...services are performed rather than poduced and are essentially intangible.*"
>
> Vandermerwe and Rada (1988, pp.315)

Neely (2008) discussed the financial consequences of Servitisation and its implication for developmed economies. Again in this context servitisation and personalisation share a common ground. Servitisation and personalisation seem connected to the return of advanced manufacturing to developed countries, that once outsourced their manufacturing to low cost countries (Baines *et al.*, 2009).

2.6 Supply Chain Typology, Supply Chain Topology and Order fulfilment Capabilities

Understanding the behavioural dynamic of supply chains requires a standard method of conceptualising the inflows and outflows of resources and points of interaction of participants. By aligning these activities, supply chains can be classified by their particular market environment and characteristics (Gosling and Naim, 2009).

Since MPer can be seen as distinct from MC, the question remains as to what type of supply chains support personalisation initiatives and what order fulfilment capabilities are necessary? Poulin *et al.* (2006) offered a good conceptualisation of the interaction between supply chain agents. Central to the provision of resources capable of satisfying variability in demand, is the development of an appropriate order fulfilment process (Kritchanchai and MacCarthy, 1999). Order fulfilment requires an appreciation of supply chain typology, the customer order decoupling point and supply chain topology and the separation of topology, typology and geography as shown in Figure 2.10.

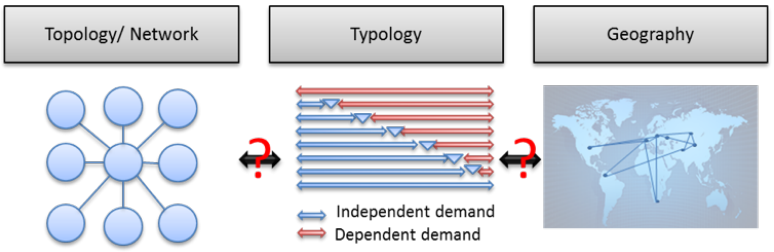

Figure 2.10: Supply Chain Typology, Logical Topology, and Spatial Geography Source: Author

All supply chains have by definition a topology which is the logical route through which resources travel, a geographic footprint representing the distribution and proximity of suppliers, manufacturing and production facilities and possibly regional and national distribution. The topology is akin to the product flow facility structure referred to in Cooper *et al.* (1997) which describes the network structure for sourcing manufacturing and distribution across the supply chain. Balasubramanian (2001) stated that the product architecture can be

responsible for up to 80% of the supply chain design and as mentioned supply chian designs can be grouped into types. A typology is simply a classification of general types.

Wikner and Rudberg (2005) described how some parts of the logistics and supply chain activity have to be performed on speculation. A concept frequently used to capture this event is the customer order decoupling point (CODP). Wikner and Rudberg (2005), stated that competing on time requires the careful design of an enterprise and puts a strain on operations management. Time-based competition is supported by fewer and faster activities as the customer waits and customisation requires the performance of unique activities per an individual order.

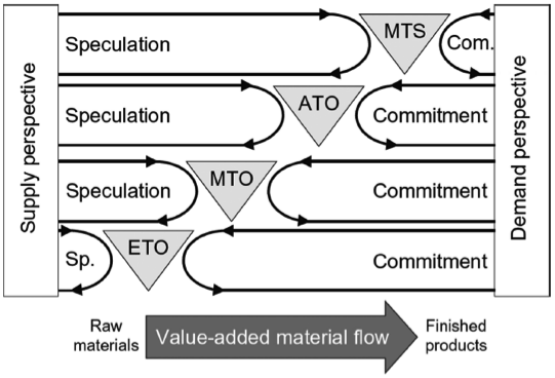

Figure 2.11: Customer Order Decoupling Point (Wikner and Rudberg, 2005)

A supply chain has a temporal, spatial and logical dimension. Christopher (2005) identified lead-time as the encompassing temporal dimension of the supply chain, while Cooper *et al.* (1997) defined the logical dimension as inventory moves across tiers. Fisher (1997) and Fine *et al.* (2005) identify the spatial dimension of a supply chain, however how all of these fit together and their implication for the three mass strategies outlined later have not been explored in the literature.

There is a correlation between the point of customer interaction and the focus of the manufacturing and production function (Haug *et al.*, 2009; Slack and Lewis, 2002; Wikner and Rudberg, 2005). The customer order decoupling point (CODP) represents the point at which the final form of the product can be postponed Wikner and Rudberg (2005). The CODP also referred to as the order penetration point (OPP) is commonly defined as the

point at which independent demand becomes dependent and subsequently production moves from being forecast driven to being motivated by a particular customer order (Christopher, 2005; Wikner and Rudberg, 2005). This relationship confers a supply chain typology and topology, by dictating how agents in the supply chain interact. The relationship has profound implications for supply chain management and design. Depicts the relationship between these two activities and positions the type of supply chain found at each position.

Understanding supply chain structures as typologies facilitates discussion on supply chain phenomenon because it views the supply chain as a system that is contingent on specific functions. Table 2.8 tabulates how supply chain typologies might fit with operations strategies from this perspective.

Supply Chain Typology	**Operations Strategy**
MTS	Mass Production
ATO	Mass Customisation
MTO	Mass Customisation
ETO	Mass Personalisation?

Table 2.8: Aligning Supply Chain Typology and Operations Strategies Source: Author

Cooper *et al.* (1997); Lampel and Mintzberg (1996); Wikner and Rudberg (2005); Yang *et al.* (2004) and the SCOR model are examples of well-cited supply chain models with specified functions. A system-wide perspective allows academics and practitioners to categorise, compare and contrast the enablers and barriers of different supply chain structure (Wikner and Rudberg, 2005). Rationalising structures into representative conceptual typology allow the trade-offs between structures to be examined, in particular, the trade-offs between productivity and flexibility (Wikner and Rudberg, 2005). Understanding this about a supply chain type is of importance when trying to apply supply chain practices that facilitate MPer. The conceptual typology makes explicit the logical topology of the supply chain structure, i.e. the logical, sequential route of a product through the supply chain. How this relates to MC conceptually and empirically has been well documented, MPer much less so.

Hilletofth (2009) provided multiple case studies describing how two companies devel-

oped differentiated supply chain strategies. The studies identified that, understanding the capabilities to serve the market and developing necessary supply chain solutions, where part of four essential steps. It is the argument of this research that capabilities change and the development of supply chain solutions are contingents on these capabilities. Also, Hilletofth (2009) identifies the geographical location, type of product and type of consumer are pertinent in establishing a differentiated supply chain strategy.

The extant literature does not currently provide a taxonomy or categorical framework which makes explicit the relationship between supply chain operations strategy and manufacturing technology in relation to MPer. Therefore, it is hard to infer or even provide conjecture on MPer or its implications for supply chain logical and physical topology and typology beyond the theorised relationship with MC. Supply chain designs are not stable and are in fact transient (Fine, 2000; Fine *et al.*, 2005). For example, supply chain structures can cycle from integral to modular. Modular industries such as the personal computing industry tend to have modular supply chain structures that experience fierce commodity-like competition (Fine, 2000). Modular products are often built by modular processes and modular supply chain (Fine, 2000). As a result, the ATO supply chain type is typical with centralised assembly and production of modular components spanning a geographically dispersed supplier base.

In summary, the CODP demarcates the point at which independent demand becomes dependent, within a supply chain (Wikner and Rudberg, 2005). The CODP also referred to as the order penetration point (OPP) is defined as the point at which independent demand becomes dependent. Production moves from being forecast driven to being motivated by a customer order. The CODP is a fundamental consideration when appraising the current status quo of supply chain design and whether or not MPer has a basis in the supply chain typology as it is theorised in the extant literature. The CODP is a fundamental consideration because a taxonomy of supply chain design and topology is an abstraction favoured supply chain literature, especially when discussing order-to-delivery cycle times. As shown in Table 2.8 most order fulfilment types fit an either MP or MC. Engineer-to-Order (ETO) supply chain models are most comparable to MPer in their ability to manufacture individualised

products.

2.6.1 Form Postponement

Achieving the manufacturing flexibility and cost efficiency necessary to provide affordable customised products requires an approach that facilitates manufacturing flexibility. Form postponement is a much-cited method which allows for customisation while minimising lead-time.Harrison and Skipworth (2008) defined FP as:

"*...the delay, until customer orders are received, of the final part of the transformation processes, through which the number of different items (stock keeping units) proliferates, and for which only a short period is available. The postponed transformation processes may be manufacturing processes, assembly processes, configuration processes, packaging, or labelling processes.*"

Harrison and Skipworth (2008, pp174)

Forza *et al.* (2008) identified types of form postponement and relates them to order specification flexibility, defining it as:

"*...the ability to accept and launch partially general orders or to accommodate configuration changes after order launch while maintaining time and cost effectiveness.*"

Forza *et al.* (2008)

Many authors have cited form postponement as an operations design principle that minimises the adverse effects of product variety on operational performance (Forza *et al.*, 2008). The literature on form postponement covers a broad range of areas of study, including conceptual and mathematical models. However, identified that previously there was not a consensus as to the definition of form postponement. Subsequently, there lacked a theory capable of explaining the effect of form delay. Previously form-postponement has been linked to delaying the time a product assumes its final configuration (Forza *et al.*, 2008; Lee, 1993). The main contention between authors defining form postponement was whether the production differentiation activity was differed along the manufacturing and distribution process or not (Forza *et al.*, 2008).

The main enabler of form postponement mentioned by Forza *et al.* (2008) from the literature are: process sequencing, component and process standardisation product/process modularisation and deliver lead-time renegotiation. Critically Forza *et al.* (2008) stated that the enablers of form postponement do not necessarily lead to form-postponement. The application of postponement or developing correct order fulfilment capabilities requires explicit a supply chain type, requires a common method of conceptualising the inflows and outflows of resources and points of interaction of participants. As previously mentioned the Cooper *et al.* (1997) model is a traditional framework from which to view the supply chain and its functions.

2.7 Advanced Manufacturing Technology

The pursuit of manufacturing innovation requires production systems that are more flexible and assist in achieving shorter lead-times (Caron and Fiore, 1995). Advanced manufacturing technology (AMT) is a useful term to summarise such technologies Chung and Swink (2009). An AMT represents a broad range of technologies developed to improve manufacturing capabilities (Chung and Swink, 2009; Fulton and Hon, 2010). AMT's can be fit conceptually into three types: design, manufacturing and administration (Chung and Swink, 2009). According to Chung and Swink (2009) over the last two decades advanced manufacturing technology implementation have improved manufacturing firms flexibility, quality, productivity and lead-time. However, manufacturing technologies such as enterprise resource planning systems are often costly and poorly implemented (Little *et al.*, 2001). Fulton and Hon (2010) discussed the management of advanced manufacturing technology implementation in SME's through a longitudinal study of company performance. Fulton and Hon (2010) describe key barriers to the successful implementation of AMT which included:

- An ignorance to the benefits and solutions available; and
- A lack of confidence in in-house capabilities.

Fulton and Hon (2010) cited the investigation into the attitudes and benefits of AMT among

300 manufacturing SME's; many were unaware of the benefits some AMT's offer. An example provided by Fulton and Hon (2010) were 3D CAD systems holding bills of material (BOM) and other information shared through the supply chain. These systems often rely on sales literature and representatives with vested interests (Fulton and Hon, 2010). Lack of confidence is, therefore, a significant impediment to the adoption and successful implementation of AMT's (Fulton and Hon, 2010). AMT's allow for the production of customised products and enable the production of low volumes at competitive costs (Chung and Swink, 2009; Kotha, 1996). (Fulton and Hon, 2010) list the benefits of AMT's are well documented and include providing a leading edge in:

- profitability;
- strategy;
- agility;
- reduction in lead-times;
- increase machine utilisation;
- reduction in labour costs; and
- reductions in work in progress (WIP) .

Complex products utilising MPer and MC for which a custoer can configure their product, often rely on customised products and therefore require AMT's to retain the affordability criterion. Extant literature, however, does not consider the importance of the AMT's in the manufacturing function when aligning with the operations strategy explicitly with the supply chain.

The intuitive move to integrate the technology into the supply chain comes from:

1. The agglomeration of several supply chain activities inside one device;
2. Proliferation of manufacturers, manufacturing 3d printing devices; and
3. The technologies maturity and subsequent reduction in cost as a barrier to entry.

In the last decade the presence of additive manufacturing, has increased significantly. Types of additive manufacturing include stereolithographic, fused deposition modelling laser sintering and three-dimensional printing .

The name additive manufacturing indicates the method through which the process fabricates a product. The three-dimensional layers of an item extruded in an incremental fashion, over successive layers.

Additive manufacturing compares to the factory in a box or the self-replicating machine. One initiative by RepRap, an open source initiative aimed at making 3d printers more accessible, has self-replication as a stated objective. Other long-standing commercial vendors such as Hewlett-Packard which has been manufacturing industrial grade 3d printer for several years have also are coming closer to the price point at which consumer grade devices would become a viable option.

Additive manufacturing is a disruptive technology in many respects. The ability to interface directly with the fabrication process using computer aided design also means that the tooling step commonly associated with the manufacturing process is no longer a constraint. Designing for manufacture (DFM) is easier with additive manufacturing (Sinclair, 2012). Previously in ETO and BTO not knowing the cost of engineering changes and the high cost of low volume production is a real concern (Balasubramanian, 2001). Small volume production at low cost with almost no impact on lead-time is a possibility afforded by additive manufacturing (Kumar, 2007a; Reeves *et al.*, 2011; Sinclair, 2012). However, its application in the supply chain and manufacturing function has little documentation. Literature relating to additive manufacturing is predominantly in the field of manufacturing with a small focus on the wider implications to the supply chain and operations management.

While CAD programmes are notoriously complicated and often require years of tuition, some organisations are removing this barrier to entry. Shapeways is an online manufacturer who has embarrassed and indeed built their whole service model around the provision of an online platform for designers to design and have their designs fabricated . Though the technology for printing working circuit boards is still not a reality, the material sciences are also pursuing methods of extruding conductive materials through the same process as

additive manufacturing opening the door for more complex products.

It is not farfetched to assume the effect of additive manufacturing could be very far reaching in the supply chain (Reeves *et al.*, 2011). The application of additive manufacturing will have profound implications for lean and agile practices, modularity and postponement. The fabrication of products may be pushed further downstream than ever before, leading to a leaner supply chain. Instead of the traditional source, make and deliver additive manufacturing may contract these stages and customers may have more of a relationship with the suppliers of raw material as opposed to the assembler and manufacturers with large scale production facilities.

The application of advanced manufacturing has been an enabler of mass customisation (Chung and Swink, 2009). Additive manufacturing may be the enabler for personalisation and newer forms of customisation (Reeves *et al.*, 2011; Sinclair, 2012). All the early signs indicate this to be the case. The application of additive manufacturing in the industry and its effect on customer co-creation, supply chain typology and subsequently order fulfilment capabilities requires empirical exploration.

Additive manufacturing technology is maturing and experiencing a reduction in cost as a barrier to entry. The manufacturing assets of a plant are the bottleneck in its operational performance and therefore, impact its order fulfilment capabilities. However, the advancement in manufacturing technology is witnessing an expansion of this frontier (Chung and Swink, 2009). Advanced manufacturing technology helps to manufacturing plants to improve their capabilities in multiple ways (Chung and Swink, 2009).

Arguably since the establishment of open system interconnections (OSI) , the demise proprietary networking protocol, and the proliferation of affordable networking technology organisations have increasingly sought more integration across planning systems. Material Requirements Planning (MRP) , Materials and Resources Planning (MRPII) and enterprise resource planning (ERP) have become standards requirements for distributed production units. Integration firms, with the main suppliers, is also commonplace Chung and Swink (2009). The benefits achieved from the successful implementation of an MRP are well documented (Yusuf and Little, 1998). MRPII implementation assists organisations in attaining

greater flexibility and responsiveness, to meet the demands of international competition (Yusuf and Little, 1998). While MRP technology is prolific, integration with AMT has often been problematic (Yusuf and Little, 1998). MPer would require successful integration between MRP and AMT to achieve the efficient provision of a vast product variety.

Design and engineering technologies such as computer-aided design (CAD) and computed process planning (CAPP) are often the first type of AMTs to be implemented. The adoption of advanced technologies such as CAD/CAM, their integration and the benefits that their use confers, have been well documented in manufacturing and supply chain literature.

AMT's are divided into three types:

- Design;
- Manufacturing; and
- Administrative.

Many companies seek to integrate these three types into one comprehensive system (Chung and Swink, 2009; Fulton and Hon, 2010). The ability to create a design using an online CAD system and then printing the design is a new business model for organisations such as Spoonflower and Shapeways. How the administrative function and technologies used are affected by this novel method of providing variety has not been discussed in the literature . There has been little research on the impact of new technologies such as additive manufacturing on the supply chain and the order fulfilment capabilities that they offer (Sinclair, 2012).

The link between supply-chain structure and product architecture acknowledges the impact that product integration vs. modularity has on the geography of the supply chain. Additive manufacturing technology, however, integrates some of the functions and processes of geographically dispersed supply chains (Sinclair, 2012). The potential implied though not explored is the reduction in such activities as distribution costs, working capital (less FGI and WIP). These potential gains are mitigated by the speed of throughput available in current printing technology and subsequent incarnations and the method of integrations used

in the manufacturing function and supply chain to facilitate order fulfilment capabilities (Reeves *et al.*, 2011).

2.7.1 Responsive and Flexible Manufacturing

Kritchanchai and MacCarthy (1999) defined responsiveness as the ability to:

"*...react purposefully and within an appropriate timescale to significant events, opportunities or threats (especially from the external environment) to bring about or maintain competitive advantage*."

Kritchanchai and MacCarthy (1999, pp.814)

The term "responsiveness" is discussed in the literature along with several areas of management research including time-based competition, flexible manufacturing, business process reengineering, agile manufacturing and MC (Kritchanchai and MacCarthy, 1999). MPer focuses on catering to extreme variability in products, which implies a manufacturing system flexible enough to achieve a high level of responsiveness.

Responsiveness in a supply chain context has been discussed by Fisher (1997) who argued that the products characteristics (innovative or functional), discussed in Section 2.9, need to be linked to the supply chain. A criticism of Fisher (1997) mapping of product characteristics to the supply chain and responsiveness, is the unavoidable fact that a product can be both innovative and functional (Holweg, 2005; Mason-Jones *et al.*, 2000; Naylor *et al.*, 1999). However understanding the products characteristics and its implications for the supply chain is an important consideration for the manufacturing function (Kritchanchai and MacCarthy, 1999).

The debate as to the responsiveness of the manufacturing operation was an on-going discussion spanning over a decade (Holweg, 2005). The debate had its origins in "time compression" or "time-based competition originally promoted by Stalk (1988) and later adopted by other researchers. In addition to time compression, concurrent engineering has been proposed as a method of reducing the time to market in MTO systems (Balasubramanian, 2001; Fine *et al.*, 2005; Gosling and Naim, 2009). Stalk (1988) recommended system

procedures be simplified, and computer-based technology is improved.

Originating in MC the provision of web-based platforms and e-commerce services are even more prolific in the pursuit of personalising customised products or at least product interactions, at least in the online incarnation (Arora *et al.*, 2008; Chellappa and Sin, 2005).

Supporting increasing product variety is placing the manufacturing function under increasing pressure to satisfy individual customers. Authors acknowledge the differentiated requirements necessary in non-make-to-stock contexts (Hilletofth, 2009; Zorzini *et al.*, 2008).

The concept of responsiveness is of consequence because it aligns with a wide range of manufacturing strategies (Holweg, 2005). The provision of products within acceptable time frames is considered an important requirement of sustained competitiveness (Christopher, 2005; Holweg, 2005). Holweg (2005), therefore provided a more detailed model that aims to highlight the multiple contingency factors involved in providing responsive order fulfilment. Flexibility is the general ability to adapt to internal and/or external influences (Holweg, 2005). In regards to the manufacturing, system flexibility is required to achieve responsiveness and is contingent upon the systems structure and environment. Pil and Holweg (2004) identified three dimensions of a successful BTO strategy which include process flexibility, product flexibility and volume flexibility.

Responsiveness and flexibility are essential characteristics in a supply chain that supports personalised products. The application of both has been highlighted to some extent in supply chain management related to customisation however their application for MPer is an unknown.

2.8 From Engineer-to-Order to Mass Personalisation

ETO supply chains are described as supply chains with a CODP located at the design stage or the order penetration point (Gosling and Naim, 2009; Hicks and McGovern, 2009). ETO companies are characterised by time-limited projects, and are often unique Caron and Fiore (1995). ETO supply chains are synonymous with complex project environments in sectors

such as construction and capital goods and high uncertainty (Hicks and McGovern, 2009). Short lead times are considered a competitive advantage in ETO (Wilkner *et al.*, 2016). Engineering changes can be costly and time-consuming and as such speed is a differentiator. As described by Gosling and Naim (2009) the main defining characteristic of an ETO supply chain is the CODP positioned at the design stage of a products supply chain. The ETO market is often a mature market with supply often exceeding demand (Hicks and McGovern, 2009). This is an attractive proposition from the perspective of the MPer where many of the innovations are less mature in their application in business models. Although the technologies themselves may be mature.

This research is concerned with reconciling the traditional view of ETO with ETO practised in organisations seeking MPer. An ETO variant, theorised by Wikner and Rudberg (2005) using the subscript PD and ED to denote the production and engineering dimensions, develops a two-dimensional typology in which a tuple represents the traditional types. Wikner and Rudberg (2005) ATOED to define a typology, where a new product is predesigned or has modular design components (Gosling and Naim, 2009; Wikner and Rudberg, 2005). There is much contention in the literature, as to whether or not a product design is unique to each order (Gosling and Naim, 2009). Table 2.11 tabulates the dimensions and aligns them with the traditional conceptualisation of them in the literature.

Traditional CODP	Engineering CODP	Production CODP
ETO	ETO_{ED}	MTO_{ED}
-	ATO_{ED}	MTO_{ED}
MTO	ETS_{ED}	MTO_{ED}
-	ATO_{ED}	ATO_{ED}
ATO	ETS_{ED}	ATO_{ED}
MTS	ETS_{ED}	MTS_{ED}

Table 2.9: Customer Order Decoupling Point: Engineering and Productioin Dimensions (adapted from Wikner and Rudberg (2005))

The traditional customer order decoupling points are ommited where they are not applicable. Wikner and Rudberg (2005) developed a typology to account for the engineering dimension, which was excluded in previous conceptualisations of the CODP and supply chain typologies.Wikner and Rudberg (2005) made a distinction that ETO is a particular case of MTO. In both MTO and ETO the authors argued that 100% of the production flow is driven by an actual customer order. Wikner and Rudberg (2005), stated that ETO and MTO differ in the design and engineering function. In ETO, engineering and design activities can be independent of the customer order. It is the argument of this research that this typology is the last logical point for applying standardisation at which some economies of scale can be achieved. This typology also represents the final position at which the product and process stability, facilitated by advanced manufacturing techniques, could deliver the individualised products envisaged by the promoters of MC and MPer.

According to Gosling and Naim (2009) ETO supply chain definitions, in the literature, agree that the production flow is all driven by actual customer orders. The logical typology defined by Wikner and Rudberg (2005) provided an ETO variant where both possibilities can be explored.

Figure 2.10 illustrates the dimensions for supply chain type based on CODP. Figure 2.10 includes the theoretical position of an ATOed and MTOpd that may come to typical of personalisers.

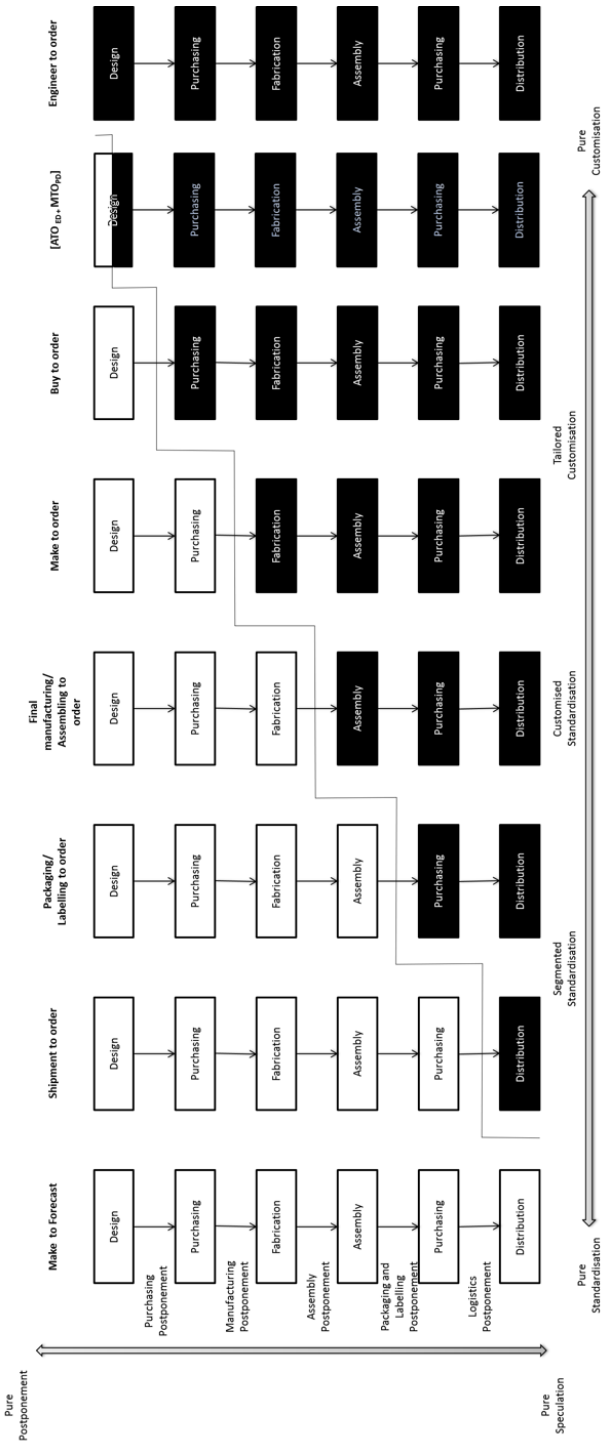

Figure 2.12: Supply Chain Typology and Postponement (adapted from Wikner and Rudberg (2005); Yang *et al.* (2004))

2.9 Product Architecture

Product architecture is a prominent theme in the corpus that forms the extant literature under review. The descriptor *Product architecture* refers to the scheme through which functions are allocated to products Ulrich (1995). It is important to understand the significance of product structure regarding personalisation because product design has critical implications for the cost of the supply chain (Fisher, 1997; Forza *et al.*, 2008; Kotri and McKenzie, 2010). In support of mass customisation standardisation at component and subassembly level allowed the implementation of modular configurations. This approach increased quality while enabling a mode of order fulfilment named Build-to-order. Many authors credit the final construction of a product as minimising finished goods inventory (Ro *et al.*, 2007). Pine and Gilmore (2011) insist that modularity in product architecture is a prerequisite for mass customisation.

Matching supply chain management techniques and process with products characteristics and architecture is a critical consideration for understanding MPer (Kumar, 2007b). The relationship between product design, product characteristics and supply chain structure are well-documented (Fixson, 2005).

Fisher (1997) provided a model that matches supply chain with product characteristics as shown in Figure 2.13. One of the criticisms of the model is its simplicity; there may indeed be varying degrees of functional and innovative products.

In the discussion around *product design space* product modularity has been cited as a significant enabler of design for mass customisation (DFMC). Modules with embedded commonality can be reused among product families (Tseng *et al.*, 2010). Product architecture as the primary enabler of differentiation is often considered as configure-to-order, however personalisation is the differentiation of the product:

> "*...beyond the original set of product offerings...While customisation assumes fixed product architectures and pre-defined configuration models, personalization implies possible changes of the basic design and product features*."
>
> Tseng *et al.* (2010, pp.175-176)

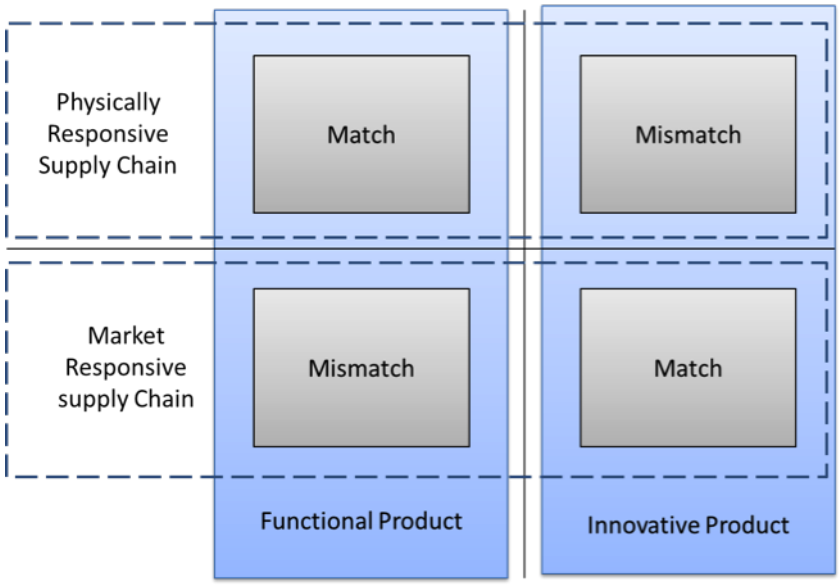

Figure 2.13: Fisher Model (Fisher, 1997)

The supply chain management, operations management and manufacturing literature, consistently acknowledge the varying degrees in, modular or integrated product architecture Fixson (2005). Modular and integrated product architecture can be defined by the degree to which components can be separated or integrated (Ulrich, 1995). Modular products are said to have a one-to-one relationship with architecture while integral products possess a one-to-many. The most prominent types of modularity are defined by (Ulrich, 1995). Modularity also defined as the degree to which a systems components can be separated and recombined; a bundle of product characteristics (Ulrich, 1995). Modularity exists in a product architecture that exhibits a high level of loosely coupled subsystems for example bicycles and desktop computers. Modular products are therefore interchangeable, comparatively easier to replicate in comparison to integrated products. Modularity as a field of enquiry is prominent in design theory and operations management. Modular products are therefore interchangeable, comparatively easier to replicate in comparison to integrated products. Modularity as a field of enquiry is prominent in design theory and operations management. Modularity seeks to bridge the trade-offs between product variance and operational efficiency, through component commonality. In the automotive industry, modularity has been embraced to enable the efficient and cost-effective provision of significant product variety. Ro *et al.* (2007),

identified that American auto industry was moving towards modular products in the mid-1990's claiming strategic benefits such as cost and lead-time reductions as well as the ability to customise product lines in mass quantities. Modular product architectures success rests in the tying the efficiencies gleaned from product design and fabrication and tying them to strategic performance objectives as lead-time and product variation.

The utilisation of modularity is an attempt to bring some form of standardisation and gain some economies of scale (Ro *et al.*, 2007). This focus is one of the reasons MC only achieves a middle ground between individualisation and standardisation. The focus by practitioners has been to reduce the complexity, caused by products variants, in the supply chain. Pursuing uniformity wherever possibly is understandable since the cost of continuing mass customisation can be prohibitive. It begs the question: What therefore are the implications for personalisation? A key aspect of integrated products is that their interfaces tend to be closed systems protected by copyright law (Fine *et al.*, 2005).

For personalisation of products and processes, the impact of modularity and the degree of modularity incorporated is an unknown. However, the application of modularity for customisation is well documented. In reality products will have an architecture that has varying degrees of modular and integrated components. The application of postponement and subsequently MC is the ability of modular product architecture to limit the negative impact of product variety. This can be achieved as previously by enabling form postponement, already mentioned by Forza *et al.* (2008).

Modular products often lead to modular supply chains. The commoditisation of modular components and standardised interfaces remove some of the barriers to competition experienced by some integrated products. Modular industries such as building a personal computer, laptops or bicycles tend to create extreme commodity-like competition Fine (2000) Therefore supply chains also experience a degree of modularity, (Fine, 2000) identified that product's supply chains may also have an architectural structure that mimics the modular vs. integrated paradigm. An integrated supply chain is one in which the participants are close in proximity; proximity is measured in four dimensions (Fine *et al.*, 2005; Voordijk *et al.*, 2006). A modular supply chain, on the other hand, exhibits a structure with geographically

dispersed participants.

In modular supply chains, modular components experience a proliferation of suppliers; after some time, the commoditisation of the product may be an eventuality. One of the aims of mass personalisation is to eliminate the commoditisation of the product(Kumar, 2007b; Pine and Gilmore, 2011; Riemer and Totz, 2003). Doran (2003) identified first tier suppliers as enablers of modular supply chains. The results from three exploratory case studies identified modularity as having an effect on the buyer-supplier relationship.

Modularity offers the ability to move the product differentiation downstream while moving inventory further upstream (Doran, 2003). Salvador *et al.* (2002) concluded that the embedding of modularity into the product family architecture impacts the sourcing decision and consequently supplier relations.

Dell gained an advantage over bigger competitors in the personal computer market such as IBM, Apple and Compaq by offering more configurable variety Ro *et al.* (2007). Dell achieved this while maintaining acceptable assembly and delivery times at a competitive price point.

Product architecture and specifically product modularity has played a visible role in facilitating the postponement of product differentiation until a custom has entered an order. As personalisation is a departure from customisation, questions remain as to the role of modular product in this setting.

2.10 Information Technology

Open innovation describes the shift in focus, by organisations, from internal R&D activities to soliciting change from outside. Trends highlighted in this study such as the proliferation of advanced manufacturing and communications technology and the pursuit of flexibility and agility are credited with breaking the previously closed practice of innovation (Dahlander and Gann, 2010).

R&D as a strategic asset has played a significant role as a formidable barrier to entry for organisations seeking to produce products Chesbrough (2006). However, second genera-

tion internet technologies (so-called web 2.0) are challenging the parameters of innovation. Companies such as Shapeways have provided a new business model that allows customers to design and fabricate products online.

Alderman (2004) argued that the shift in technology from the provision of goods to the supply of services will increase the global search for partners and suppliers rather than focus on the geographically closer partners. The utilisation of information technology is ubiquitous throughout Industry. Information technology plays an important part in integrating the separate entities in the supply chain (Gunasekaran and Ngai, 2005). Dell computers provide an example of the power of this integration and are often cited as an example of successful mass customisation strategy Ro *et al.* (2007). The successful incorporation of web-based configuration tools and modular components enabled this achievement. Achieving the high product variety and mass production, at reduced costs and with significant economies of scale

Electronic data interchange (EDI), Web platforms, mining big data sets all require the computational power of information technology can afford. Web-based configuration tools offered to customers have been the main feature for mass customisation. In personalisation information technologies like the Internet play more than just a supportive role and can be seen as critical. This review focuses on information technologies that support supply chain infrastructure, virtual enterprise and eCommerce for personalised products and services.

Network aware technologies allow separate supply chain entities to share competencies and resources and are considered capable of improving communication and coordination (Gunasekaran and Ngai, 2005). The integration of ERP systems such as SAP with supply chain processes, production planning, logistics and marketing promotions allows functions like procurement, production and distribution to better plan how to meet customers demand. While many authors discuss the application of IT in supply chain management much of the discourse focuses on integration and enabling communication. Gunasekaran and Ngai (2005) acknowledged that much of the literature was biased towards sales and marketing and states that the supply chain dimension of Business is mostly ignored.

However, Hoek (2001) acknowledged the difference between the supply chain's ap-

proach to e-commerce in comparison to traditional e-commerce and procurement, specifying the focus of using the information for long-term innovation and better customer relationships.

Recommendation engines, big data and loyalty cards and the impact on supply chain function have not been explored explicitly by this thesis, however through branching and passing discussion in other works of literature their role in integrating customer habits into the supply chain planning and operations process are highlighted. The use of data mining has become increasingly prevalent in the online retail domain. Arguably the driving force behind personalisation is the increase in data. In the last decade data storage and data processing have increased significantly. The migration of products into data as well as physical widgets or the digitisation of goods. This digitisation makes physical widgets as susceptible to the infringement and piracy once associated with the music industry and more recently the publishing industry. One such disruptive technology identified as increasing this process is additive manufacturing, more commonly known as 3d printing. The use of this technology, however, raises the possibility of personalisation Gershenfeld (2007).

The application of IT in non-MTS environments is an important consideration. Traditional technologies like MRP often differ in their central assumptions and so do not support operations in non-MTS settings (Gosling and Naim, 2009). Hoek (2001) acknowledged the difference between the supply chain's approach to e-commerce in comparison to traditional e-commerce and procurement, specifying the focus of using the information for long-term innovation and better customer relationships. Tesco is a prime example a company utilising big data and e-commerce to personalise customers shopping experience with targeted deals.

Globally operating firms often utilise expensive hardware and software to coordinate their activities. However, the proliferation of affordable web X.0 technologies has offered the increased integration at a lower cost (Tam and Ho, 2006). Davenport and Harris (2007), stated that capable technological environment is required to take advantage of real data. Access to customer related data and subsequent analysis may play a significant role in Mass Personalisation.

Kumar (2007a) discussed business analytics as empowering and provide economic ar-

guments for pursuing Mass Personalisation strategies, covering; consumer, supply chain, financial performance and cost management, new product/service development and strategic planning. Traditionally a significant challenge in implementing Personalisation has been customer integration (Arora *et al.*, 2008). Globally operating firms often utilise expensive hardware and software to coordinate their activities (Clegg *et al.*, 2008).

The economic arguments for pursuing Mass Personalisation strategies are:

- Mass Personalisation reduces the commoditisation of products by personalising product differentiation Gilmore and Pine (1997). Individualisation of product and service allows for one-to-one price differentiation removing the comparability Riemer and Totz (2003) and subsequent commoditisation;
- Increased customer retention through increase contractual, physical and psychological obligations derived from Personalisation Riemer and Totz (2003).

Another of the significant issue with organisations providing personalised products is the various ways personalisation can be achieved. The variety of supply chain design configurations makes decisions about supply and demand network design complex (Poulin *et al.*, 2006). Introducing personalised products imply significant changes for an organisation. Determining the level of personalization required by the market and the profitability of making such a provision is difficult to assess (Poulin *et al.*, 2006).

2.11 Research Gaps From Literature Review

After reviewing the literature, it is clear there are several research gaps. From the discussion of mass personalisation, mass customisation and servitisation in the literature, there is still ambiguity regarding their scope of theory and practice. The ambiguity is prominent when viewed from the perspective of strategic choice and the implications for supply chain design and management (Kumar, 2007b). Answering the question *What are their tangible differences between Mass Personalisation and Mass Customisation in theory and practice?* through an empirical study, will provide an insight into the strategic considerations management can make in the pursuit of personalisation. Asking this question requires

an appreciation for engineering required for a personalised product and the mode of order fulfilment. As mentioned in Section2.6 and Section 2.9 product architecture and method of order fulfilment will have significant implication for the supply chain both foreseen and unseen.

Another gap identified in the literature is to what extent do the consideration made for pursuing influence supply chain management and design. There is a paucity of empirical research discussing the *"real world"* implications of pursuing personalisation as a strategy. The last gap in the research is an empirical analysis of the effect personalisation has on the supply chain design and management.

2.11.1 RG1:What are the empirical differences between Mass Personalisation and Mass Customisation practice?

MC has the stated aim of providing individualised products, but as Sinclair (2012) points out, customers have traditionally been engaged in customisation in a limited way through online product configuration platforms. A typical, long-standing example being the NikeID online store offering customers choices of colours, designs, materials and soles to configure a custom product. Most online configuration platforms provide the customer with a base product to make *soft* alterations (Tseng *et al.*, 2010). MC is synonymous with a configuration solution space, but it is unclear whether MPer is as restrictive in practice. A critique levied at Kumar (2007) by Sinclair (2012) is the failure to understand the customer outside the existing paradigm of configuration. However, the question remains as to whether this is a short coming inherent in the industry. This research question is therefore grounded in the literature and answering it contributes to the extant literature on MPer.

2.11.2 RG2: To what extent does the pursuit of Mass Personalisation influence the strategic managerial considerations for supply chain management?

Mass customisation is bound by the configuration solution space (Lampel and Mintzberg, 1996; Sinclair, 2012). The provision of a platform for configurators is an example of a consideration many mass customizers would accept as a sensible one. However, is such a requirement as prolific for those pursuing personalisation? Further constraints on the type of customisation companies offer include the industry served, the product specification, whether the organisation is selling B2B or B2C, legal restrictions, import-export tariffs and so on. Product configuration is of importance because it can confer significant boundaries on the supply chain. Balasubramanian (2001) states that the product architecture can be responsible for up to 80% of the supply chain design. Product design is explored later in Section 2.9. The boundaries for personalisation in an operations and supply chain context are missing in the extant literature. Understanding the of personalisation in the same vein from an empirical study would be a contribution to the literature.

2.11.3 RG3: What are the effects of Mass Personalisation on supply chain organisation, design and management?

Supply chains intentionally or unintentionally have a design; these models arguably fit some of the known classifications of supply chain typology (Wikner and Rudberg, 2005). The classic types have informed discussions on form postponement and manufacturing strategy. In mass customisation it acknowledged that supply chain components have to align in a configuration that assists the customisation goal (Wikner and Rudberg, 2005). Pine (1993b) commented on this stating:

"*To achieve successful mass customization, managers need first to turn their processes into modules. Second, they need to create an architecture for linking them that will permit them to integrate rapidly in the best combination or sequence required to tailor products or*

services."

Pine (1993b, pp.112)

Is the same true for MPer? Is modularity as important for persuing the mass personalisation of products? These are question that do not have an empirical answer in the literature.

2.12 Summary

One of the significant issues with organisations providing personalised products is the various ways personalisation can be achieved. The variety of supply chain design configurations makes decisions about supply and demand network design complex (Poulin *et al.*, 2006). Introducing personalised products implies significant changes for an organisation. Determining the level of personalization required by the market and the profitability of making such a provision is difficult (Poulin *et al.*, 2006). Without the understanding of the specific implications of supporting combinations of personalization option (Poulin *et al.*, 2006). Demand trends are often highly influenced by external factors such as the media or relevant standard-setting associations and not internal R&D for example (Poulin *et al.*, 2006).

Table 2.4 and 4.1 represent excerpts from tables in the database. Entries from the literature and the field study are linked by their themes and claims, while the claims from the literature are linked to the authors of the journal article. These relationships enforce a referential integrity and provide a consistent method to corroborate the field research with the view presented in the literature. There is a level of subjectivity in the thematic coding, and the process of identifying themes is highly interpretivist (Guest *et al.*, 2011), as mentioned in section 2.1.8.

In this section, a literature taxonomy will be presented. The taxonomy in Tables 3.2 tabulate the themes and contributors to the taxonomy. Table 2.10 shows the number of articles retrieved from each database for each search. When searching through Science Direct, it is important to note that the search strings used single quotation marks instead of the double quotes used in the ABI/Inform database.

Search	No. Papers		
	Abi Inform*	Science Direct*	Google Scholar
1	148	6	1
2	87	0	0
3	69	0	53
4	39	0	6,810
5	83	0	85
6	233	0	1,100
7	100	0	46
8	638	0	6,040
9	119	0	2,320
10	27	16	20

Table 2.10: Results Literature Search

Simchi-Levi *et al.* (1999) defined supply chain management as a set of approaches aimed at integrating suppliers, manufacturers, warehouses and stores to produce merchandise. A focus of SCM is the distribution of products at the right quantities, to the right locations, at the right time and a minimum cost; satisfying service level requirements (Christopher, 2005). Product variety complicates the management of the process associated with SCM as an a result the pursuit of MC products is difficult Piller (2007); Piller *et al.* (2004); Pine (1993a); Salvador *et al.* (2002); Silveira *et al.* (2001). MC has fallen short of the promise of product individualisation Kumar (2007b) and as a result, personalisation is a frequent topic within supply chain literature. The rise in prominence of new information communications technologies and manufacturing technologies such as additive manufacturing means pursuing personalisation in products and services has become a prevailing trend Reeves *et al.* (2011). MS is an important strategic consideration when seeking product variety requires alignment of the capabilities of the manufacturing function and the overall business strategy (Chan, 2005; Christopher, 2005; Hayes and Wheelwright, 1984). The question that follows is what are the strategic implications for SCM and MS decisions when pursuing personali-

sation?

Manufacturing strategy is a major component of Mass Customisation and indeed any mode of production that deviates from the standardisation of Mass Production. Much of the literature regarding MS strategy discusses Mass Customisation, assemble-to-order, build-to-order and engineer-to-order strategies, very few discuss manufacturing strategy and personlisation. Mass Customisation and Mass Personalisation are separate fields of enquiry, but they share significant overlap, the extant literature has regarded them as synonymous in some case. Personalisation retains an essential characteristic that separate it from ETO, and that is the criterion of affordability (Kumar, 2007b). ETO is not synonymous with affordable products and as such Mass Personalisation is an interesting theory with intriguing implication for empirical research.

3. Conceptual Framework, Propositions and Research Questions

Chapter 3 presents a literature taxonomy, a synthesised framework and develops the framework into a conceptual model. The conceptual model encapsulating the themes explored in the literature review. How these themes are mapped to the conceptual model and inform the propositions is explored. In this Chapter, it is proposed that manufacturing strategy and order fulfilment processes must align to achieve Mass Personalisation. It is also suggested that strategic manufacturing considerations, such as manufacturing technology, are critical for achieving Mass Personalisation. Finally, it is proposed that strategic implementation information technology enable Mass Personalisation.

3.1 Literature Taxonomy and Synthesised Framework

The synthesised framework preseneted in this section summarise the relationships implied by the taxonomy and literature. Figure 3.1 illustrates in more detail, the implicit and explicit relationships from the literature, fitting the topics together in a synthesised framework. There is not a one-to-one relationship between the themes in the taxonomy, Figure 3.1 is a illustration of the literature and exploration into Mass Personalisation.

The synthesised framework in Figure 3.1 illustrates the causal factors and other themes in a relationship. The core of the framework is based on the internal processes and decoupling points that separate dependent demand from independent demand. Above and below the core of Figure 3.1 are the factors from literature and are orientated to indicate the motivation or expectation when moving up and down the spectrum of CODP's. In the proceeding paragraphs, each factor in the framework illustrated in Figure 3.1 is explored.

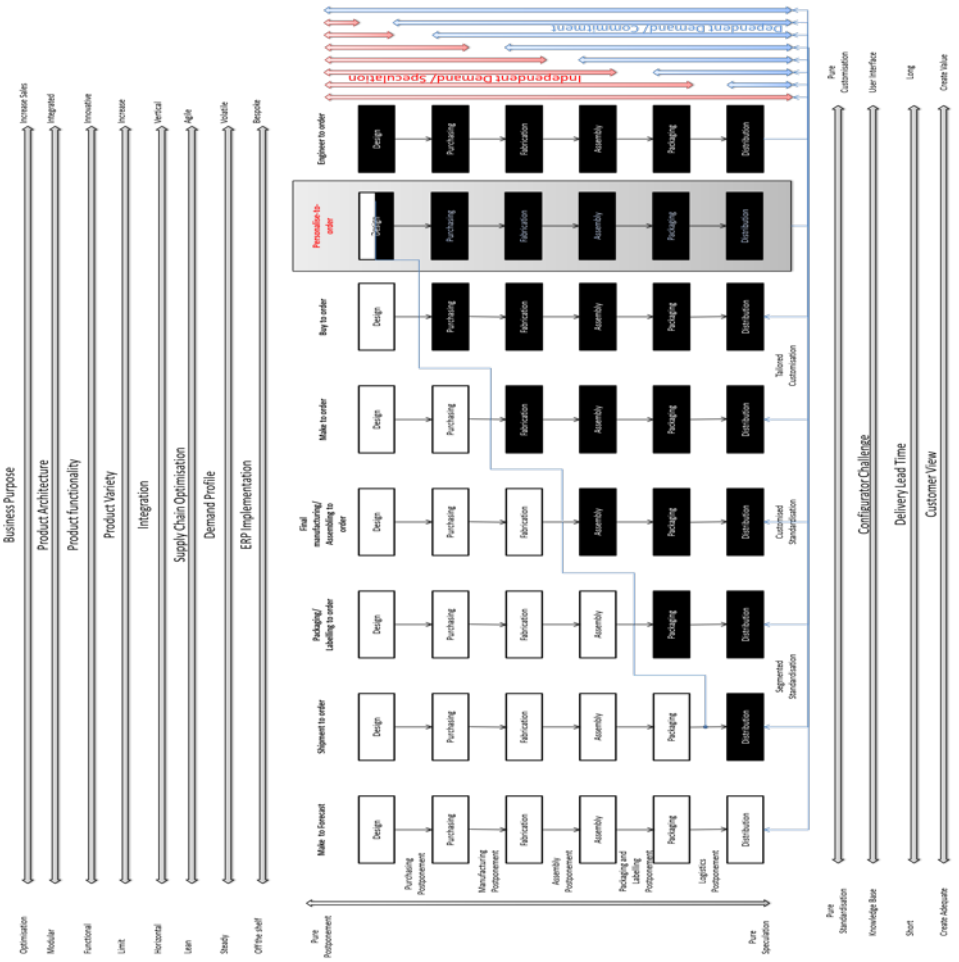

Figure 3.1: Synthesised Framework

Business Process illustrates the rationale for organisations to seek decoupling points based on pursuing product and process optimisation or seeking increased value. Both are represented as antithetical and summarise the dichotomy between using lean or agile SCM techniques. In one direction the expectation is of increased sales, invariably requiring greater resources and reduction of efficiency, in the other direction an organisation can expect to improve optimisation (Haug *et al.*, 2009). Supported by the fact mass producers are often classified as make to forecast (MTF) , illustrated the beginning of the spectrum and characterised by *pure standardisation*. Pure standardisation as discussed in the literature review is typical of MP, where product and process are seen as an integral whole and where standardisation leads to economies of scale and lower costs (Jiao and Tseng, 2004). Companies identifying themselves as 'personalisers' should be located on the side of the spectrum that seeks increased sales. Although as Haug *et al.* (2009) pointed out companies who move from ETO may indeed try to optimise and decrease product variety (Haug *et al.*, 2009; Lampel and Mintzberg, 1996). Haug *et al.* (2009) speculated that process automation is necessary when moving in the direction from ETO to MC.

Product Architecture can be modular or integrated. Organisations seek greater product modularity as they move towards ETO. MTF products can and often do exhibit a high degree of integration. As pointed out by Forza *et al.* (2008), increased modularity enables FP, an essential feature of ATO and BTO products. Modular product, such as computers and bicycles, have subsystems which are loosely coupled Voordijk *et al.* (2006). A high degree of modularity allows components to be interchangeable and often means several OEMs can provide subsystems. Also, product modularity affords the opportunity to delay the final form of a product and instead of stocking FGI, more WIP is prevalent until orders are received. In personalised products, the product architecture may indeed move to being integrated again, as the benefits of FP and modularity may be less clear. Modular products also confer modularity to the supply chain and manufacturing processes. According to Fine (1998) and Voordijk *et al.* (2006) supply chain modularity can be described as the degree of proximity between:

- Geography– the physical distance between members of a supply chain;

- Organisational – the sphere of influence each participant of the supply chain exhibits;
- Cultural – the social barriers that an impediment to productivity like legal issues and language;
- Electronic proximity – the level of interconnectivity between the members of the supply chain using EDI .

It is fair to assume that personalised products will exhibit varying degrees of modularity, and modular product architecture is unlikely to be the primary focus.

Product Functionality represents a spectrum of product types. Functional products are characterised by stable demand, and a long product life-cycle, economies of scale is achieved through large volumes and high utilisation of resources (Selldin and Olhager, 2007; Vonderembse *et al.*, 2006). On the other side of the spectrum, innovative products are new and aimed at new markets. Fisher (1997) indicated the pursuit of responsiveness as beneficial for innovative products.

Product Variety indicates the likely consolidation of product variety when moving towards MTF or the proliferation of product variants moving towards ETO. Increased product variety is better suited to combinatorial modularity, aligning with the architecture product factor, and low volume production Salvador *et al.* (2002). MPer is dependent on the theory that organisation capable of ETO will be the best situated to personalise products at scale.

Integration positions companies as horizontal or vertical integrators. The acquisition of a similar organisation is considered horizontal integration. While, the acquisition of organisations upstream or downstream, engaged in different activity from the focal organisations, is termed vertical integration Voordijk et al. (2006). Growth is the common motive for horizontal integration, while vertical integration is often pursued to attain new competencies. The implication for personalisation is unknown.

Supply Chain Optimisation aligns the dominant supply chain strategies, agile and lean, with the fulfilment types and the other factors. SCO is the strategy that incorporates the focus of the organisations operations with the business strategy. Agile supply chains often require more resource and are not the common pursuit of MP. Therefore, the lean position

of the spectrum is located on the same side as MTF and optimisation as the business purpose. The supposition is that it is unlikely to find a self-proclaimed personalise who is also strategically focused on being lean; agility may be a stated aim. Lean supply chains are typically concerned with cost; the cost is also much more of consideration for functional products (Selldin and Olhager, 2007). Lean supply chains seek internal efficiencies and reduced setup times (Vonderembse *et al.*, 2006). From the literature review, it can be inferred that personalises will not pursue a traditionally lean supply chain but may seek to gain some efficiencies through leaner processes. The cost savings of continuing leaner processes may however, be offset by the pursuit of agility and responsiveness elsewhere again enforcing that lean practices may not be the dominant search. Agility is much more aligned with personalisation as the strategy seeks to respond to rapid changes and fragmentation of the market (Vonderembse *et al.*, 2006).

The configurator Challenge refers to the design choices offered to the customer. Depending on the position of the spectrum companies may prioritise harnessing the knowledge base versus the provision of a user interface to configure the product Haug *et al.* (2009). ETO organisation will typically find it difficult to rationalise their processes and product offering into a subset of configurable products (Haug et al., 2009). Since the move to customisation is not the goal of MPer, it is expected that personalises will have found a way to avoid this requirement.

Importantly Stonebraker et al. (2004) found that technology drives structure. The implication for supply chain designs and following order fulfilment capabilities is summarised by Stonebraker and Afifi (2004):

> "*... the implications of this study are that the more evolved the technology, the greater the differentiation, and consequently the greater the amount of integration effort required.*"
>
> Stonebraker and Afifi (2004, pp.1142)

The framework was then captured as a conceptual model for questions to be posed against. Propositions have been made about the implications of these contingent factors for achieving mass personalisation. Table 3.1 aligns the conceptual components with their related

framework components.

Conceptual Model Component	Framework Component
CODP	Delivery Lead Time Customer View Supply Chain Optimisation
Manufacturing Strategy	Business Purpose Product Architecture Product Functionality Product Variety Integration
Information Systems	Configurator Challenge ERP Implementation

Table 3.1: Aligning Conceptual Model with Sythesised Framework

The factors and themes are formalised in the conceptual model, illustrated in Figure 3.2.

The pursuit of personalised products is a multifaceted problem. MC promised individualisation and was hailed as the final frontier in business (Davis, 1987; Pine and Davis, 1999). However, the extant literature discusses MPer as distinct from MC (Kumar, 2007a,b). Several themes converge on the topic of personalisation. Throughout the literature review, the ideas used as categories in the thematic analysis evolved iteratively through the research. A handful of groups were implicit from the keywords used to create the search terms; the rest developed over the course of the review and field work. These classifications were instrumental in developing the theory and subsequent propositions. In this chapter the framework, conceptual model and hypotheses are explored.

Tables 3.2 contains a taxonomy of the literature, breaking down the themes from the authors and aligning them with . The theme desriptions can be found in Appendix.

Category/Theme			Contributing Author
Main Focus	Conceptual	Literature Review	
Mass Personalisation	Manufacturing Strategy	ETO	Anderson *et al.* (2011); Caron and Fiore (1995); Gosling and Naim (2009); Haug *et al.* (2009); Hicks and McGovern (2009); Hicks *et al.* (2000); Little *et al.* (2001); Lockamy (1993); Parente *et al.* (2002); Tsinopoulos and Bell (2009); Wikner and Rudberg (2005); **?**
		Time Compression	Gosling and Naim (2009); Kritchanchai and MacCarthy (1999); Zorzini *et al.* (2008)
		Flexibility	Gosling and Naim (2009); Holweg (2005); Meyer *et al.* (1989); Spring and Dalrymple (2000); Zorzini *et al.* (2008)
		Manufacturing	Amaro *et al.* (1999); Bask *et al.* (2011); Bozarth and Chapman (1996); Caron and Fiore (1995); Chan (2005); Childe *et al.* (1994); Chung and Swink (2009); Dekkers (2011); Harrison and Skipworth (2008); Hicks *et al.* (2000); Holmstrom *et al.* (2010); Kumar (2007b); Li-Ling (1999); Little *et al.* (2001); Pal and Torstensson (2011); Reeves *et al.* (2011); Toni *et al.* (1992)
		Mass Customisation	Ahlstrom and Westbrook (1999); Bask *et al.* (2011); Duray (2002); Forza *et al.* (2008); Gilmore and Pine (1997); Hart (1995); Haug *et al.* (2009); Helms *et al.* (2008); Huffman and Kahn (1998); Kotha (2007); Kumar (2007a); Piller (2007); Piller *et al.* (2004); Pine (1993a); Pine and Davis (1999); Trentin *et al.* (2012); Zhou *et al.* (2013b); **?**); **?**
		Mass Personalisation	Kumar (2007a); Poulin *et al.* (2006); Sunikka and Bragge (2012); Tseng *et al.* (2010); Tseng and Piller (2003); Vesanen (2007); Zhou *et al.* (2013a)
	Supply Chain Design	Supply Chain Integration	Kache and Seuring (2014); Pero *et al.* (2015)
		Supply Chain Structure	Alderman (2004); Amaro *et al.* (1999); Chen *et al.* (2003); Holweg (2005); Pero *et al.* (2015); Tsinopoulos and Bell (2009); Wikner and Rudberg (2005)
		Strategy	Kim *et al.* (2015)Alderman (2004); Chan (2005); Dekkers (2011); Frias-Martinez *et al.* (2009); Gosling and Naim (2009); Hilletofth (2009); Hofer (1975); Kotha (1996); Maull *et al.* (1995); Molina *et al.* (2007); Pal and Torstensson (2011); Saisse and Wilding (1997); Singh *et al.* (2010); Wikner and Rudberg (2005)
		Postponement	Forza *et al.* (2008); Harrison and Skipworth (2008); Walker (2010); Waller *et al.* (2000); Yang *et al.* (2004)
		Product Design	Akinc and Meredith (2015); Lu and Wood (2006); Pal and Torstensson (2011); Zhou *et al.* (2013b)
	Information systems	Information Management	Anderson *et al.* (2011); Dekkers (2011); Goodhue and CFPIM (2005); Tseng and Piller (2003); Yusuf and Little (1998)

Table 3.2: Literature Taxonomy

The themes from the literature have been grouped into topics that cover them more completely in the literature and offer broader scope when posing propositions. In the following sections, each of the theme that compose the conceptual model are discussed.

Manufacturing Strategy has been selected as a topic that subsumes key themes in the literature review. Achieving manufacturing strategic goals depend on several criteria, orchestrated at tactical and operational level. An important component of Manufacturing Strategy is the accurate control of materials, processes, people and information at several organisational levels within a value adding chain (Little *et al.*, 2001). Critical to attain this level of control is the success at the technological level, where integration and monitoring of some devices comprising a complex system are now the state of the art (Little *et al.*, 2001).

ETO is a logical component of Manufacturing Strategy, as stated in the literature review in section 2.3 managing the trade-off inherent in prioritising variety is important. Special consideration is necessary for the alignment of the manufacturing function processes with the way product orders are fulfilled (Chen *et al.*, 2003). ETO has long represented a mode of order fulfilment which aligns with a manufacturing strategy concomitant with reconfigurable physical processes, engineering design and a tendering process (Gosling and Naim, 2009). While ETO lends itself to product variety, it traditionally has not been acknowledged as a Manufacturing Strategy that is affordable or with an acceptable lead time for mass consumption. It is unknown how Mass Personalisation and ETO order fulfilment are related, however, it is likely that many important concepts from ETO will inform Mass Personalisation due to there similar stated goals and constraints.

Supply Chain Design is critical to exploring the possibility of providing low-volume high-variety production through a supply chain, is supply chain design. There is a significant correlation between the point of customer interaction and the focus of the manufacturing and production function (Slack and Lewis, 2002; Wikner and Rudberg, 2005). Due to this relationship exploring the possibility of mass personalisation also requires an exploration into the structure of the supply chain, including point of customer interaction and implications for the manufacturing and production function.

3.2 Coneptual Model

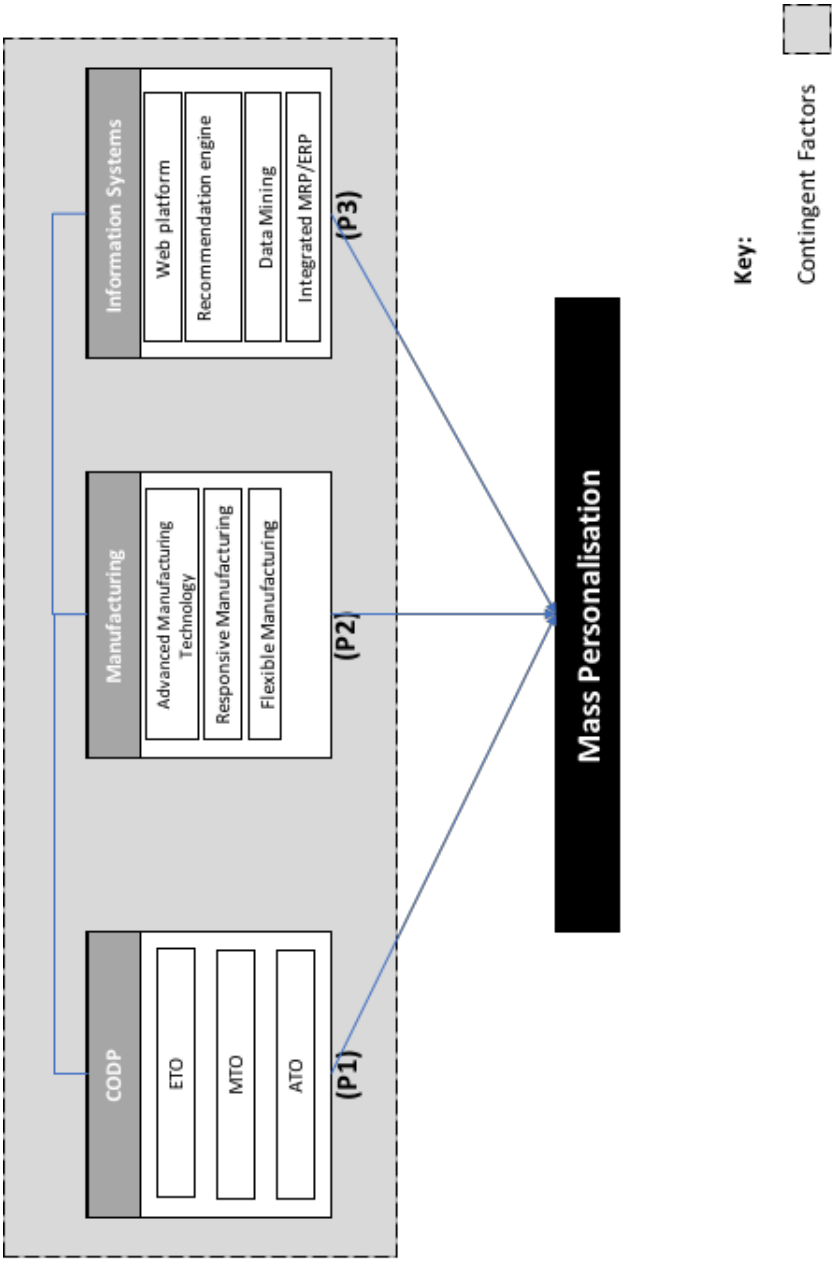

Figure 3.2: Conceptual Model Source: Author

The propositions were developed for testing, as the empirical questions. Punch (2013) idntified two criterions that indicate when hypotheses should only be used to guide research. The criterions specified by Punch (2013), are that for each question:

- A prediction can be made on the likely findings, in advance of the empirical research;
- The rationale is derived from propositions and theory in the literature.

The two criterion specified by Punch (2013) have been met by the research questions posed in this study. Yin (2011) stated that research questions alone often do not isolate what the study should focus on or the evidence required. Yin (2011) insisted that stating hypotheses will focus the research. In keeping with this approach a theoretical framework was deduced in Chapter 2 from previous literature on Mass Personalisation and Personalisation in Mass Customisation. The theoretical framework addresses the research questions by illustrating what Mass Personalisation attempts to achieve and how in theory it may achieve it.

3.2.1 Proposition 1 (P1): Order Fulfilment Capabilities Must Align with Manufacturing Strategy to Allows Mass Personalisation.

Product design characteristics and architecture are responsible for upto 80% of supply chain design decisions (Balasubramanian, 2001; Boardman and Clegg, 2001), specifically the supply chain typology and topology discussed in section 2.6. Cooper *et al.* (1997) stated that product development is likely one of the clearest examples of a function that should be integrated across the internal operations of a business, for efficient control, planning and implementation of a strategy. Several processes such as design for manufacture (DFM) and concurrent engineering (CE) have made progression with the application of this relationship. It therefore stands to reason that any supply chain purporting to support the personalisation of products and services, should align with a mode of order fulfilmet concomittent with delaying, as far up the value stream as possible, the point at which indepnedent demand becomes dependent on a customer order. The implied benifits of reducing the cost of the product and making it more affordable are stated aims of Mper (Kumar, 2007b). Engineer-to-order is a typology that already exists in the supply chain taxonomy which deals with

the postponement of differenciated products at the design stage and is not synonymous with affordability. Therefore it is unlikely that form-postponement on its own will be responsible for achieving affordable Mper products. While postponement at the design stage seems logical, the question still remains regarding the cost of configuring a supply chain to support a personalised product, where there is an abscence of a supply chain supporting mass customised products.

Common themes associate with this proposition are modularity and integration of prodct architecture and and the configurability of the product. Product architecture have a strong link to production and manufacture as well as providing customised or personalised functionality. Table 3.3 tabulates the author and contribution to the proposition.

Component	**Author**
ETO CODP	Balasubramanian (2001); Böhme *et al.* (2014); Caron and Fiore (1995); Dekkers (2011); Gosling and Naim (2009); Haug *et al.* (2009); Hicks and McGovern (2009); Hicks *et al.* (2000); Hilletofth (2009); Kim *et al.* (2006); Tsinopoulos and Bell (2009); Walker (2010); Wikner and Rudberg (2005); **?**

Table 3.3: Literature Contributing to Product Design Component of Conceptual Model Source: Author

From the literature it is clear that product architecture can vary from being modular to being integrated; the degree to which the product architecture is either or, affects the supply chain (Holweg, 2005). Specifically, the order fulfilment capabilities of the supply chain are contingent upon the design of the product. The design of the product also includes its

functional type as outlined by Vonderembse *et al.* (2006). Fisher (1997) and Selldin and Olhager (2007).

Form postponement is a theme which is associated with this observation in the literature. According to Forza *et al.* (2008) improves responsiveness while enabling a high level of customisation (Harrison and van Hoek, 2005). However, mass personalised products seek the responsiveness of MC while also being entirely demand driven. Therefore, this hypothesis is based firstly on the logic that if MPer did make use of a sort of postponement strategy, it would be a make-to-order, build-to-order or engineer-to-order domain. At the extreme a personalised product should have an infinite parameter to a component of its specification and so there for the customer order decoupling point is crucial.

Some products may lend themselves to MPer more than others. It is already clear from the literature that a distinction like the product (*hard* or *soft*), has an implication for the practicality of adopting Mass personalisation strategies (Kumar, 2007b; Pine and Gilmore, 2011; Tseng and Piller, 2003). The description relates to the product's composition, either information or physical. The consensus amongst these authors is that soft products reside as information while *hard* products have a physical aspect. Tseng *et al.* (2010) went further to describe this nature along a continuum and discusses the composite nature of product ecosystems. All authors mentioned above agree that the*soft* characteristics of the goods and services readily lend themselves to Mper in comparison to *hard* products. The conjecture that ETO supply chain capabilities enable MPer, implies that more than just the soft components of a product can be personalised

Personalisation of the functional attributes of a product has significant structural implications for the supply chain and related processes while personalization of non-functional attributes of a product offering can be accommodated with less disruption to the supply chain and its operations Tseng *et al.* (2010). The mass personalisation of the functional product may require high levels of product architecture modularity or advanced manufacturing technology.

3.2.2 Proposition 2 (P2): Strategic Manufacturing Considerations and Practices Enable Order Fulfilment Capabilities for MPer

The architectural decisions in strategic manufacturing, as identified by Hill (1993) were given more weight in the conceptual model. Yang *et al.* (2004) stated that delaying the final processing or manufacturing of a product as late as possible is an option for dealing with design and volume variability. The postponement of construction activity until the last possible point allows the production function to be both responsive and agile. Typically in ETO, the mode of fulfilment most aligned with MPer, all production activity is initiated by the customer. Understanding if this is the case in practice is an important decision in understanding MPer.

As discussed in the literature review the ability to respond to changes in the demand of customers is an important ability when dealing with product variety (Lu *et al.*, 2007). For personalisation, this research aims to test the hypothesis manufacturing strategy is critical in defining the order fulfilment capabilities that support range while minimising the cost of small volume production in a mass personalisation context. In mass customisation, the alignment of output and manufacturing function with the supply chain was critical, and misalignment could cause inefficiencies. In personalisation, the alignment of the manufacturing services processes with the method of order fulfilment should be much more integrated. From anecdotal evidence and previously literature on MC, the translation of a manufacturing strategy to operational targets will likely be vital in maintaining the company as a going concern.

Component	Author
Advanced Manufacturing	(Amaro *et al.*, 1999; Davis, 1987; Duray, 2002; Parente, 1998; Reeves *et al.*, 2011)
Responsive Manufacturing	(Hilletofth, 2009; Holloway, 1997; Holweg, 2005; Wikner and Rudberg, 2005)
Flexible Manufacturing	Holweg (2005); Kumar (2007b); Lampel and Mintzberg (1996)
Inventory Management	(Kotha, 1996, 2007; Walker, 2010)

Table 3.4: Literature Contributing to Manufacturing Strategy Component of Conceptual Model Source: Author

The strategic pursuit of both lean and agile capabilities makes sense for mass personalisation. A standard issue for MC is the need to contest with high demand uncertainty at finished goods level when providing a broad product line. It is logical to consider the cost implications for the personalisation of a product. Although Pine and Gilmore (2011) pointed out that MC could be an expensive undertaking, Kekre and Srinivasan (1990) based on their study of over 1400 businesses showed that MC can confer significant benefits and increased market share. The extant literature does not deal with personalisation as extensively. To overcome this dichotomy postponing the final differentiation of a product is often promoted in the literature.

Agile supply chains aim to be responsive to changes in demand, focusing on growth and less focused on the application of standardisation. Earlier it was identified that product modularity enabled post-postponement which assisted BTO modes of order fulfilment. The relationships are expanded as Postponement is an enabler of agile supply chains.

Standard products that are functional with low innovation benefit from the lean supply chains while innovative products require agile supply chain's to respond to the higher demand uncertainty.

The pursuit and application of lean or agile practices in parts of the supply chain are a response to the proliferation of product variants. The focus on quick changeovers and small lot production enable the rapid response to market demand while simultaneously keeping inventories to a minimum (Holweg, 2005).

The application of lean practices simplifies and reduces variance within supply chains, in an attempt to create more predictable demand behaviour (Holweg, 2005). The application of lean practices in personalisation is unclear. The APICS body of knowledge focuses on methodologies for achieving lean operations (Walker, 2010).

The competing interest at stake when considering lean, agile or hybrid competencies in delivering products to market is the level of responsiveness the organisation wishes to achieve. The ultimate decision as to the feasibility of pursuing either rest on the group's knowledge of the market and the position of the order decoupling point (Holweg, 2005).

In relations to standardisation versus individualisation, there are disagreements as to the boundaries, definitions and applicability of both approaches. This proposition seeks to establish that:

1. A final supply chain design is strategic forethought in the provision of mass personalised products;

2. The strategy translates into a tangible operationalised method of manufacture and production;

3. The core supply chain structure and supply chain management tenets will be concomitant with, if not resemble exactly, an ETO mode of order fulfilment. The participating company will have a highly capable manufacturing process and significant vertical integration.

3.2.3 Proposition 3 (P3): Information Technology Enables Order Fulfilment Capabilities that Support the Pursuit of Mass Personalisation

Component	Author
Web Platform	(Doran, 2003; Fisher, 1997; Fixson, 2005; Haug *et al.*, 2009; Hilletofth, 2009; Vonderembse *et al.*, 2006; Voordijk *et al.*, 2006)
Integrated MRP ERP	Danese (2007); Kache and Seuring (2014); Lockamy and McCormack (2004)

Table 3.5: Literature Contributing to Information Technology component of Model Source: Author

Gunasekaran and Ngai (2005) stated that few articles deal with IT in supply chain management but that it is impossible to achieve an efficient supply chain without the support of IT. This study believes that information technology capabilities are even more pertinent to the efficient production and distribution of products that are personalised than that of customised products. As discussed in the literature review much of the personalisation of goods and services occurs on the internet or requires information technology as a medium to store and compute vast amounts of data to personalise services. Christopher (2005) famously stated that information is replacing inventory in the supply chain, it is not surprising that information plays such a significant part in supply chain management. Cooper *et al.* (1997) acknowledged the coordinating role of informatics, Gunasekaran and Ngai (2005) identifed IT as an enabler and integrator of supply chain participants and processes. Cooper *et al.* (1997) identified that a central question was how to integrate the supply chain and whether dyadic, channel integration, analytical optimisation or keiretsu is a better choice of combination. Integrative technology at the manufacturing level is also required for the

appropriate coordination of activity on the shop floor.

The integration of frontend systems and backend systems has been important in many mass customisers. Dynamic products and processes are key factors, for Mass Personalisation Strategies (Kumar, 2007b), yet manufacturers must contend with the difficult proposition of controlling costs and service levels when increasing variety and reducing delivery delays (Christopher, 2005).

ERP systems are prominent pieces of IT in organisations, in SMEs they suffer from implementation and adoption issues (Helo *et al.*, 2008). These problems often creep in due to the undefined roles and clear ownership of functions in many organisations (Jain et al., 2008). A personalised who is capable of MTO or ETO-like products will have to overcome these issues or exhibit ability that makes them less prominent. Bespoke implementations are a likely pursuit and common in ETO, where off the self-product do not satisfy the complex manufacturing processes undertaken by ETO organisations (Gosling and Naim, 2009).

3.3 Summary

After synthesisng a framework from the literature a taxonomy of the themes coded from the review has been presented. The themes from the literature have been aggregated into larger themes for further discussion.

4. Methodology

This chapter explains the research methodology and describes the applications of applied thematic analysis (ATA), its analytical purpose, its theoretical grounding and its implication for semi-structured interview questions and case studies. The division between research strategy and research methodology is described, including the authors decision to select a case study approach. The objectives, approach and epistemological nature of the case study and thematic analysis are described. Alternate research designs are considered and a justification of the case study and semi-structured interview is made explicit. Finally the research methodology is presented as a framework for pursuing the empirical enquiry and is operationalized into a protocol which mediates the data collection for later validation and triangulation of strategic considerations for enabling mass personalisation.

This chapter proceeds with a discussion of the steps taken in the research design, concluding with a summary of the overarching context of this dissertation. The literature review process, thematic analysis and case study approach are central to the methodology.

A methodology is:

"*...a way of thinking about and studying social reality*."

(Anselm *et al.*, 1990, pp4).

There are several consideration to make when selecting an appropriate research methodology. Two key considerations posed by Yin (2011) include:

- The identification of the type of research question posed; and,
- The extent of control a researcher has over behavioural events.

In addition to this consideration several other foactors were deemed relevant, due to the nature of strategic decisions in organisations, their system wide implications and ambigouity surrounding the pursuit of personalisation. These factors included the ability to:

- make deductive characteristics for deducing consequences and making preditions;
- manage ambiguity and unidentified phenomenon previously unreported;
- contextualise complex phenomenon ;
- consolidate data from a primary source close to the phenomenon with a sphere of influence that includes the phenomenon in it's natural setting.

Based on these criteria a case study and thematic analysis were selected.

4.1 Epistemology and Research Paradigms

Epistemology is the belief system that represents and interprets of knowledge. Epistemology questions the nature of knowledge, examining its form. In the context of social science, epistemology is the division between positivism and interpretivism and inductive versus deductive methods (Blaikie, 2007). Inductive and deductive methods differ in that inductive

methods are more generalisable and require a method of observing the phenomenon, while deductive methods require the role of participant-observer. A research paradigm is a philosophical framework for performing scientific research (Collis and Hussey, 2013). There are two main paradigms, Positivism and Interpretivism, representing opposite ends of a continuum (Collis and Hussey, 2013).

4.1.1 Positivism

Positivism is a paradigm that is closely associated with the natural sciences and has its roots in realism (discussed in subsection 4.1.4) (Collis and Hussey, 2013). The positivists perspective focuses on the causal relationship observable phenomenon (Grubic and Fan, 2010). A central assertion of positivism is the belief that reality is independent of the observer and that through empirical studies this independent reality can be known (Collis and Hussey, 2013). Under a positivist paradigm, it is expected that theories provide an explanation and offer a way to predict and control the phenomenon (Collis and Hussey, 2013; Grubic and Fan, 2010). The assumption that social phenomena can be measured and monitored aligns positivism with quantitative methods of analysis.

The ability to predict and control a phenomenon based on an observable objective reality is considered a strength of a positivist approach. However, it is also seen as a weakness if is believed that a phenomenon is subjective and affected by the act of investigating (Collis and Hussey, 2013).

4.1.2 Interpretivism

Interpretivism is a paradigm responding to the shortcomings of positivism and is based on the belief that reality is highly subjective and as such shaped by our perception (Collis and Hussey, 2013). The exploration of complex social phenomenon results in an interpretative understanding as opposed to an objective explanation. These findings are most likely not derived from some statistical analysis of quantitative data but through observation of the phenomenon. Interpretivism research aims to describe and interpret the meaning of social

phenomena. Traditionally qualitative research is associated with an interpretivist approach. However, it is worth noting that it is what is done with the qualitative data and not the methods themselves that determine whether the research is interpretive, positivist or indeed a hybrid (Guest *et al.*, 2011).

In research based on an interpretivist philosophy, researchers collect data pertinent to an informant, preserving the uniqueness of the contribution for contextual insight (Grubic and Fan, 2010). An important part of an interpretivist study, is that the participants have developed heuristics and symbolic forms that represent the structures they are participating in (Gioia and Pitre, 1990).

When performing research rooted in an interpretivist philosophy, analysis begins during data collection (Gioia and Pitre, 1990). Coding procedures are used to establish patterns from what is usually qualitative data. The coding procedures aim to provide:

"*... descriptive codes, categories, taxonomies, or interpretive schemes that are adequate at the level of meaning of the informants can be established.*"

(Gioia and Pitre, 1990, pp.388)

The pursuit of further analysis, theory generation, and data collection are continued through the research. Therefore, the process of theory building is iterative and nonlinear (Gioia and Pitre, 1990). This process can culminate in tentative speculations about observed phenomenon and proposition and conjectures can be confirmed or disconfirmed.

4.1.3 Pragmatism

Pragmatism was first defined by James (1975) and is an alternative paradigm to Positivism and Interpretivism. Pragmatism does not require the rigid adherence to reality with causation, accepting instead that there is both a singular reality and multiple realities (Yvonne Feilzer, 2010). Fundamentally pragmatism takes a firm stance against the duality of positivism and interpretivism and seeks to converge both qualitative and quantitative methods (Yvonne Feilzer, 2010). The practical implications for a pragmatic approach are the use of mixed methodology. Mixing two or more of the alternative research methods presented in Section 4.2, offers a way of providing a richer more *complete* view of a phenomenon (Yvonne Feilzer,

2010). A criticism of pragmatism is mixed method research still seems to treat each method as being either positivist or interpretivist. Yvonne Feilzer (2010) stated:

" *... it seems that some if not most empirical mixed methods research has not been able to transcend the forced dichotomy of quantitative and qualitative methods and data...*"

(Yvonne Feilzer, 2010, pp.4)

4.1.4 Realism

Realism sits between positivism and interpretivism and has several branches including *empirical, critical, actualism, transcendental and scientific* to name a few. In a realist paradigm *things* exists separately from the observer's perception of them. Empirical realism acknowledges that ordinary items persist separately from the observer and are independent of others thoughts or experiences (Brewer, 2004).

4.2 Alternative Research Strategies

Several research strategies apply to the exploration of mass personalisation; they included case study, grounded theory and action research. However, case study research aligned best with the positivist perspective of the research.

4.2.1 Grounded Theory

Grounded theory is an extreme form of induction and emphasises generating theory from data alone (Perry, 1998). Although authors such as Anselm *et al.* (1990) claimed that inductively developed grounded theory is superior to logically deductions from prior assumptions, they later concede that this ideal is unlikely to be achievable and importantly not as desirable as once stated (Perry, 1998). Anselm *et al.* (1990) later stated it is neither practical nor preferable, to conduct grounded without any prior theory (Perry, 1998). While Personalisation is related to mass customisation, there is a paucity of the literature making a case study a more appropriate research method.

Grounded Theory can be compared to applied thematic analysis in that it emphasises supporting claims with empirical data. Grounded Theory is described as consisting of systematic and flexible guidleines for collecting and analysing qualitative data to construct theories grounded in the literature (Charmaz, 2014).

4.2.2 Phenomenology

Edmund Husserl and Maurice Merleau-Ponty are credited with the philosophical works on which phenomenology is based (Collis and Hussey, 2013). In phenomenology, the perceptions and feelings of the subject are the focus of the analysis. Phenomenology follows in the social-anthropological traditions of *"giving a voice to the other"*. Open minded questions and roving inquiry are the means through which data is elicited. Though the qualitative data crucial for the exploratory study of personalisation is achievable in a Phenomenological methodology, it does not meet the time constraint for participants and telling a story is not enough to derive generalisation and inform hypothesis for future research. An aim of this thesis was to explanation of important themes considered by Senior supply chain professionals when pursuing personalisation. Phenomenology is more evocative and story based than an applied thematic approach (Guest *et al.*, 2011).

4.2.3 Ethnography

The roots of Ethnography lie in the nineteenth-century western anthropology (Van Maanen, 2011). In the traditional sense, an ethnography was a descriptive account of a community or culture (Hammersley and Atkinson, 2007). In supply chain management some principles from ethnography are used in mixed methodology research, such as the *grand tour* style open ended questions in interviews to elicit a broad and detailed response and create opportunities for further exploration (Mollenkopf *et al.*, 2007). An ethnographer can participate overtly or covertly with the community or culture being studied, gathering artefacts and materials pertinent to providing an accurate account of the observations (Van Maanen, 2011).

Ethnographies are often longitudinal in nature and require substantial resources including the time of the participants. Time constraints for observing the phenomena concerning this research means that longitudinal studies such as an ethnography or grounded research were unfeasible. Senior managers and the operations they are in charge of are not accessible for such study over extended periods of time. The setting for this research made such a research strategy unfeasible.

4.2.4 Action Research

Action research is:

"*a participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview which we believe is emerging at this historical moment. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communitie*"

(Reason and Bradbury, 2001, pp.1)

Action research challenges positivism and holds peoples knowledge as valuable beyond an objective causal reality (Reason and Bradbury, 2001). Action research is an amalgam of several disciplines and has been subject to several developments over the years (Reason and Bradbury, 2001). An important aspect of action research is that it holds the belief that the researcher, if also a participant, is likely to experience change and acknowledging how and why is important (Reason and Bradbury, 2001).

4.3 Case Study Research Strategy

As mentioned in the opening of this section on methodologies, the case study method was deemed an appropriate fit for the research being conducted. A case study is typified by an investigation into a contemporary phenomenon, within a real-life context Yin (2011). The case study method addresses the need to:

1. Make observation in the framework of the phenomenon being studied;

2. interview primary sources for data;

3. using multiple cases or multiple interviews increases triangulation and validity of generalisations.

A case study can be a single case or multiple case studies. When pursuing a case study based research strategy, the decision as to whether a single or multiple case study becomes pertinent. A single case study allows the researcher to get close to the phenomenon. However, they are also the least capable of making a generalisation, also the boundaries between the phenomenon and context may, however, be unclear (Yin, 2011). A multiple case study offers the observer the opportunity to investigate the phenomenon in various settings, increasing the value of any generalisations. There are however issues to consider when choosing either.

The validity and reliability analysis that adds to theory or the body of knowledge of a particular field of enquiry, a case study must focus on a specific unit of analysis (UoA) . Since this research is investigating the strategic decisions made by senior management, the UoA for MPer is the supply chain of the organisation, the context is the organisation and their pursuit of MPer.

Yin (2011) described a matrix of possible solutions for developing a comprehensive case study. The basic types of case study research design are illustrated in Figure 4.1.

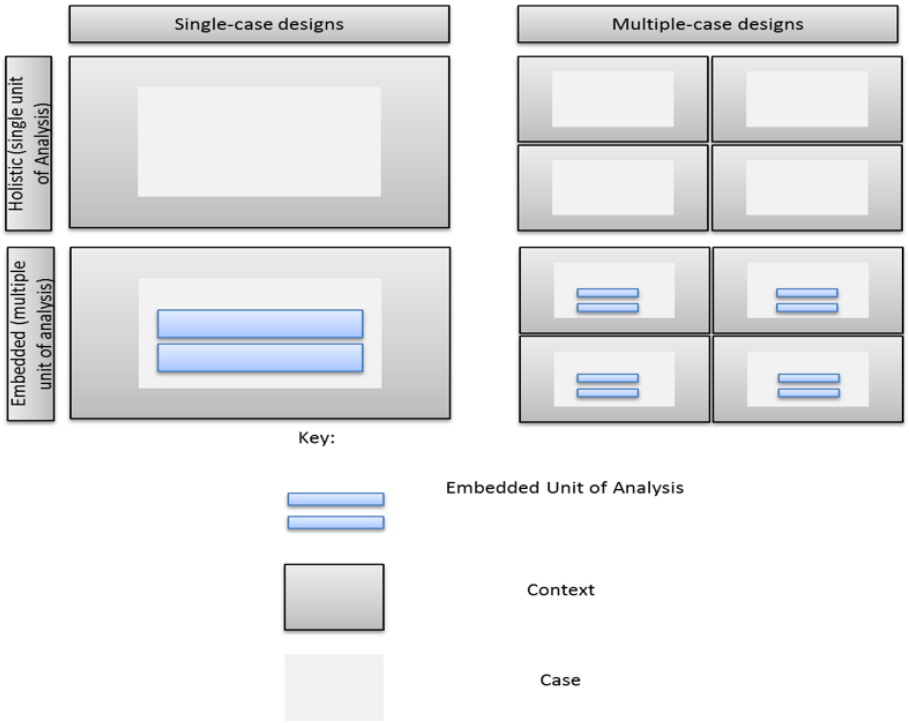

Figure 4.1: Basic Types of Research Design for Case Study (adapted from Yin (2011))

Multiple cases enable comparisons, which rule out idiosyncrasies that are not replicable (Eisenhardt and Graebner, 2007). Mass Personalisation as a strategy must be tangible, communicable and therefore replicable. Based on the parallels with MC and the is the belief of this research that key components will be replicated across cases and different contextual situations.

A multiple case study with a single unit of analysis was pursued as illustrated in Figure 4.2.

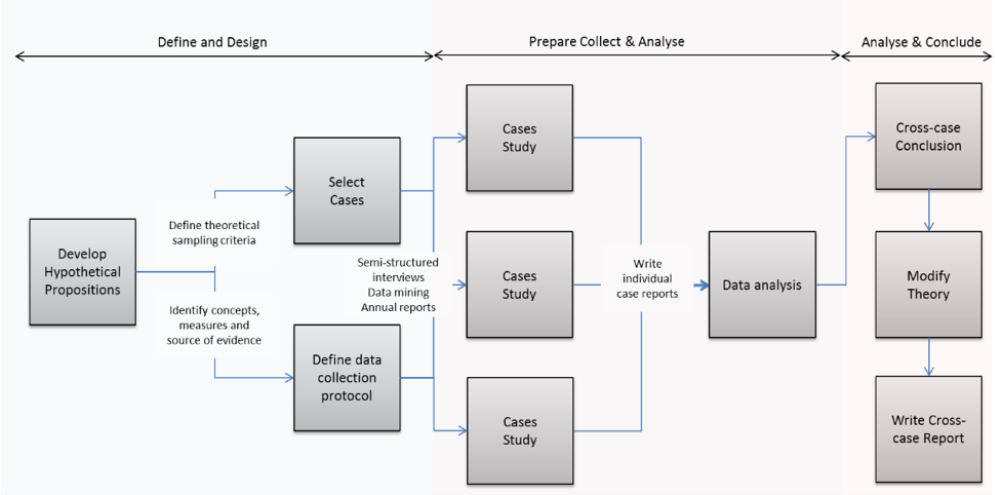

Figure 4.2: Case Study Design

The justification for chosing a multiple case study single unit of analysis and the subesequent case study design is outlined in Section 4.3.4

4.3.1 Selection and Justification of Case Study Participants

The case study companies were selected based on stating their aim to pursue personalisation of some variety via company literature, including websites and published reports. Participant organisations were also required to have senior operations and supply chain directors. Senior management was deemed capable of communicating the corporate strategy the organisation was pursuing to achieve their personalisation goals while omitting information considered confidential. Directors were also considered the most capable of intimating the implication of those strategies across operation and tactical activities as well as placing them in a supply chain context. Senior managements' participation ensured the highest level of access and therefore the most insight source of evidence.

The main criteria for inclusion of a case included:

- A stated pursuit of personlisation in the literature;
- Complex products with upstream suppliers;

- Senior management privy to strategic planning knowledge and operational experience.

Purposeful sampling was deemed appropriate for this study, due to its exploratory interpreivist nature. While it would have been preferable to have more than four companies and five participants, there were a few mitigating factors. A senior manager may well be the best source of context rich information; they are also the most sensitive members to secure. The time constraint made it difficult to gain access to more participants in a formal setting. Another barrier for inclusion was the sensitive nature of the topic. Many organisations viewed their pursuit of personalisation as a strategic advantage and did not want to divulge information that would erode their competitive advantage.

The number of participants included in this research provides a rich contextual source of information for analysis. More participants would have strengthened the ability of this thesis to make generalisations. Eisenhardt (1989), suggests that between four and ten cases are adequate for theory building using case study research. As this study is exploratory, it meets the accepted threshold for participants, supported by the literature and mandated by the research design.

4.3.2 Case Study Research Strategy Bias and Trianglation

While engaging senior management proved an excellent source of data for an in-depth response, more participants across the organisation could increase the generalisability of the results. However, the likelihood that the participants may suffer from bounded rationality, regarding their understanding of the agency's strategic focus justifies their exclusion and is in-keeping with the research aims. At the selection stage, the participant companies were not screened based on their products inherent need for personalisation versus personalisation as a differentiator. Although, the stated aim of this research is to explore the strategic implications of the pursuit of mass personalisation, which does not necessarily require the differentiation. However, the acknowledgement of these different requirements could add to the discussion and would be beneficial for future research. Also, not focusing on the products reason for personalisation, allows room for contrary findings, an important requirement

for avoiding bias in case study research (Yin, 2011).

A substantial amount of the evidence presented in Chapter 5, was taken from the transcribed interviews. A strength of using a semi structured interview protocol is the ability to ask focused questions on the topic. The responses contain insightful explanations and inferences. Critical weaknesses are: response bias, inaccuracies due to the incorrect recollection of events and reflexivity-the interviewee is compliant and tells the interviewer exactly what they want to hear (Yin, 2011). Although these biases cannot be mitigated completely, this research also used alternative sources of evidence such as documentation and archival records. According to Yin (2011), alternate sources of information can be a good source of verification and validation.

4.3.3 Justification for Qualitative Research

The nature of strategising to bring about an outcome requires making contextual decisions. Quantitative methods do not adequately recognise the variability in human behaviour without the use of numerous well-defined variables, which in an exploratory study is not feasible due to the paucity or literature. As an exploratory and qualitative study, this thesis is interested in qualitative data. The quality data from the literature corpus as defined by the search terms and exclusion criteria were first coded based on emerging themes. The emergent themes were used to construct a conceptual model for latter validation and triangulation. Validation is achieved through further thematic analysis of field data in the form of semi-structured interview questions from selected case studies. Qualitative data may also be collected in various ways, including the compilation of audio records from interviews which can be later transcribed. This thesis uses transcripts of audio recording, transcripts of text are analysed as a proxy for experience containing the perceptions and knowledge of the respondents.

4.3.4 Justification for Case Study

Ascertaining whether the strategic decision by senior management is different when pursuing MPer over MC requires validation, verification and triangulation. As a new phenomenon MPer inherently has less coverage and as such a single case study and context will not suffice. Observing multiple organisation that self-identifies as personalisers of products, increase the validity of the arguments and conclusions made that may be counter intuitive or previously undocumented.

A single case study was immediately decided against due to the inability of such a research approach to providing adequate generalisations about the phenomenon of Mass personalization. Multiple case studies are better for theory building (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; Yin, 2011)

The paucity in the literature for MPer increases the likelihood that there will be several undocumented phenomenon and idiosyncracies. In comparison to MPer, there is a mature body of literature available for Mass Production and Mass Customisation, a view supported by the taxonomic research conducted by Kumar (2007b). The consensus for exploratory research is that using inducting theory using case studies from the specification of research questions, is an appropriate approach in new topic areas(Eisenhardt, 1989).

Keeping the organisation as the single UoA will mean that the contextual information within each case will differ, and it is precisely these differences that this study is interested in. Understanding how a range of organisations in different contextual situations makes strategic decision regarding MPer. Their combined data will provide corroborative evidence of critical processes, procedure and decisions will provide more empirical evidence on the subject.

4.4 Research Design and Data Collection

The main stages of the research can be broken down into processes that span the background theory, focal theory, data theory and culminate in a contribution (Phillips and Pugh, 2010). Figure 4.3, an overview of the research design process, illustrates the sequential tasks in the

research design.

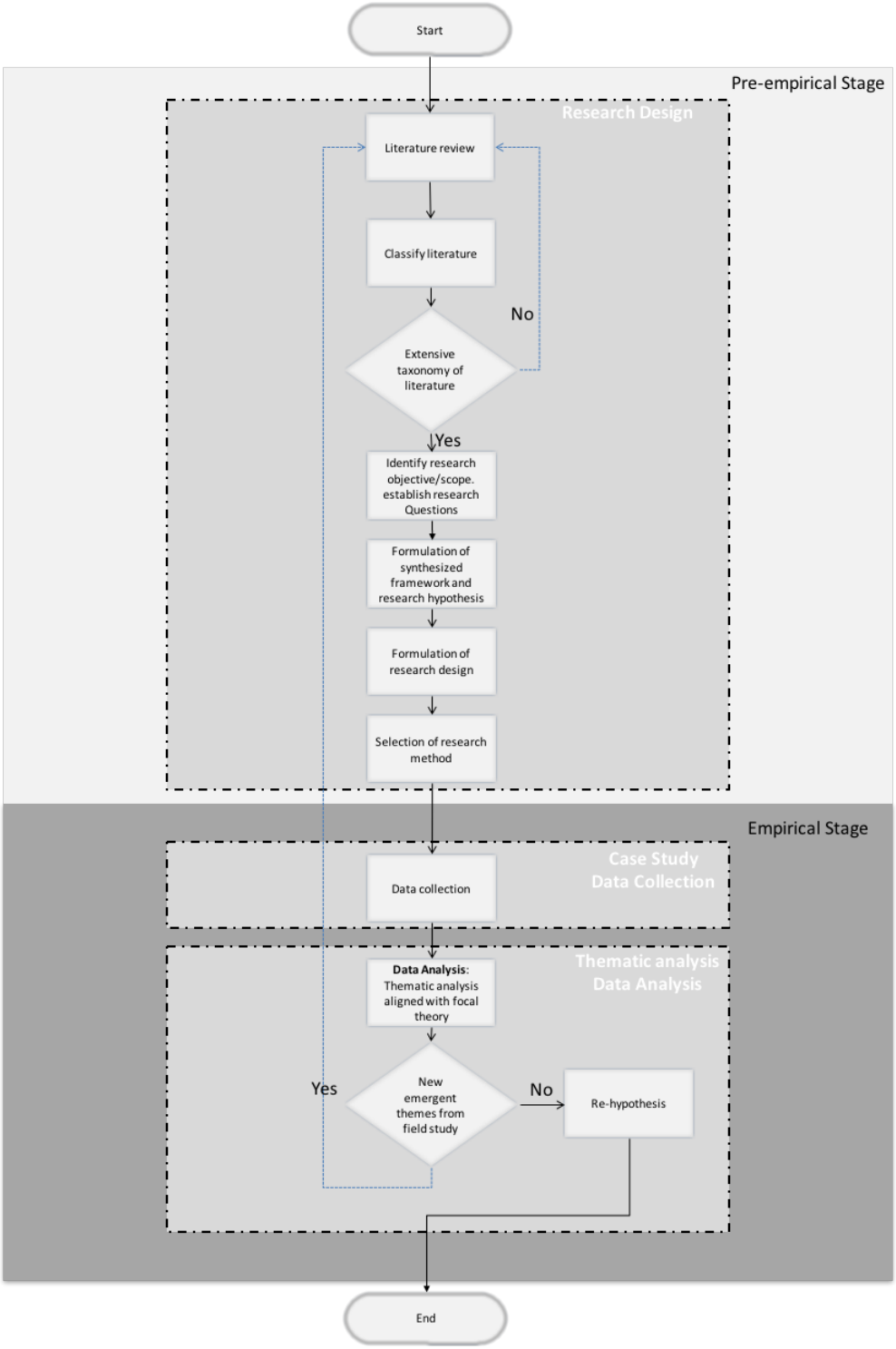

Figure 4.3: Research Design Source: Authour

Background theory extracts the state of the art from the extant literature covering the field of inquiry, defined in chapter 2. These processes take up most of the pre-empirical stage of the research. The pre-empirical stage clarifies the research questions, discerning the different issues and re-stating the identified problem as a series of research questions (Punch, 2013).

The first set of tasks that comprise the research design section of Figure 4.3, present the philosophical argument and hypothesis covered in the Chapter 3 and the methodology presented in the proceeding section. This dissertation continues with a discussion of the research strategy and methods comprising the *approach* to collecting the data, in contrast to the research design which is the sequential task based process depicted in Figure4.3. Followed by the study design, detailing *how* the research is to be carried out, *why* a research question demands an answer and *what* conclusions can be drawn from the thematic analysis of the data Yin (2011). Before the analysis and extrapolation of the data and their appraisal against the arguments made in Chapter 3, the research methodology will be held explicit in the following section.

Qualitative research is associated with an interpretive approach. Qualitative data provide room for interpretive enquiry. However, qualitative data does not presuppose a qualitative method of analysis (Guest *et al.*, 2011). While the data collected may be qualitative, the analysis can be quantitive. With the understanding that qualitative research does not implicitly mean inductive research, it is necessary to define the qualitative investigation and analytical purpose. Below is a summary of the types methods that fall into data and analysis types.

This research is exploratory and therefore deductive in the analytical stages. In keeping with the literature this research is content-driven, using specific codes that are a mix of predetermined and emergent. Exploratory analysis is commonly used to *generate* hypotheses for further study (Guest *et al.*, 2011).

4.4.1 Data Collection

MPer and the personalisation of products in a supply chain context require organisations to coordinate their functions and business units in a specific way. Therefore, the strategic decisions must be communicable and have already been communicated. Using semi-structured interviews to interrogate senior employees, will help develop illustrative cases of the phenomenon (Yin, 2011).

A participating organisations' pursuit of personalisation may or may not translate into objective and tangible differences in strategic decisions or their execution at an operational and tactical level. Due to the sensitivity of the subject and the implications of confidential information being requested, members of senior management were the only employees capable of divulging the information required. So while it may not be possible to interview several employees, who were arguably not in possession of the information the research agenda aimed to solicit, directors from each company were interviewed. Directors were both in the position to make these decisions but to also explain in more depth the rationale.

The substantive issues of this empirical analysis were the:

- Exploration of Personalisation and Customisation as separate fields of inquiry, and delimit their scope in a supply chain management context through a literature review;
- Identification of supply chain related strategic decision necessary for pursuing mass personalisation;
- Explanation of enablers from the empirical study in comparison to the literature through a thematic analysis;
- Summary of the critical supply chain decisions and interrelationships between the strategy and its operationalisation, specifically focusing on the allocation and utilisation of constrained resources.

Meetings were scheduled with companies that were approached, met the criteria outlined in Subsection 4.3.4 and agreed to participate. All the data was collected during one-on-one meetings. Each Interview took between 50-90 minutes, during which time an audio

recording of the respondent was captured for later transcription. The meetings also provided an interactive analysis of the case study agenda. The completion of an interview was an opportunity to refine the plan if required, adding, removing or rephrasing a question if the response was too terse or vague. The full questionnaire can be found in AppendixB.1 - B.5.

4.4.2 Exploration of Case Study Protocol

A pilot study can serve two distinct purposes. A pilot study may be used as a trial run for the more comprehensive study; in this case, the pilot study could be utilised as a feasibility study in preparation for the primary study. The second application of a pilot study is to test an instrument (Baker and Risley, 1994).

The perceived advantage of conducting a pilot study is the possibility of identifying problems with the research in general as well as the protocol. While large-scale qualitative projects may undertake several pilot studies; this thesis did not require one as part of the case study design.

There is a risk of contamination is a concern when pilot studies are used (Van Maanen, 2011). The contamination can occur due to the inclusion of the pilot study data in the primary results or the inclusion of the pilot study participants with new information. This, however, is more of a problem in quantitative research. The concern that arises from the inclusion of the pilot data into the study is the likelihood that modifications will have been made to the pilot. The modified instrument used in the rest of the survey may invalidate the pilot study and as such the data proffered is flawed or inaccurate .

The concern over contamination by the inclusion of the same participant from the pilot with an amended instrument is the participants biased behaviour (Van Maanen, 2011). The biased behaviour may be exhibited by the respondent's previous interaction with the instrument inducing a response that is not consistent with other participants that have yet to participate. For example, the respondent may be more capable or less cooperative with the protocol. In both cases, a bias has been introduced.

As previously mentioned this was a qualitative study and as such was progressive as the interviews were held in series. It is expected that the interviews would get progressively

better. The transcription and learning curve experienced in conducting semi-structured interviews will invariably increase the quality of successive meetings.

Holloway (1997) suggested that pilot studies are not necessary for qualitative research because the process of iteration. A pilot study was, therefore, unecessary as the qualitative nature and sequential progression of the interview process mean that further refinements which are less material will invariably be made during the study. Omitting a pilot study also limits the impact of both types of contamination as any significant bias will be apparent across the majority of cases. The completion of a pilot of the infallibility of the interview protocol. The pilot study offers the opportunity to identify problems and pre-empt foreseeable issues, which is already an inherent quality of semi-structured literature reviews.

4.4.3 Case Study Interview Protocol

Case study research requires empirical evidence from the contextual environment under study.Therefore, it is necessary for the data gathering method to be capable of capturing data from sources in this contextual environment. In the case of this research, the context was companies pursuing mass personalisation. Since these organisations do not cease to function through the duration of the study, it is important that a protocol can handle some of the difficulties associated with this type of research, mentioned in Subsection 4.3.2.

It is necessary for the data collection method to outline:

- Who is to be interviewed and why. In the case of this research, directors were deemed appropriate as justified in Section 4.3.1.
- How the data is to be collected. For this research, interviews were conducted and transcribed as discussed in Section 4.4.1.

An interview protocol served as a method of collecting data from the participant companies. It is import to note that case study research is an iterative process, as stated by Eisenhardt (1989):

"*The process of building theory from case study research is a strikingly iterative one. While an investigator may focus on one part of the process at a time, the process itself*

involves constant iteration backward and forward beween steps"

(Eisenhardt, 1989, pp.546)

As such, the expectation is that the data collection instruments may receive adjustments. Protocol modifications can include the addition of questions to an interview protocol or questions to a questionnaire to better probe emergent themes (Eisenhardt, 1989).

The previous theory derived from the literature review informed the interview protocol presented in AppendixD. The interview protocol has two section, section A and section B. Both parts align with the themes presented in Table 3.2 introducing the taxonomy in Section 3.1. The questions presented in interview protocol explore the proposition in Section 3.2.

4.4.4 Applied Thematic Analysis and Unit of Analysis

Thematic analysis was used to categorise the literature as mentioned in Section 2.1.8. Applied thematic analysis was also used to categorise the responses from the interview protocol.

Although thematic analysis starts with keywords and codes for grouping similar data points, thematic analysis is not simply the counting of keywords. The aim of thematic analysis is to describe both implicit and explicit ideas from the field data (Guest *et al.*, 2011).

Reliability may be of concern in thematic analysis because the codification of text and representation of knowledge, are predicated on the researchers interpretation. Thematic analysis is a data reduction technique, which may be biased towards a positivists perspective however the process of identifying themes is highly interpretivist (Guest *et al.*, 2011). The defining feature of applied thematic analysis is indentifying repeating themes in the literature, a key limitation for thematic analysis is the possibility of overlooking more nuanced data.

For the identification of themes within the transcripts presented in this thesis, the smallest unit of analysis was a sentence, and the largest a paragraph. A specific selection of text, could receive several different codes. The importance and significance of the code is based in the context of the argument both set forth by the text but also by the emergemnt

dicussion guided by the interview protocol. While the interpretation is ultimately down to the researcher, the internal validity of the inference and explicit arguments set out in the analysis chapter are guided by the research protocol. A theme is defined by DeSantis and Ugarriza (2000) as:

"*A theme is an abstract entity that brings meaning and identity to a recurrent experience and its variant manifestations. As such, a theme captures and unifies the nature or basis of the experience into a meaningful whole.*" (DeSantis and Ugarriza, 2000, pp.362)

4.4.5 Coding Interview Responses

In a thematic analysis, content under review is allocated a code indicating the meaning the text may exemplify (Guest *et al.*, 2011). Content can be coded in many ways including, hierarchical relationships, cause and effect and repetition for example.

The coding of the transcripts followed the same process as coding of the literature. The coding of transcripts used both codes derived from the previous deductive process of reviewing the literature, and emergent themes from the inductive process of observation (reviewing the transcripts). The codes from the literature provided a framework for the investigation. Morse and Mitcham (2002) proposed a similar methodology described as a *stepwise conceptual research process* that includes deconstructing the concept to be explored from the existing literature and developing a framework for data collection. The approached outlined by Morse and Mitcham (2002), focuses the research without defining the limits. Table 4.1 shows an example extract from a coded field transcript.

Theme	Claim Type	Claim	Field Respondent
Mass Customisation	Claim of Fact	The mass customised sounds exactly where we are at. We are not talking about enormous quantities they've sold a total of 20,000 machines. And the total number of machines that were sold since 1997, so over the last 17 years, was only 1,500 machines. 1,500 machines is not generally what you would refer to as mass production. So to a certain extent those big machines are almost bespoke products. But they are made to a standardised design.	Director B

Table 4.1: Coding Field Study Transcript

The example used in Table 4.1 contains the words Mass Customisation and therefore the ascribed theme of *mass customisation* seems apt. However, not all the codes follow this formulae. A selection of text can receive a code based on the contextual meaning, without explicitly using the word ascribed as a code. It is important to note that there is a difference between the theme as expanded in the analysis and the code used to group the theme (Saldaña, 2015).

4.5 Limitations of Research Design

A possible limitation of the research comes from the use of a case study approach. While the case study approach was based on scientific merit justified in Section 4.3.4, case studies have some inherent weaknesses (Eisenhardt, 1989; Yin, 2011). The main inherent limitation is that the context of the case is part of the study and for this reason the number of variables is very high (Yin, 2011). Cross-case analysis is also criticised byMiles (1979) for being:

> "*...even less well formulated than within case analysis*"
>
> (Miles, 1979, pp.599)

Of which he states as being:

> "*...essentially intuitive, primitive and unmanageable.*"
>
> (Miles, 1979, pp.597)

However using multiple cases allows a case comparison approach to be used, which as stated earlier allows:

- Idiosyncrasies to be scrutinised; and
- The maintenance of replication logic required for comparison (Eisenhardt and Graebner, 2007).

Each case should, therefore, provide corroborative evidence of specific hypotheses, with each case serving a similar role as discrete experiments (Eisenhardt and Graebner, 2007). This study endeavour ed to:

> "*...preserve the chain of evidence as each analytical step is conducted.*"
>
> (Yin, 2011, pp.63)

The study achieved this by explicit citation of pertinent evidence from data collected when substantiating overall findings and making conclusions. It is also worth noting that the use of this logic is not dissimilar to the logic used to bring together multiple experiments in

a science study (Yin, 2011). This is particularly poignant as both do not have a codified rule of how this should be done and yet scientific studies in the natural science accept this analytic step as rational Yin (2011). The possible pitfall of the rambling narrative will also be avoided due to the use of hypothesis formulated from research questions. Answering these issues delivers the objective of the study and realises the aim. Structuring the case studies narrative around the hypothesis, therefore, provides a logical progression.

The over complication of the theory is another possible deficiency, due to misplaced emphasis on personal relationships found in the empirical evidence Eisenhardt (1989). The proposed research, however, is designed to minimise this likelihood. Using Multiple case studies reduces the significance of idiosyncrasies and focuses on the replicability across several cases (Eisenhardt and Graebner, 2007).

Another weakness identified by Eisenhardt (1989)and may limit the study, is the risk of a narrow -focus. Although testable, novel and empirically valid a case study based research may still be subject to this limitation (Eisenhardt, 1989). The ability to generalise the findings of the research is therefore low and subsequent theory less

> "...grand" (Eisenhardt, 1989, pp.547)

5. Analysis

Chapter 5 describes the background of the Companies that participated in this research and explores the respondents through a thematic analysis. The responses were classified and critiqued against the extant literature and the conceptual framework. A prevailing theme that intersected many others was that of the skilled employee. Several respondents identified their qualified employees as essential to their pursuit of personalised products and services. The implication of skilled labour was not considered in the original framework and is a finding that will be incorporated in the re-hypothesis. Respondents also contributed to the empirical evidence suggesting personalisation has important strategic considerations for senior supply chain professionals that are distinct from those taken when pursuing mass customisation. Chapter 5 also revisits the conceptual model and refines based on the analysis of the this chapter. The strategic importance of Manufacturing Strategy, Manufacturing Technology, the CODP and Employees were evaluated.

5.1 Background to The Cases

The field study included 4 Companies. A summary of each participant company is shown in Table 5.1. The level of personalisation in every business is indicated with 'High', 'Medium' or 'Low'. 'Low' indicates mainly standardised products; Medium indicates personalised options and High means ETO. Although the only requirement was that the participant self-identifies as a personalised, Company D is the only organisation that also fits the traditional ETO definition.

Company	Empoyees	Products	Personalisation	Depth of Product Structure
A	300,000	Enterprise and Consumer Electronics including 3d Printers	Low	High
B	8,000	Financial Services, Credit Cards, Sim Cards, and Currency counting, sorting and counterfeit detection machines	Medium	High
C	10	3d Printing Services and 3d printer OEM Retailer	Medium	Medium
D	1000+	3d Printing Services and 3d printing	High	High

Table 5.1: Participating Companies and their Products

As discussed later, Company B could also be a significantly high personaliser. Company B is however restricted by the regulatory requirements of their industry. Company B has the greatest level of technical expertise amongst their employees; this assertion is based on the fact they hire the highest number of qualified engineers. Using categorisation system similar to Hicks et al. (2000, pp.181), the processes in each company are summarised in Table 5.2.

Company	Process	Manufacturing Processes	Vertical Integration
A	DP	JA	Low
B	DPMA	JBFA	High
C	DM	JB	Low
D	DPMA	JBFA	High

Table 5.2: Process in Participating companies

Processes: D - design, P - Project Management, M - manufacturing, A - assembly Manufactring Processes: J - Jobbing, B - batch, F - flow, A - Assembly

The level of vertical integratioin is indicative of wether the company performs all manufacturing in-house to whether they Design and contract out the manufacturing step (Hicks *et al.*, 2000).

Table 5.3 summarises the companies who responded to this research:

Company	Director	Main Business
Comapany A	Director A	Enterprise servers and networking hardware
Company B	Director B, Director C	financial services, credit and sim card manufacturing, currency pocessing machines
Company C	Director D	3D printing product service
Company D	Director F	3D printing services and consumer grade printer retailer

Table 5.3: Summary of Participant Companies and Directors

5.1.1 Company A

Company A is a large multinational OEM and retailer of enterprise servers, networking and consumer grade personal computing hardware. A radical restructuring during this research

has led them to a smaller employee base however at their peak, company A employed over 300,000 personnel worldwide. The company's penchant for mergers and acquisition as a growth strategy has informed the organisations internal structure, business units are separated by function and also by the region they serve. Company A has tens of thousands of product lines and engages in make-to-stock (MTS) and assemble to order (ATO) order fulfilment for both Business to Consumer (BTC) and business to business (BTB).

Product customisation and personalisation are more dominant in their BTB fulfilment. The respondent for Company A was a Senior Operations Director for business units predominantly focused on the retail and servicing of Servers and Networking hardware. The supply chain for this organisation spans the globe, requiring staff with supply chain specific competencies. Procurement, supply planning, inventory control, order fulfilment are all represented as discrete functions and are compelled to follow the business strategy as set forth by senior management. There is a direct imperative for the senior management to translate strategic goals into operational and tactical objectives with real processes and task. The communication of business requirements implies that an actual transference of intent is common. Company A provides a complex environment to explore the themes that are prevalent in personalisation at scale.

5.1.2 Company B

Company B is a multinational financial services organisation. Their business includes cards and services and currency note processing. Its primary business is providing banks services and is heavily regulated. Its Employee base is over 8000 with 50+ subsidiaries around the world. While each subsidiary has some regional autonomy to service local customers, they are an extension of the parent company and as such a central strategy is followed. Company B's main products are currency counting and authentication devices which vary in size and capacity. Its flagship machines are retailed to banks and are considered capital assets. Its production is to order, and personalisation options may be engineered into the machines however the cost and profile are similar to traditional ETO. Company B primarily the mode of order fulfilment is MTO, with the possibility to ETO. However, the industry it operates

in is heavily regulated, and engineering changes are costly and in some cases bound by regulatory rules.

Company B has two senior operations directors across the two main operating divisions; both were interviewed as respondents to this research. Both participate in the central strategic planning for supply chain activities and are present at meetings held at Headquarters.

5.1.3 Company C

Company C is a 3d printing service provider. Their services include product printing and training as well as the retail of custom machinery. As of the time the research was conducted research, the Company less than a year. Their flagship store opened in London as the first of it's kind. As of the time, the field study was conducted there were under ten employees. The Director started the company as part of a venture capital group, with the goal of being an early participant in a new market. The Company is primarily a retailer. However, they provide product design and manufacturing services. Company C primarily retails products from OEMS, some of these are provided as production equipment small products. Company C provide complimentary services such as tuition and clinics to assist customers with engineering and design specific problems. Company C produces small runs for clients but predominantly makes a one-off product. Typically fulfilling the role of a prototype manufacturer, with engineering and design consultancy services.

5.1.4 Company D

Company D is also a 3d printing service provider, however, unlike group C they work on an industrial scale and for all intents and purposes an ETO company. Company D predominantly use bespoke additive manufacturing technology built in-house and do not consider themselves designers. Company D employ 1000+, a contingent of which are engineers. Its focus on the technical competencies required to fulfil orders and innovate mean they are the most highly capable personalised to participate in the research. Company D is capable of manufacturing a range of products with varying levels of complexity. Unlike Company B,

their product line is not prespecified. It is a B2B and B2C company and service demand products for industrial type runs as well as consumer runs. They typically run batches but each product they provide printing services for are bespoke. Company D is a child company to a much larger multinational. The flexibility achieved by this company is considered their competitive advantage. The responses from the field are classified thematically. The themes used to organise the literature and subsequently build a synthesised framework, tabulated in Appendix Ehave been rationalised into groupings to make the analysis flow more consistently. As not all the themes in Appendix E contributed to the framework and conceptual model, some are not included in Table 5.4.

Group	Themes
Personalisation	• Mass Personalisation
Supply Chain Management	• ETO • Postponement • Time Compression • Supply Chain Structure
Manufacturing	• Strategy • Flexibility • Product design
Processes and Work Force	• Technologies

Table 5.4: Grouping Themes for Analysis

Each theme's contribution to the argument is discussed, referring to the literature, the research questions, framework and propositions. The critique, where possible, will cite the empirical evidence that supports or contradicts the research and subsequent conceptual framework. The chapter's conclusion will summarise the contributions and highlight the

amendments to the framework is developed further in Chapter 3.

5.2 Thematic Analysis of Interviews

The themes identified in the literature and emerging from the interview protocol, have been analysed below. Each theme analyses the source data from the interview protocol making cross case analysis (Yin, 2011).

5.2.1 Personalisation

The personalisers are deciding what is to become best practices and canonical and what simply will not work. Understanding this is part of the competitive advantage that many of the companies in this research actively seek to preserve.

Company D's Director clearly stated the perceived difference between customisation and personalisation:

> "*Well definitely as something unique most of the products we print for people are one off prints for people who make something and people who we make a 3D print of these designs. Is this customisation, not completely I would say in my opinion customisation is when you have something existing that you adapt to your tastes or to your needs. So some of the products we provide are customised but a majority of the work we do are just unique products made by individuals*."
>
> Director F Source: Appendix B.5

There is a consensus among the respondents that personalisation and customisation are separate strategic considerations. That the pursuit of personalisation and customisation are separate strategic considerations, is not a given in the literature. Just as in the literature, respondents could have conflated the two using customisation and personalisation as synonyms.

> "*Personalised yes we do. So if you think about our products especially, if you think about products in the enterprise group space. You will see that our quan-*

tity lot size could be one or go up to many thousands and that why I say we have personalised systems because the customer can chose exactly the configuration he or she wants to have. So they can have a very unique set of requirements in terms of I want to have a server which just wants to have exactly that configuration and that exact configuration will never be ordered again."

Director A Source: Appendix B.1

The product type or category itself is fixed the ability to provide any configuration unbound by a solution space is a key differentiation from MC. Tseng *et al.* (2010) *hard* personalisation is the dominant type, with product architecture and functionality being personalised. The modular characteristics of the product architecture mean these products are ATO, BTO and MTO. As Identified in the Literature ATO, BTO would align more with MC than personalisation (Forza *et al.*, 2008; Kumar, 2007a,b). Witnessing this alignment in the field does give credence to the proposition that deep personalisers have capabilities less in line with BTO and ATO. The modularity of the subsystems enables FP and flexibility to build solutions from subsystems manufactured by different providers. Director A comments on this, also highlighting that personalisation can be the amalgamation of systems.

"*So if you think about the supply chain for all of our products it probably ranges from blank to blank to blank you will see that we have a multi tiered supply chain and that means that components come out of Asia then there will be sub assemblies built in Asia and these sub assemblies mirror some of the modules we talked about earlier, then they are done by a supplier then these sub assemblies will be moved to either blank factories or blank manufactures and they could be in a world wide location feeding all customers world wide or they could be sitting in a region and feeding the customers from there okay so and then what then happens as well is that sometimes that sometimes the regional manufacturers would feed a blank factory too because there would be combinations of our products which makes a solution*."

Director A Source: Appendix B.1

It was expected that personalisers would not focus on the reduction of their product, the so-called configurator challenge discussed in Chapter 3. Typically personalisers such as Company D are not concerned with designing goods and worrying about reconfigurability:

> "*We are a 3d printer that is our strength. Our strength is not in designing something for this you have the billions of designers all around the world who can do a much better job of that around the world. We try to stay to our core strength and hat is making good 3d prints* "
>
> Director F Source: Appendix B.5

As expected a inventory management is a big issue to tackle. FP and modularity are methods to minimise FGI but with a large enough product portfolio the problem persists. When discussing the inventory profile, Compan A's Director highlighted that although you can satisfy smaller niches of product an overlooked enrichment inventory (miscellaneous documentation, manuals and packaging items) proliferate also explaining that the short product life cycles exacerbate this problem:

> "*Now obviously that has a very short lifecycle typically because as soon as you have transformation or a revision change, in the ideal case you immediately burn new CD correct and also have new documentation which refers to the latest features you have inside of the product. So that can actually be a challenge in that space and one of the points we had in our factories in region for many many years, we actually did what we call print on demand or replicate on demand or CD on demand, what we called it at the time, so maybe we had all theses flyers maybe it was a full book. The bits for the CDs/ DVDs we had them on file but we never had them on stock and we basically then printed them on demand so at the time when the server was built depending on the country and the customisation of the server and the software loaded we triggered a process in parallel which was inside of our factory to actually print and write the manual and write the manual on the CD and basically whilst doing that on demand it basically reduced our requirement for excess and typically these things are*

> *cheap correct but the amount of them we had for variations up to 20 thousand and we have high or short life cycle of three to six months basically that will cause quite some substantial excess because even if you just print 10 of them you will never get rid of them.*"
>
> Director A Source: Appendix B.1

Postponing the enrichment and "printing to order" was a critical operations strategy in minimising the waste, adding to the merit of manufacturing strategy as a core consideration for pursuing MPer. While Company A acknowledged the importance of managing the negative aspects of make-to-stock, this did not translate into increased technological competencies when implemented operationally. When discussing whether the management of the inventory utilised innovative platforms and methodologies, Company A's Director responded negatively saying:

> "*Do we use any sophisticated tools like big data engines or anything like that? I would say no.*"
>
> Director A Source : Appendix B.1

According to the conceptual model presented in Chapter 3, MPer is also contingent on capable information systems. While not definitive proof that a lack of strategic consideration in IT for operations management negatively affects the ability to pursue MPer, Company A's inability to perform personalisation to a high degree in comparison to some of the other respondents fits the propositions of the conceptual model. Director A conceded that their systems are:

> " *loosely integrated. The best connection we have is in terms of understanding big deals where we basically have all our regions hold meetings with the regional sales force and accounting management team to understand big deals and promotions.*"
>
> Director A Source: Appendix B.1

The loosely integrated system results in a loosely coupled sales and operations planning (S&OP) process which may be indicative of an organisation pursuing value over optimisa-

tion (Haug *et al.*, 2009). Company A's growth through acquisitions and pursuit of perosnalisation together may cause inventory management not to be a concern or even incentivise and exacerbate siloed decision making and sub optimisation.

Not all the responses fit neatly into the prevailing theory of MPer as conceptualised. Company B, Director B, associated their fulfilment process for assorted credit cards and sim cards as Assemble to order with some engineer to order components. Overall the process was described as MTO.

> "*Because it is make-to-order every card print is to their design. We use a variant configurator here because of the complexity of the selectable options in terms of the production process. We calculated out recently out that to replicate out our configurator in a flat structure, we would have 400,000 combinations of variability in the production process. So for that reason the configurator is a very important part of our strategy to deliver our service and maintain the underlying master data related to the production process* "
>
> Director B Source: Appendix B.2

The interesting divergence is that Compant B, still operated with a fixed solution space quoting 400,000 combinations. With the largets technical workforce, it is likely the nature of their products are the reason for such constraints. Company B' industry is very beuaracratic and heavily regulated. Could regulation and beuracracy are barriers to personalisation?

5.2.2 Supply Chain Structure and Management

The product architecture can also stymie the pursuit of personalisation. A popular metric is that 80% of the supply chain cost is committed in at the point of product specification. Director A discusses Printed Circuit Assemblies (PCA), described their expense and relative importance .

> "*...our volume products maybe... have upside capacity but your limiting factor there will be your PCA lines because PCA lines are very expensive, they are not owned by company A they are always done by our subcontractors*"

Director A Source: Appendix B.1

As a result, the product architecture makes it difficult to build responsive supply chains around. Agile supply chains allow organisations to be responsive (Holweg, 2005; Little *et al.*, 2001; Reichhart and Holweg, 2007). The pursuit of agile or lean practices is encompassed by the SCO in the framework and supply chain design in the conceptual model.

ETO order-fulfilment is typified by the CODP, the point at which independent demand becomes dependent, positioned at the design stage. ETO as a mode of order fulfilment, in a supply chain management, is synonymous with long lead-times and high costs (Gosling and Naim, 2009). A critical distinction for a ETO supply chain typology is that all production dimensions are customised for each order in the ETO supply chain (Gosling and Naim, 2009). The extant literature disagrees on the design aspect and whether entirely new designs are created for each order (Gosling and Naim, 2009). This definition and contention are necessary for the first aim of this research, to delimit the scope of MC and MP. It became very clear that Company C are capable of fulfilling product orders specified from the design stage, an ability concomitant with ETO, and yet they are not a traditional ETO company. The managing director and founder of Company C stated, it was possible to have same day turn around of functional, mechanically complex products:

> "*...print on demand requests*."
>
> Director D Source : Appendix B.4

ETO companies are classified by their physical processes (Zorzini *et al.*, 2008) and Company C shows tell-tale signs of ETO-like fulfilment capability. The CODP as described in chapter 2 is at the design stage. Although in Company C the customer is primarily responsible for the design, a company may assist in alterations to correct file formatting or resolution mismatching with the machine. AMT are primarily responsible for enabling ETO style order fulfilment at ATO and BTO leads times. The contraction in lead-time is afforded by 3d printing AMT and having a large number of in-house engineers. All the companies interviewed made a significant emphasis on having in-house engineering capabilities. The ability to leverage the skill set of these mechanics and in some cases designers was considered crit-

ical to the strategic goal of providing personalised goods and services. For Company C expert staff serve a dual purpose:

> "*Yes because we realise that people need that, some of them come in with no knowledge at all most of them or a lot of them just read something or watch something on youtube and we definitely recognise that if somebody where to come in and have some training for maybe 2 hours 2 and a half hours, dedicated to beginners*."
>
> Director D Source : Appendix B.4

The engineering staff's technical competencies were credited with aiding the ability for having quick setup times for production machinery and realising a customers product design. Several of the companies also achieved the criteria for ETO also making bespoke products for each new client. Company D places more of an emphasis on fabrication and production:

> "*We are a 3d printer that is our strength. Our strength is not in designing something for this you have the billions of designers all around the world who can do a much better job of that around the world. We try to stay to our core strength and hat is making good 3d prints*."
>
> Director D Source: Appendix B.4

Cost and quality not being valued differentiators for customers is an assertion made in the literature (Wikner and Rudberg, 2005). For Company B, the price for their product is already very high and time and customisation are in fact more important for their customers. For Company C, the cost of material and purchasing are important considerations as they have a direct relationship to the level of personalisation they offer and are also constrained by the types of machine that can use them. However for their customers Company C also acknowledged that the cost of these products also matters to the client. So while cost was not a differentiator for products that have personalisation integrated as a core offering of the product, if the customisation also relies on repeat purchasing of the product then the total cost becomes a concern and possibly a differentiator. As a result Company C source premium materials, while Company B focuses on affordability. Unlike the customisation found

in the automotive industry, where higher spec material such as carbon fibre can be found in premium models, in Mper, the cost of materials is driven by innovation, manufacturing and production technology and product functionality. These costs are traditionally absorbed by the mass scale of customised products and associated production techniques. For Mper, while this may also be the case, it also falls directly on the production technology and the material to achieve the production economics that makes the Mper viable.

A Director of Company A alluded to the fact that new entrants unencumbered by a traditional cost to service profile can take advantage of the new technologies and achieve in markets where traditionally larger companies held a strong position.

> "*...that is why other comapnies that start in the market don't have that baggage*."
>
> Director A Source: Appendix B.1

Strategically cost is a critical consideration for all the companies. However, it is clear that the younger companies with a less traditional supply chain infrastructure were more willing to accept the cost of trial and error, in exchange for what they consider the first mover advantage. When considering what the unique strategic considerations are for setting up a business the As mentioned by the director of company

A key conclusion taken from the literature review is that the pursuit of Mper reduced the commoditization of products by their personalisation being a product differentiator (Pine and Gilmore, 2011; Riemer and Totz, 2003). The assumption in this conclusion is that personalisation itself would not become a commodity. The question may be asked that if such a value proposition existed for personalisation then why are none exclusively personalised? This question was not asked directly and in hindsight, the responses would have been interesting. It can be inferred that the cost of the technology and workforce that enable personalisation are prohibitive. For example, a criticism levied at pursing personalisation is that it can be achieved in various ways although that is an unsatisfactory and simplistic answer.

The management of uncertainty using customer order decoupling points was treated in different ways by all the companies. While company A and C both retail machines, company

A is more aligned with traditional MTS/BTO. Company A standardises on design. However, final build and configuration are dependent on demand. Though the operations director was quick to highlight that there are opportunities to support personalised requests from some customers. Build-to-Order (BTO), the configurator challenge and their implication for supply chain design and order fulfilment were most pronounced in Company A. Their large organisation and supply chain for computers, and computer peripherals are a natural fit with BTO. Since Dell revolutionised BTO PC's, BTO is standard practice for postponing product finalisation.

In the literature, personalisation is an activity that could be initiated by the consumer or the company (Sunikka and Bragge, 2012). The reality for Mper is at the CODP that separates independent and dependent demand many of the companies do not have the technology to initiate the personalisation process and nor did any express a wish to do so. The lack of any web-based platform is astonishing considering; this is a prerequisite in many cases of MC.

Company B shared that forecasting for consumption accounted for:

> "*only 60 percent of the picture. A large amount of the work we produce is project driven, so it is mostly to do with a reissue or a marketing activity that we would then provide for. So it's project driven logistics, so we would understand what the forecast would be for a specific campaign the materials are provisioned for that campaign the moment the campaign goes live. The underlying forecast is good for understanding standard daily type uptake*."
>
> Director B Source: Appendix B.2

Again Company B is unique, and their industry may skew their fit into the conceptual model. Nevertheless, the role of forecasting for FGI is unusual and unexpected.

The main issue highlighted by the literature is the relationship between product affordability and variety (Ahlstrom and Westbrook, 1999; Kumar, 2007b). The relationship causes the manufacturing function for a company to compromise between flexibility and cost efficiency (Meyer *et al.*, 1989).

5.2.3 Manufacturing Strategy and Technology

Management information systems can account for a quarter of all IT investment within major manufacturing companies, and much of it focused on planning and scheduling (Little *et al.*, 2001). A common mistake that dominates the implementation of manufacturing information systems, specifically MRP, is their universal application regardless of suitability(Little *et al.*, 2001). The poor execution and integration of such systems lead to an inability to respond to short-term changes in customer needs (Little *et al.*, 2001). In light of the problems associated with generic MRP, it is not surprising that Companies C and D's place particular emphasis on employees technically capable of bespoke solutions. Company D were adamant that their machines were developed in-house and that they are not shared beyond the company for this very reason stating:

> "*This has really given us a lot of advantage in the 3d printing world and it is also a benefit that we don't want to share with the others. We don't sell these machines we use them in house to provide the service that we want to give but we are not going to sell these*."
>
> Director F source: Appendix B.5

Fulton and Hon (2010) acknowledged much of the research about resistance to technological adaptation, focuses on the fear of change and that the implementation of AMT is a precursor to job cuts. Company D had made technological adaptation part of the company culture, lowering the possible resistance and possibly speeding up adoption of new technologies due to their employees intrinsically technical nature. Arguably new entrants with a focus on AMT are better placed to avoid this stigma. Hicks *et al.* (2000) and Christopher (2005) acknowledged the inherent danger of outsourcing the companies core competencies. Company D's industrious nature aligns with the archetypical ETO organisation, albeit with non-standard technologies. The trend for ETO organisations to pursue vertical integration has been observed by Hicks *et al.* (2000) and is attributed to cost reduction and financial pressures. From the respondent, another is the need to maintain a competitive advantage. Although it is questionable how generalisable this behaviour is, retaining competitive advan-

tage and not pursuing outsourcing is contrary to the conduct exhibited by most companies. Business process off-shoring has been an important part of the globalisation of industry, especially in high-volume industries (Vollmann *et al.*, 2005). Does this indicate a reversal in trend? It is especially not worthy that all the participating organisations are based in post-industrial countries. These countries have experienced the offshoring of their manufacturing processes. Company D behaviour is in stark contrast to this trend.

Lack of confidence was cited by Fulton and Hon (2010) as a barrier to implementing AMT.

> "*... SME's are reluctant to adapt to new technologies not only because of the financial investment involved but also due to a lack of confidence in their ability to acquire and sucessfully deploy the knowledge required*."
>
> Source: Fulton and Hon (2010)

Company D due to their relationship with a larger parent company and focus on employing technically competent staff, avoid this significant impediment to the successful uptake of AMT. This is a non-trivial success as Fulton and Hon (2010) concludes that there is a positive correlation between company growth and increased learning, specifically that there is a positive relationship between a manufacturing SME's digital competencies and turnover per head. Ballé *et al.* (2016) acknowledged that in studies over the past two decades, the application of *lean* practices to every process does not achieve operational excellence and instead the cultivation of employees aptitude and continuos development are critical.

> "*...people not processes make great products*."
>
> (Ballé *et al.*, 2016, pp.63)

The perfomance gap associated with new technologies, is often the It is quite normal for smaller companies to adopt ERP systems later if at all (Little *et al.*, 2001).

Company A focused on using subcontractors with highly specific technical competencies to respond quickly to consumer demand.

For larger companies business process outsourcing (BPO) can be a key strategy for managing cost. BPO is a topic with substantial literature, however, is often associated with ma-

ture industries citation. It is surprising that company elaborated on BPO as a source of their AMT. They are the largest company in the study with a substantial supply chain spanning several continents. Therefore their supply chain and business processes are mature. On one hand it is not surprising that BPO is a feature of their supply chain. However, it is surprising that it occurs for AMT. Company A's size may afford it the advantage of scale, but it is curious how BPO and AMT do not conflict when persuing MPer. It is especially curious since C and D view AMT as a core competency when persuing MPer and therefore a function to retain in-house. AMT as a core competency in this situation implies the company has some intellectual property invested in the technology or process they use to bring a product to market.Company A, however, does have several patents in this area and are also pioneers in additive manufacturing, especially as a consumer or prosumer product and not just B2B. Company B also outsourced some production:

> "*The machine are a bit like any large complicated machine. Are system engineered, in the sense that, large parts of it are bespoke designed in-house, and then manufactured out by specialist manufacturers who are selected by tender. And then certain parts will be bought off the shelf and they might, to a certain extent, have to be customised and so on, or built to specification*."
>
> Director C Source: Appendix B.3

Advanced manufacturing technology confers an advantage and enables manufacturers to improve their capabilities in several ways (Chung and Swink, 2009). Although not all the participants agreed regarding the sharing of knowledge. Company C aims to provide their customers with a service that assist them in creating the best products possible. Although in comparison group D cater to clients with larger production runs and so the protection of their technology and tacit knowledge is mainly to prevent competition at scale. Company D have to make special considerations for the operating environment of their production equipment stating:

> "*It might seem very easy print something but as I said to you we have conditioned rooms for the different technologies and there is such a big influence of where these machines are located to have nice prints*."

Director F Source: AppendixB.5

Company C sell AMT as well as services teaching how to use the technology. Company C's director viewed the ancillary service as a way to drive demand for their machine retailing business and servicing demand for small runs on less affordable machinery.

Company A was the largest company from the study also retail consumer products but do not engage in the ancillary service like providing tuition. Company A has a history of providing complex products that are early in their product life cycle but not engaging in ancillary services such as tuition or certification. Much of company A's innovative technology is through acquisition; this is in stark contrast to the others in the study.

According to the framework outlined in Chapter 3, strategic manufacturing considerations and practices enable order fulfilment capabilities for MPer. Every company responded affirmatively to the importance of AMT in their strategic goals for MPer. AMT also was also expected to aid in the responsive and agile manufacturing of MPer products.

The business unit director for Company D also shared the belief that many new entrants into the market were often stymied by their inability to marry the strategic decisions required with the operational implications of manufacturing technologies, further supporting that not only is strategic manufacturing considerations and practices enable order fulfilment capabilities for MPer but that in fact poorly aligning these strategic and operational goals were reasons for failure.

Proposition 4 stated that information technology enables order fulfilment capabilities that support the pursuit of MPer. Several of the companies have emphasised employee skillset as a significant factor in leveraging the IT to support Mper.

Flexibility is considered the general ability to adapt to internal and /or external influences (Holweg, 2005). Successful BTO strategies are flexible along three critical dimensions, process flexibility, product flexibility and volume flexibility (Pil and Holweg, 2004). Company D described a high level of flexibility in process, product and volume. Process flexibility is driven by a competent technical team, capable of re-engineering the production machines and processes for a given production run, resulting in volume and product flexibility. The primary constraint to company D exhibiting even higher levels of flexibility are the environ-

mental requirements of the manufactures machines, rooms requiring specific temperatures and humidity are prohibitive.

> "*if you have to print or make millions of the same product a day, then yeah you are bound by the restrictions of the product. But becasue we even don't know what the product of the day will be so we have to adapt constantly*."
>
> Director F Source: Appendix B.5

Company D also pointed towards advanced manufacturing technology enabling their ability to work in this flexible way:

> "*...I think most 3d printing can act in the way that we do it is just the nature of the technology*."
>
> Director F Source: Appendix B.5

The Director for Company B stated that the strategic consideration of the product design is integral to the ability to service a personalised strategy. The specification of the product is deemed to have a significant impact on the design of the supply chain and the ability to postpone the product at the correct stage, seperating dependent demand from independent demand.

Holweg (2005) commented that many of the studies conducted into flexibility have been qualitative, with significant gaps in:

> "...
> *strategising , designing and aligning the supply network...are some of the existing gaps in the body of research*."

Typically this research has dealt with the customisation domain; little qualitative research has been conducted in the area of personalisation. The thematic analysis of flexibility in the context of this research contributes to increased emphasis on advanced manufacturing technology and highly skilled employees. The consensus for production is that the increased mechanisation of the workforce will reduce the skills required. There are however clear signs that innovation in personalisation requires more highly skilled employees. This theme

further strengthens the need to include an employee dimension to the framework in the hypothesis.

The manufacturing continuum summarises the supply chain based on their dominant mode of order fulfilment. While all the companies from the field studies were considered personalisers, their position on the manufacturing continuum differed. Company C and D are capable of Configure-to-order (CTO) and a limited form of Engineer-to-order (ETO), while company A can be considered predominantly Build-to-order (BTO) and Assemble-to-Order (ATO) group B are BTO with high product standardisation, however offering a mechanism for personalising the product. Attempting to satisfy customers, requires the ability to differentiate products (Holweg, 2005). Specific ETO, BTO, ATO postpone the products final form to varying degrees allowing some personalisation steps. What type of personalisation and how they differ has not been covered well in the literature or translated into a comprehensive framework?

The position at which the demand changed was not dependent only on the design of the product but the in-house capabilities of the company. Traditional a modular product signalled a BTO or ATO mode of order fulfilment, the field study indicates that companies are allowing the customer to chose where they interact with the order fulfilment process. Advancements in manufacturing technology have allowed the companies to be more flexible as to where on the continuum their manufacturing process can service demand. This is an interesting finding from the study; it would be interesting to study this phenomenon in a more generalisable way as it implies not only companies seeking to personalise are moving further up the value stream to postpone the product but actively seeking ways to satisfy customers across several customer order decoupling points (CODP). Little if any literature explicitly acknowledges this as a possible result of attempting to satisfy personalised product. The implication could be that as manufacturing technology becomes more advanced, servicing demand is may not be incumbent on an ability to satisfy customer demand from simply one tightly defined mode of order fulfilment with the supporting position on the manufacturing continuum.

In Company C's case the director pointed out that serving a print-to-order type position

and then retailing MTS products is a complimentary strategy for them:

> "...emphwe hope they also purchase a machine."

There was a mixed response when discussing the relationship between the information systems and the business operation. Company B product customisation process is the least integrated with their internal systems. For example, Company B does not have a customer facing product configuration solution. Company B does not have a website for specifying the components of the product. One reason given for this is that although they provide the facility to personalise the products, it is not a primary service and also the products are big ticket items and as such likely to go through a tendering process. The machines also have a significant number of regulatory requirements. A request to integrate other technologies into their standard products can be supported and is often achieved through a series of face to face consultations. When asked further as to why the Director responded:

> "*It's something that I know is being looked at, and I think it has a lot of applications for it across several different fields...I doubt it's ever going to be used for parts of the sales process, becasuue that's much more suited to fast-moving consumer goods*."
>
> Director B Source: Appendix B.3

Company B's director also indicated that the enterprise-grade service application the company rolled out was not fit for its original purpose and indeed was repurposed as a spare parts management system. A customer facing product configuration tool, for customers to design their product before purchase, is a tool cited in the literature review as popular among retailers practising MC (Haug *et al.*, 2009). The question raised as to whether this trend would extend itself to personalisation. Two things are striking about the assumption that a product configurator is a default point of interaction for specifying a custom product when discussing the companies in this study. The first is that the two companies with the most traditional MC capabilities, who also profess to be personaliser, do not offer such a configuration solution tool.

Company A being the most surprising as most of their competitors do, following Dell' example as an order qualifying capability in the personal computing space. The second is that extending product configuration tools as the panacea for the provision of personalisation may not be the natural progression for industry. Instead, it seems organisations engaged in personalising products are reaping the rewards of the diffusion of manufacturing technology amongst the general public and prosumers and instead leveraging the file formats from CAD software to begin the process of personalisation. This may be a drastically cheaper method of soliciting a customers specification, however obviously implies a bigger barrier to entry for consumers without the specific skills. Company A view this problem in a more holistic way and seek to control the means through which these skills are acquired.

Unlike Company C, who offer training on generic 3D printing machinery, Company A actively develop products that lower the barrier to entry, in the hopes that they will be able to service the demand for raw materials and subsequent iterations of the product that lowers this barrier. This is a model Company A has previous experience with and as such, they are hoping that they will be able to repeat the success they once enjoyed in the traditional printing space. In the literature review, it is pointed out some authors criticised the brazen adoption of MC, resulting in unnecessary cost and complexity. It could be argued that a lesson has been learned, and companies seeking personalisation are choosing a more cost-effective way to interface with their customers and prosumers, who are more willing to take on the cost of exploration, seem a sensible audience.

The question a The acquisition and implementation of comprehensive ERP/MRP systems can be expensive. While customer insight and sound information management systems like ERP MRP and CRM are considered necessary tools for organisations at scale, it seems that there is a lack of consensus on the best approach. Web-based configuration systems were ubiquitous when mass customisation reached it's zenith. From car companies to sportswear, the online configuration of a customised product was standard. With personalisation, there does not seem to be a new axiom, and instead, there is a willingness to repurpose and personalise the infrastructure is pervasive amongst the participants.

In the literature, the discussion of business analytics and customer integration have been

challenged when implementing Mper (Arora *et al.*, 2008). Company C and D also lack a client facing website where the product can be configured, although they provide a service that allows for the customer to give designs via a digital format. There is a shift among personalised from the configuration platforms that allow the user to customise their products combinatorially to the provision of CAD files and consultation, similar to ETO. Traditionally ETO is associated with big ticket items or prototypes for products that will in future be mass produced.

The cost of the good information management system is also a strategic consideration beyond just the initial cost and setup. Maintenace and continuing service costs are also a concern. The consensus is that product architecture has significant strategic implication for the design of the supply chain. Company D' Director explained the nature of their production environment and manufacturing technology allowed for complete integrated products to be manufactured in one run without requiring further assembly. This has a significant impact on contracting the supply chain and possibility of having to source products for small production runs. However, they were often generic parts and required little strategic sourcing. While this is only possible for the mechanical parts of the products and certain materials, Company D are a testament to this mode of production being economically viable.

Company A and B described their products as having a standardised and modular architecture, although both can personalise the product. The alignment of product architecture and process is a strategic concern and not an afterthought for many. Company B described the process for the personalised cards they supply as a print-to-order. The substrate has already been processed to a point, and production is delayed until required.

Product families and architecture standardised for a market segment was prevalent for Company A and B but not for the rest. The implication is that the remainder of the personalisers do not require product architecture standardised around a particular product because they are not the engineers of the product. Flexibility in this arena is reduced to the production capabilities and skill of the workforce, another reason why so much emphasis is placed on the skill set of employees. The discussion about modularity vs. integrated and functional vs. innovative product is only relevant among the more traditionally established respon-

dents. Component reuse is not a focus for the newly formed personlisers in comparison to the old guard. Who although not directly queried seemed more likely to have products with the higher quantity of components in the BOM (Tseng *et al.*, 2010).

There are varying levels of product variety displayed by the companies involved in this study. The personalisers that exhibited more tradition supply chains with a mix of goods and modes of order fulfilment had a significant number of products but they were unlikely to use their personalisation to extend the product range. A definition of personalisation promoted in the literature views the automation of the product adaptation on behalf of the customer as personalisation as opposed to at the customers request.

The production focus summarises the overarching mode of order fulfilment. As mentioned in previous sections the company's involved in the study had different methods of order fulfilment. A single mode of order fulfilment and therefore mode of production did not unify them, in fact, variation in this area was the commonality.

Technological advancements have increased the prosumer and technical skills available to customers and clients. The process of personalisation expects customers to have conducted most of the personalisations themselves, albeit to an extent where the file format or interface is a standard and one the company support. In many respects this is extreme that has precedence in the movement from mass produced goods in which the knowledge required to purchase the product does not extend much beyond the need for the consumer to appraise the value or satisfy the desire to buy, to mass customisation in which the customer is expected to have some more ownership of the ultimate form of the product and therefore supposed to appreciate the implication of their choices although this only really extends to the aesthetic however is still a departure from mass production. In mass personalisation the knowledge of the implication seems to extend to the core architecture, manufacturing constraint (materials and machinery). Ultimately this increases the barrier to entry and personalisers are not just customers who desire an aesthetic change in this way mass personalisation has a self-selecting bias for prosumers B2C and companies with in-house engineering abilities BTB. Companies such as C and D are equipped to assist.

The structural decisions of the manufacturing strategy from Hayes and Wheelwright

(1984) were the most important when constructing the conceptual model. This research viewed the facility, capacity, vertical integration and specifically the technology as the primary strategic considerations for manufacturing strategy. The infrastructural decisions as outlined by Hayes and Wheelwright (1984) and that include workforce, quality, production planning and control and organisational decisions were undervalued. Specifically the workforce component, which has been commented on time and time again by the respondents as an important part of achieving attaining the capabilities to personalise products.

5.2.4 Organisational Factors

In technology companies their product offerings and production, capabilities are directly constrained by production equipment and capacity. This so-called "asset frontier" requires significant capital (Chung and Swink, 2009). It is therefore not surprising that parent companies would arise as a theme in this context. The universality of this theme is surprising as it seems independent from the maturity of the technology utilised and more dependent on the companies reliance on bespoke machinery or complex processes to support the technology. In the case of company C while the technology is mature the upstream market of OEM of personal 3D printers, are younger companies, and the cost or production may be higher in general for an industry in the early stages of development.

Company D made it clear their in-house abilities allowed them to build bespoke hardware:

> "*What are the most developed machines we have? Well I would say these are the machies which were developed in house*."
>
> Director F Source: Appendix B.5

It is clear that this fact is a very important point for Company D. The machine tolerances and capabilities are all inside knowledge that confer a competitive advantage:

> "*This has really given us a lot of advantage in the 3d printing world and it is also a benefit it also a benefit that we don't want to share with the others. We don't sell these machines we use them in house to provide the service that we*

> *want to give but we are not going to sell these. They also are fantastic, they do what they have to do ...they do what they are meant to do. We are not a machine producer, a machine producer would put a nice cover around them and put a nice brand on it. For us these are purely technical machines* ."
>
> Director F Source: Appendix B.5

The role of Parent Companies is a theme that developed from the field data and was not initially used in the classification of the literature. All the companies acknowledged that their personalisation initiatives required a substantial investment from their parent companies or headquarters else they were already large customers with global supply chains. The personalisation of a product by the child company was made feasible by previous investment in infrastructure and established supply chain competencies that already service mass customised goods and status as a going concern of the previous companies. This supports Kumar (2007b) insistence that personalisation retains some aspect of MC, specifically the affordability associated with economies of scale, to achieve Mper. Company C, however, were markedly different in that their parent company is a venture capitalist (VC) firm and as such do not have an established supply chain or a history of MC. It was also the smallest in size possibly indicating anecdotally that larger organisations must leverage their previous history in MC to pursue MPer at scale, while smaller companies without the costly infrastructure do not need MC efficiencies to achieve MPer. Further research into the role the size of an organisation plays in attempting MPer, may provide more empirical validity for MPer as a strategy. This theme adds to the need to include a size dimension to the framework.

During the search of the extant literature many conceptual claims, regarding ETO, were made by several authors. Wikner and Rudberg (2005) claimed that ETO can be seen as a special case of MTO. Company C may stand as an empirical example of such an organisation.

The aquisition and retention of skilled staff is considered an important strategic cnsideration for the Directors of all the companies. A consistent theme between all of the personlisers was a distinct belief in ability of their employees to innovate and maintain flexibility for non-standard ways of working. Company D insisted that without their engineers

their focus on personalisation would not be possible. Kritchanchai and MacCarthy (1999) referred to the importance of highly flexible processes as well as excess resource as a means to achieve flexibility. The supply chain literature does not mention much about implication of employees and technical skills on the strategic decisions required for personalisation or indeed mass customisation. Company B made it clear that their skilled staff critical to the development of the company over the coming years where more traditionally found in the R&D department. This is a more traditional situation for most companies

5.3 Evaluating the Research Gaps

After the analysis of the respondents and the comparison of the thematic analysis of the field data with the literature a few revisions to the model are required. This section discusses the conceptual model in relation to the propositions made originally in Chapter 3. After the new knowledge will be factored into the original framework and a new model presented. This chapter concludes with a summary of the insights gleaned, that are responsible for augmenting the oringally theorised model.

5.3.1 What differentiates Mass Personalisation and Mass Customisation in practice?

The supposition that design is an activity that is carried out by the personaliser, made sense when viewing personalisation as a phenomenon concomittent with engineer-to-order supply chains. The reality from the responses from industry is that design at the personalisation stage is likely conducted by the customer. The alignement of product charatceristics and architecture where not really challenged and indeed the traditionl view of product architecture and order fulfilment capabilities informing where the seperation of dependent and independent demand occurs fits with the perception of company drectors. The personalisation of products *hard* characteristics, according to all the repondents, push the customer order decoupling point (CODP) towards an ETO or ATO typology.

The manufacturing decsion are indeed held critical by all the respondent. The assertion

made by Yang *et al.* (2004) that postponing design and manufacture to as late as possible is a strategy for dealing with extreme variation in demand and volume, is still a valid maxim for personalisation. The emphasis on skilled workforce has been a prominent part of concurrent engineering and 3 dimensional concurrent engineering literature. The focus of much of this literature has been on the inclusion of cross functional team members at the beginning stages of product development. The focus in cross functional teams is indication of the need to include more knowledge from within the organisation. The literature covered in the review only had slight suggestions of the importance of employees technical abilities in the product personalisation.

5.3.2 What are the effects of Mass Personalisation on supply chain design and operation?

For the larger organisations with more established supply chains, pursuing personalisation beyond mass customisation is challenging. Customisable products may lend themselves to perosnalisation, but some product types are more ammenable to the process than others. Understanding and explaining which products are more personalisable and why is worth while further research. Even with a supply chain designed with customisation and then subsequently personalisation in mind, business process re-engineering (BPR) and the unique context of a supply chain make managing rapid and radical redesigning of core processes difficult (Böhme *et al.*, 2014). At least strategically it seems that pursuing personlisation from the onset, for a product or for the organisation, makes achieving personlisable products less complicated. For this reason the proposition that supply chain design considerations are enablers of mass personalisation is sensible, specificaly the pursuit of greater modularity. Collaboration across the tiers was less important than proposed. Companies C and D prefering more generic relationships with component suppliers attests to this consideration. The systems that maintain and manage their pursuits are more reliant on in-house knowledge than a strategic partnership with a systems provider.

Table 5.5 provides a taxonomy of the companies in light of the thematic analysis, literature and responses.

Company	Typology
A	Traditional Mass Customiser with soft personalisation options for consumer base and hard personalisation for B2B not true Mass personaliser
B	Traditional Assemble to order company with personalisation options. All activity is B2B and personalisation options are akin to ETO.
C	Personaliser lacking the capacity for large personalisation runs.
D	Mass personaliser. Capacity for large industrial runs, compitent engineering employee base with flexible manufacturing and supply chain.

Table 5.5: Taxonomy of companies

5.4 Revisiting the Conceptual Model

To support the insights gleaned from the analysis of respondents the conceptual model in Figure 5.1 is presented adding an employee dimension and the proposition that:

- The pursuit of MPer requires the strategic consideration of the technically compitence of employees.

While this may seem obvious, it is counter intuitive. With the proliferation of automation and machines in the manufacturing function and supply chain, there is increasing conversation regarding job security and the role of the employee base. Much of the discourse views the proliferation of technology as synonymous with the loss of jobs. There does, however seem to be an increased emphasis on technical skill when integrating AMT into an organisa-

tion. The addition of this dimension better conceptalises the important components of MPer and supports the general response from industry. Solymossy and Gross (2015) identified the rise in engineering graduates in managerial positions and the importance of technical staff on innovation. Unfortunately Engineers often seek self-employment or mangerial roles in the medium to log-term, a reason offered by Solymossy and Gross (2015) is that:

> "*While the organization focuses on the value-added nature of knowledge and appropriates the value derived from it, our interviews indicate that they may not share the value with the individual.*".
>
> (Solymossy and Gross, 2015, pp.403)

The research by Solymossy and Gross (2015) was conducted in North America and Canada, however will share context in most western settings. The drivers of change in many manufacturing setting are similar for western economies and include; globalisation, extended enterprise, digital business and innovation (O'Sullivan *et al.*, 2011). These provide important strategic considerations for organisations pursuing personalisation.

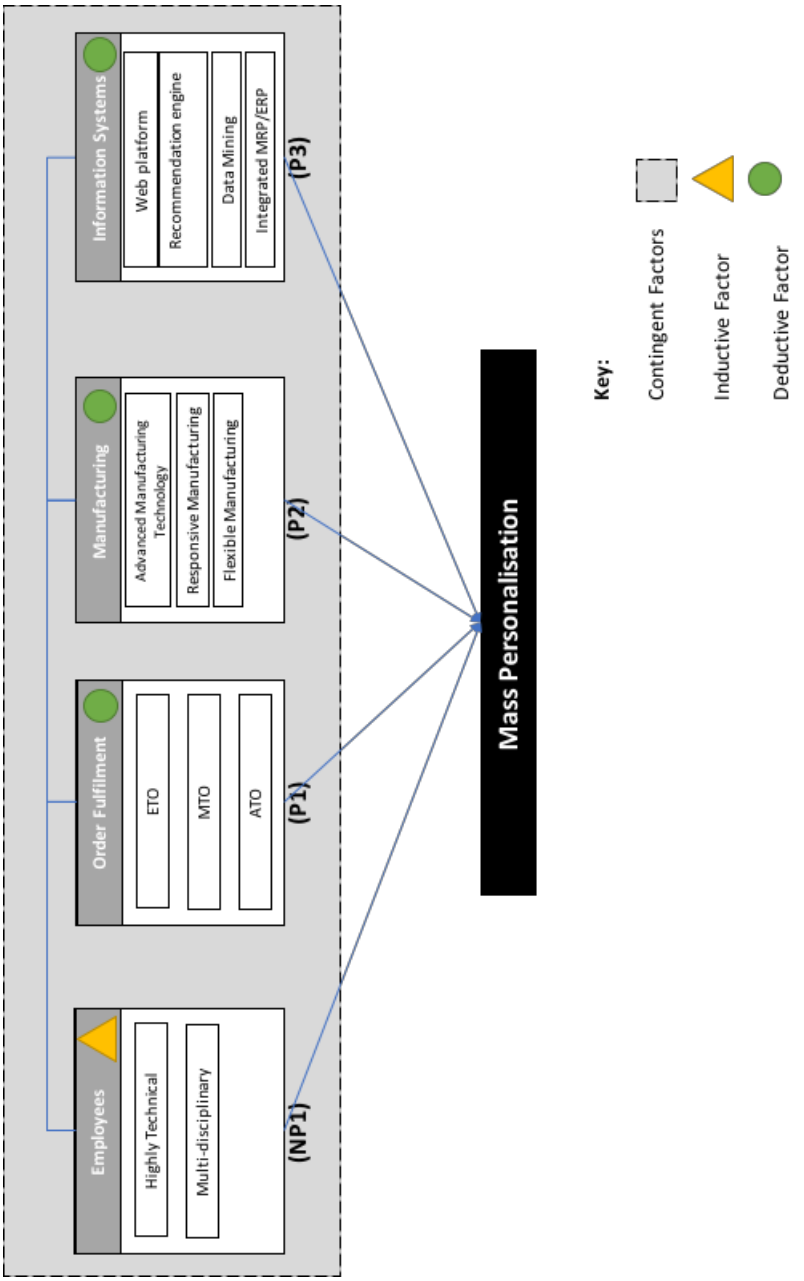

Figure 5.1: Rehypothesised Conceptual Model

MPer has a close association with service-dominant logic. Central to service dominant logic is the involvement of the customer in the design of the product (Sunikka and Bragge, 2012). Importantly when discussing the personalisation of products, tangible products can also be personalised as the result of a one-to-one interaction. Personalisation differnciated from Customisation by an infinite scope for customisation only constrained by the products function and affordability of the technology. Organisation aiming to personalise products to such a degree, require a workforce with both multidiciplinary technical skills and a service-dominant logic.

5.5 Summary

MPer is a distinct pursuit for organisations and directors, there are several factors to considered when pursuing. Manufacturing Strategy, Manufacturing Technology, the CODP and employee technical skill set are important considerations. A manufacturing strategy that is critical of manufacturing technology, specifically adoption of "off the shelf" products versus bespoke is important. The decision between generic manufacturing platforms and bespoke has always been important (Yusuf and Little, 1998), however it may be the difference between personalisation as a service offering being feasible or not. Manufacturing technology such as additive manufacturing seems critical if MPer is a to be achieved affordably. A CODP concomittent with ETO less the design dimension, is capable of providing personalised products. However without a techincal employee base who are able to increase responsiveness and agility, so as to respond rapidly changes and fragmentation of the market (Vonderembse *et al.*, 2006).

Conceptualising MPer presented in this thesis may have many underlying generalisations, further research will refine the generalisations and focus the model.

Personalisation is viewed as a distinct pursuit by senior management and is not conflated with Customisation. The emphasis on unique products that satisfy the demands of a single customer is in keeping with MPer. Contrary to the conceptualisation by (Sunikka and Bragge, 2012), personalisation can be tangible and distinct from MC. Several of the

directors responded with this a similar definition for personalisation, acknowledging a distinction from customisation. The difference focused on satisfying the unique demand of a request of an individual client. The level of personalisation and affordability did vary, with Companies B and D capable of deep technical personalisation of core product architecture with further consultation with the customer. Company B, however, is constrained to their standard product offerings which are capital assets, while Company D have the ability to produce much broader product range.

Company D is a MPer under the definition of (Kumar, 2007b), capable of satisfying various volumes and product architectural specifications. Company C has many similar capabilities as D, except their small size, lack of ability to scale and their focus on retailing 3D printing technology restricts their ability to achieve comparable MPer.

Additive manufacturing does play a significant role in the pursuit of personalisation. The two companies that were closest to the conceptualisation of MPer were also early adopters of 3D printing technologies. Manufacturing technology and strategy are important considerations for personalised; these technologies can "short circuit" traditional processes. Less emphasis is placed on ERP systems from vendors and instead bespoke systems are preferred.

Companies A is much more similar to a well-known MC company with the ability to augment their service and provide personalisation for standard products. A large supply chain affords Company A capacity to pursue personalisation in some areas, conversely their size also hinders the adoption of personalisation as conceptualised by Kumar (2007b). Kumar (2007b) and (Kumar, 2007a) theoriesed that mass efficiencies following from MC are a prerequisite for MPer may be overstated, in as much as, capabilities in MC do not necessarily pave the way to MPer; there are more obstacles than the scale of the operation. It is evident from the response of company C that fundamental economics of the venture were not the primary focus. This is a trend that followed across all the respondents; Company B was heavily supported by the parent company and Company C by the investment company. It is, therefore, fair to acknowledge that the proliferation of this technology is being driven by early adopters across the supply chain who are willing to find interesting ways of maintaining themselves as a going concern.

MPer requires a conducive business model, and Company A is not trying to implement such a model. Company B is capable of being an MPer in a similar vein as Company D. Though again their adoption of the business model that seems to support MPer is unlikely. The largest barrier to achieving MPer for Company B, is the regulated environment that they work in. The single most important factor for pursuing MPer is the technical competency of the employee base. Supply chain agility requires processes that can change to meet a customer's requirements quickly and efficiently. Traditionally process engineering and design changes have been a valuable feature of ETO supply chains. Quick changeovers and small lot production have historically enabled a rapid response to market demand (Holweg, 2005). Managing this effectively may rely less on the interface between the customer and the organisation and more between the technical employee and the business processes. All the respondents claimed to be personalisers. However only one company fit the conceptualisation of MPer, Company D. The utilisation of additive manufacturing or 3d printing, bespoke equipment, highly technical staff and support of parent company while not being embedded in the parent companies supply chain or business operation.

The following chapter re-evaluates the conceptual model in light of the responses from the field and presents a new proposition and conceptual model.

6. Conclusion

Chapter 6 summarises the conclusions gleaned both from the literature and the empirical research. A critical appraisal of the research process is provided acknowledging the fallibility and limitations of the research. The novelty of the research is present followed by recommendations of further work.

6.1 Summary

MP was incapable of supporting large product variety due to the increased cost and working capital locked in FGI Duray (2002). MC promised individualised products, based on modular product architecture and responsive manufacturing (Davis, 1987; Doran, 2003; Kumar, 2007b; Little *et al.*, 2001; Piller, 2007; Piller *et al.*, 2004; Pine and Davis, 1999; Silveira *et al.*, 2001; Tseng and Piller, 2003). Unfortunately, MC is synonymous with "customisable customisation" and as such final product individualisation is not typical for MC (Arora *et al.*, 2008; Kumar, 2007a,b) Personalisation has gained popularity in the literature discussing, the individualisation of products. Personalisation aims to provide value through the infinite reconfigurability of an aspect of a product offering; this personalisation can be the product, process, price or promotionSunikka and Bragge (2012). MPer focuses on product personalisation and as such seeks to retain the Mass efficiencies of MC, while providing affordable products (Kumar, 2007a,b). As a theory, MPer is an extension of MC. However, the empirical reality of MPer was unexplored, and there is a paucity of the literature. In recent years manufacturing technologies such as additive manufacturing have promised to increase the speed at which organisations can respond to the markets and customers (Holweg, 2005; Kritchanchai and MacCarthy, 1999; Little *et al.*, 2001; Reichhart and Holweg, 2007). These technologies, under the collective name of 3d printing, have brought product perosnalisation closer. Senior managers actively describe their pursuit of personalisation in a different context to MC.

6.2 Novelty and Contribution

The culmination of a doctoral dissertation describes the importance of the thesis, to the field of enquiry. This research has contributed to the academic understanding of mass personalisation. The preceding chapters have explored the topic and analysed empirical data from sources within the context of the study.

6.2.1 Academic Contribution

Through the literature manufacturing strategy, Manufacturing technology and the CODP were important concepts for informing the level of personalisation possible for a product. Depending on where the organisation locates on a spectrum, the organisation could fulfil orders using MTS, ATO, BTO, CTO or ETO modes of order fulfilment. These are a typical conceptualization of where independent demand is decoupled from dependent demand. In essence, the position between when products is completed to satisfy demand. Typically MTS requires the most stock but is responsive to demand, while ETO products are built to specification on (Gosling and Naim, 2009). ETO, however, is synonymous with big ticket items and long lead times. New manufacturing technologies and the pursuit of personalisation, have lead to a theory of MPer which reconciles the responsiveness of MTS with the agility of ETO.

The rigorous process of identifying and describing the problem domain culminates in a clear and narrow perspective for the research. Justifying a valid and appropriate methodology is a contribution to the extant literature. The contribution is the product of identifying and explaining where the background theory and the data theory are different. Chapter 5 and 6, summarise the findings, appraise the data approach and explain the novelty of the contribution before finally proposing further work. In Chapter 6 people factors and business process factors are emphasised as important strategic considerations in the pursuit of personalisation of products and services.

These processes are subsequently not represented in the standard typologies for supply chain design. It is unclear whether these non-standard methods come from an as of yet undocumented set of strategic decisions. What these decisions may be and how they differ from MC and known modes of order fulfilment such as engineer-to-order, are novel contributions that extend the knowledge of Mass personalisation and Mass Customisation.

The culmination of this thesis is the novelty and contribution made to the extant literature and theory. This research contributes empirically to the theory of MPer. MPer theoretically postulated the connection between MC and MPer and indicated the boundaries

of personalisation of products in the supply chain. This thesis is one of the few if not the first to operationalise and explore MPer empirically. The research examines the strategic considerations of pursuing perosnalisation in industry contrasting with MC. This thesis also contributes to the theory of perosnalisation from (Sunikka and Bragge, 2012) and the traditional theories of CODP by (Wikner and Rudberg, 2005). The systematic literature review objectively surveys the state of the art in personalisation of products and supply chain design as it pertains to supply chain management and presents a taxonomy of the literature. In acknowledging the difference between MPer and MC, this research has extended the boundaries of the conceptualisation of personalisation of products.

6.2.2 Practical Contribution

The rehypohesised framework provides a practical model of personalisation and the strategic considerations.

This research explored what mass personalisation looks like in industry and investigated what the strategic considerations were for senior managers when pursuing the personalisation of products.

Generalising from the analysis, the core strategic considerations required when seeking MPer include:

1. A manufacturing strategy that factors in the requirement for technical expertise of the employee base - Manufacturing requires the company understand where their product will be positioned in the supply chain and what will drive the FGI. The common focus here was the application of lean processes and information systems such as MRPII. When pursuing personalisation, it seems more prudent to organise your strategy with an eye for technical competence of your employees;

2. The product's architecture and it's implication on manufacturing processes - Product Architecture, modularity has always been considered an enabler of MC and as such would expect in personalised products. Although modularity of product architecture is a feature, it is not as important as other factors for organisations with high person-

alisation capabilities;

3. The implications for heavily regulated industries - Regulation limits the ability of the organisation to pursue personalisation especially in B2B transactions;

4. New entrants without an existing supply chain and with adequate capital can pursue MPer with greater specificity, than larger multinationals with global supply chains who have hitherto provided MC products using ATO;

5. Additive manufacturing is a prominent AMT in MPer companies - Additive manufacturing enables both responsiveness and agility which are core requirements for a manufacturing system that wants to satisfy high product variety and;

6. Customer interface is not necessary for MPer, unlike MC in which it is prolific and in some senses mandatory - The Web platforms for the configuration of products are a key feature of MC and an essential element of MPer. This research finds that this may not necessarily be accurate.

Mergers and acquisition are common amongst companies seeking to extend their product offerings. From this research, it seems likely that to enter the personalisation, organisations use the mechanism above or create a smaller child business. Acquisition or parent company were both cases in this research. It seems to explore the possibilities of the mass personalisation alluded to by Kumar (2007b) organisations need an established supply chain or access to readily available funding. Company C was organised by a Parent venture capital (VC) group and were the most able to mix retail and mass personalisation of product and service

Typically mass customisation at varying scale has very similar features, ATO CTO ATS type order fulfilment and production competencies, customer interface for product assembly, configuration modular product architecture, etc. Personalisation is not at uniform in mechanisms, however, standardises around the consumers ability to use personalisation products separate from the organisation required to personalise the product.

6.3 Limitations of Research Presented

The qualitative method makes it difficult to make a generalisation. Though every attempt was made to formalise the method of abstraction, converting themes from the literature and synthesised frameworks into a conceptual model, the process may be accused of being subjective. The process is auditable, all decisions regarding scope, research inclusion and search criteria have been expressed explicitly. The precise nature of the thesis increases the credibility to the inferences made.

The pursuit of MPer can be acknowledged as different from MC. The question may be asked as to how important is this separation of terms. The definitions are poignant because the differentiation goes beyond semantics and is tangible. It is importance to acknowledging MPer as having a different set of strategic considerations, especially when using technologies such as additive manufacturing. Authors such as Poulin *et al.* (2006); Sunikka and Bragge (2012); Tseng *et al.* (2010) defined personalisation in one way or another to progress from that position and contextualise their work.

The number of respondents may at first seem small for a case study. However, there are several important points to note:

1. The respondents are senior employees, board level. These respondents were best placed to provide the necessary insight into strategic decisions and as such the content required for this research to make thematic comparisons to the literature and subsequently a contribution to knowledge;

2. The unit of analysis in this study is the organisation. While further corroboration of the phenomenon further down the organisational hierarchy could have been a pursued, this research did not require extra organisation triangulation and rather required inter-organisational triangulation of the themes raised. To explore the nature of strategic decisions in the pursuit of personalisation, as it pertains to supply chain management and a stated aim of this research, generalisations about senior management between companies is a much more dominant form of triangulation as Yin (2011) expresses

essential for theory building;

3. Although similar in implication to point 2 a differing context between the companies, provides for *richer* content to analyse for both personalisation, customisation and size and scale of operation and;

4. The nature of the subject matter is very specific and requires MBA or supply chain specific knowledge to covey in any meaningful way. The bounded rationality of employees further down the hierarchy would most certainly have been a barrier.

6.4 Future Research

While it is clear that Senior managers pursue personalisation with a specific end goal in mind, the implications for the workforce and employee base have not been explored. There is more than anecdotal evidence that the acquisition and retention of technically literate staff is a major factor in personalisation. Also since systems like web-based platforms, which are a staple for customers to interface with in MC, are not prolific in MPer then an opportunity exists to explore the client interface with personalisation. CAD applications are demanding software applications are often requiring formal training, are consumer or "prosumers" the primary customers of personalised and the implications of this for growth in the supply chain are unknown.

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A. Key Contributions from Literature Review

Literature Reviewed by Theme

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Application of AMT	Claim of Concept	Although the terms chosen to describe the AMT types differ from one typology to another, many of them fit conceptually into three higher order functional types: design AMT, manufacturing AMT, and administrative (or planning) AMT. Discussions of the three types of AMTs can be found in Boyer et al. (1996) and Swamidass and Kotha (1998).	CHUNG W. and SWINK M.	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
BTO or CTO Definitions	Claim of Concept	First, this requires a mass customization definition that is broad enough to include both kinds of movements, i.e., a definition with lesser focus on having product prices close to the prices of mass produced products (or to avoid a movement to an upper marked segment). Second, there is a need for clear definitions and understanding of different sub-types of mass customizers, for which reason the basic definition of mass customization could be extended by definitions of different kinds of mass customizers. Such sub-definitions of mass customization could in the case of mass producers and ETO producers be something like: "Typically, the incentive for mass producers to become mass customizers is to allow a customer co-design process while keeping the costs of products comparable to the ones of mass produced, while the incentive for custom producers for pursuing a mass customization strategy is to optimize internal processes by defining fixed solution space in where the customer co-design can take place".	KUMAR, A.,	2007
Business purpose	Claim of Fact	The customer order decoupling point (CODP) is the stock holding point that separates the part of the supply chain that responds directly to the customer from the part that uses forecasting.	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Configuration Challenge	Claim of Fact	The factory is concerned with product availability, cash to finance new inventory purchases, and gross margin preservation in light of surprise shifts in product mix.	WALKER, W. T.,	2010
Cost	Claim of Concept	Most literature claiming that ETO companies become mass customizers has a main focus on technology and does not in a detailed manner deal with the business-oriented impact of the mass customization projects (e.g. Hvam, 2004, Hvam, 2006, Petersen and Jørgensen, 2005, Edwards and Ladeby, 2005, Steger-Jensen and Svensson, 2004; Hansen et al., 2003). This literature does, therefore, not report whether or not product prices near prices of mass produced products have been achieved	KUMAR, A.,	2007
Customer Order decoupling Point	Claim of Fact	The importance of classifying supply chains according to characteristics has been widely addressed in supply chain literature.	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Customer Requrirement	Claim of Value	there is a risk that the field of mass customization will become neither an academic discipline nor a broad strategic concept that is recognized by managers. To help avoid dilution of the concept of mass customization while not excluding ETO companies, an emphasis should be made on the importance of making a clear distinction between mass customizers that comes from mass production and custom production without ruling out any of these two kinds of movements.	KUMAR, A.,	2007
Delivery Lead-time	Claim of Fact	Procurememnt and competitive bidding as well as the design stage have been highlighted as being bottlenecks for ETO supply chains (Elfving et al., 2005; Gosling et al., 2007a)	GOSLING J. and NAIM M.,	2009
ETO as MC	Claim of Interpretation	AMT utilization enables manufacturing plants to improve their capabilities in multiple ways.	CHUNG W. and SWINK M.	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
ETO Description	Claim of Concept	This aspect can have unfortunate consequences, since it may lead to problems such as: loss of innovative capability, greater chance of imitation by competitors, and organisational resistance as a consequence of simplifying/trivializing the engineering work (Edwards et al., 2005).	Haug A., Ladeby K. and Edwards K.	
ETO to MC	Claim of Concept	Researchers have proposed a number of AMT typologies (Adler 1988, Cohen and Apte 1997, Gerwin and Kolodny 1992, Kotha and Swamidass 2000, Lei and Goldhar 1991, Meredith 1987, Roth 1996, Saraph and Sebastian 1992).	CHUNG W. and SWINK M.	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Flexibility	Claim of Concept	Customer view: When moving from mass production to mass customization, from the customer's point of view, the increased influence on the design of the product has to have a value, otherwise the possible choices are just confusing or annoying. On the other hand, when an ETO company moves towards mass customization, the creation of a predefined product solution space, obviously, involves the risk that the solution space is not adequately large in order to satisfy the requirements of all customers.	KUMAR, A.,	2007
Fulfilment Materials	Claim of Policy	Gosling and Naim point out that some authors state that improving interfaces between supply chain structures is of benefit (Koskela, 2000) Some even argue that the JIT developments in supply chain management intiatives in high volume sectors can be used such as reduction of suppliers, deeper and long lasting relationships and suppliers, deep and long lasting relationship and suppliers controlled as part of in-house manufacturing (Jahnukainen and Lahti (1999)) but ultimately the characteristics of ETO markets significantly constrainthe the application of established supply chain management methods.	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Industry characterisation	Claim of Policy	The right high-volume, high-mix approach must provide a supply chain strategy for a predictable order-to-delivery cycle time with an affordable inventory investment.	WALKER, W. T.,	2010
Information Management	Claim of Concept	Thus, for mass producers, mass customization can be achieved by minor product design changes, such as allowing that some components can be interchanged with others (e.g. the same component in different colours) or by offering addable components. On the other hand, for ETO companies the basis is in products that does not consist of only standardised components (if so, such a company would from a production perspective be classified as ATO), and a full standardisation may not be possible if to satisfy customer requirements. Therefore, from a product design point of view, a transition to mass customization seems generally to be much more complex for an ETO company compared to a mass producer.	KUMAR, A.,	2007

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Innovation	Claim of Concept	This paper pointed out that when ETO companies moves towards mass customization, these do not necessarily become mass customizers in the sense that these are capable of producing products at prices close to if such products had been mass produced. For an ETO company to become a mass customizer the challenge is to move the time of differentiation closer to the time of delivery, i.e. postponement. From an engineering point of view this means to increase the predefined part of the engineering work and from a production perspective to a greater degree to be able to assemble to order instead of manufacturing new components for each order. In other word, what ETO companies need to do is to move from an ETOED combined with MTOPD approach and towards an ETSED combined with ATOPD approach.	Haug A., Ladeby K. and Edwards K.	
Intellectual Property Protection	Claim of Policy	A possible strategy to manage the diverse product variety in the ETO sector is to 'Forward shift through the supply chain structure via mofularity.	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Inventory	Claim of Interpretation	Howleg and Pil (2001) suggest that the three dimensions of a successful BTO strategy are process flexibility, product flexibility and volume flexibility	GOSLING J. and NAIM M.,	2009
Lead-Time	Claim of Value	The application of time compression has been proposed to improve ETO supply chains. The importance of time compression is highlighted in towill's (2003) conclusion that 40% reduction in project time can lead to a 25% reduction in total work undertaken and cost.	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
LeAgile	Claim of Concept	Business purpose: The normal incentive for moving from mass production to mass customization is to make the products offered more attractive to the customers in order to generate or increase sales. In order to be a mass customizer (according to many definitions) the prices of the mass customized products must be close to mass produced ones, which means that if sales are not increased, the investment in becoming a mass customizer would not be returned. As mentioned, it seems that the most important indictment of ETO companies that move towards mass customization is to automate some internal processes. But although an increase of sales is not the main purpose, the effects of the optimisation could have a sales-increasing effect, i.e. from shorter delivery times, more customer involvement in the design process, being able to manufacture faster etc.	KUMAR, A.,	2007
Managing uncertainty	Claim of Fact	There are a range of structures that describe the characteristics of different supply chains. The majority of models use the customer order decoupling point as a way of distinguishing between different structures.	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Manufacturing continuum	Claim of Concept	The asset frontier bounds the maximum operational performance possible, thus influencing the capabilities that the plant might attain. AMT utilization represents one mode of asset frontier expansion, as it requires large capital utilizations and radical technology upgrades or replacement (Clark 1996, Schmenner and Swink 1998).	CHUNG W. and SWINK M.	2009
Manufacturing Technology	Claim of Policy	Operations strategies should recognize when customers value low cost products and make their objective to obtain cost efficient production.	WIKNER J. and RUDBERG M.,	2005
Market Share	Claim of Value	Flexibility has been considered as crucial to ETO strategy.	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Mass Customisation	Claim of Concept	By relating the example of mass customizing only a small part of the product portfolio to the engineering design processes at ETO companies some interesting conclusions can be made. By dividing the entire design process of an ETO product up into small work packages, it may be possible to completely automate some of them. This would require a predefined solution space and a consistent specification process that allows for involvement of the customer in the design process, but is actually what companies like F.L. Smidth and GEA Niro do (e.g. Hvam, 2004). Therefore, part of the price of creating the product may be at prices near prices of mass produced products, which implies that at least these products could be labelled as being partly mass customizable.	KUMAR, A.,	2007
MC=Mper	Claim of Policy	Both lean and agile strategies have been proposed in the ETO sector. However the extent to which lean principles are suitable in the ETO sector has been questioned (Cooney, 2002 cited by Goling and Naim (2009).	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Order fulfilment	Claim of Concept	Critically according to Gosling and Naim (2009) many authors agree that all production dimensions are customized for each order in the ETO supply chain, that the decoupling point is located at the design stage and that they operate in a project environment. Most importantly they disagree on the design dimension. Gosling and Naim (2009) indicate that some authors disagree on the design dimension. Gosling and Naim (2009) indicate that some authors argue as to whether completely new orders are developed to order. The most prominent framework dealing with the design dimension is provided by Wikner and Rudberg (2005), whom consider the relationship between Design and production dimensions of the ETO supply chain through a two-dimensional framework.	GOSLING J. and NAIM M.,	2009
Organisational Structure	Claim of Concept	Mass Customisation is a compromise between the requirement to contract time and the necessity to customize a product. Mass customisation seeks to shorten lead time and provide customer value in terms of unique products.	WIKNER J. and RUDBERG M.,	2005

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Parent Company/Subsidiary	Claim of Value	There are disagreements as to the boundaries, definitions and applicability of leaness and agility. Lean agile and leagile strategies can be mapped onto supply chain structure to help determine their applicability. This approach would suggest that agility is more suited to the ETO supply chain and leaness to a STS supply chain.	GOSLING J. and NAIM M.,	2009
Performance Measurement	Claim of Concept	based on the ETO related mass customization cases described in literature, such companies do not seem to fully achieve this transition, although they by standardising their products may be able to deliver customized products at prices lower than traditional ETO companies, and from a product price perspective, be placed somewhere in between ETO and mass customization. It does therefore not seem that ETO companies that move towards mass customization should be labelled as mass customizers from the same perspective as mass customizers originating from mass production.	KUMAR, A.,	2007
Personalisation	Claim of Policy	There is a lack of clarity as to the appropriate terminology to use to describe the 'engineer-to-order' supply chain type.	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Postponement	Claim of Concept	There is a large body of literature that promotes the movement from a MTS strategy to BTO strategy to gain competitive advantage (Gosling and Naim, 2009; Gunersekaran and Ngai, 2005; hicks et al. 2001; Salvador et al., 2007). A much smaller body of work exists exploring organizations and the supply chains that operate in markets that dictate a BT and ETO approach. Amaro et al. (1999) highlights that the ability to customize is not always an advantage, in pure customization markets it may only qualify an organization to operate in such a market.	GOSLING J. and NAIM M.,	2009
Product architecture	Claim of Policy	This article describes the application of a collaborative, multilevel postponement strategy to solve this high-volume, high-mix puzzle.	WALKER, W. T.,	2010
Product Functionality	Claim of Concept	Gosling and Naim (2009) site Amaro (1999) and Hicks et al (2001) as both identifying four types of ETO organization.	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Product Variety	Claim of Fact	The customer is concerned only with price, product customization, and delivery. The customer assumes product functionality and product quality are “givens.”	WALKER, W. T.,	2010
Production Focus	Claim of Concept	Based on the studies of Olhager and O ¨ stlund [15], the manufacturing continuum can be classified as Make-to-Stock, Assemble-to-Stock, Make-to-Order and Engineer-to-Order. These researchers indicated that the bottleneck in the production network is the critical decision point at which the production system is chosen. Their study claimed that the BTF is similar to the Make-to-Stock and Assemble-to-Stock; BTO is similar to Make-to-Order; and CTO is similar to Engineer-to-Stock. Many Taiwanese manufacturers are compelled to employ BTO/CTO production systems to meet quickly the diverse demands of customers.	CHEN R., LU K., YU S., TZENG H., CHANG C.,	2003
Research and Development	Claim of Value	In addition to time compression concurrent engineering has been suggested as a way of reducing the time to market in a MTO system (babu, 1999).	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Responsiveness	Claim of Concept	ETO supply chain frameworks agree that the production flow is all driven by actual customer orders with the decoupling point located at the design stage but disagree on the definition for the design dimension. Some argue that ETO companies modify existing orders while others argue that completely new designs are developed to order. Wikner and Rudberg (2005) decoupling approach offers a useful starting point for considering the relationship between design and production dimensions.	GOSLING J. and NAIM M.,	2009
Returns	Claim of Concept	Although information management systems are said to be of use various authors (Bertrand and Muntslag, 1993; Little et al 200) agree that the nature of ETO systems differ from the central assumptions of MRP systems.	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Service modularity	Claim of Policy	Design/engineering technologies such as computer-aided design (CAD) and computed process planning (CAPP) are often the first type of AMTs to be implemented, due to their relatively low cost and usefulness as stand-alone pieces of equipment (Boyer et al. 1996, Sacrista´nDi´az et al. 2003). On the other hand, utilizations of administrative AMTs are likely to be pursued concurrently with utilizations of design and manufacturing AMTs, because administrative AMT focus on controlling and monitoring manufacturing processes, from the acquisition of raw materials to the delivery of finished goods (Meredith 1987).	CHUNG W. and SWINK M.	2009
Strategic Supplier Relationships	Claim of Interpretation	Cost and quality is no longer valued as the key differentiator for customers in comparison to time and customisation.	WIKNER J. and RUDBERG M.,	2005
Strategy	Claim of Interpretation	For an ETO to be come mass customizer according to the common definitions would imply that the engineering work becomes more standardised, i.e. approaching an ETSED state by predefining a solution space in where customized products can be configured.	KUMAR, A.,	2007

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Supply Chain Integration	Claim of Concept	Configurator challenge: The design choices of the customers in a scenario where a mass production company becomes mass customizer are normally limited compared to an ETO company that becomes a standardized customizer, and since the focus of mass producers that become mass customizers typically is to increase sales, the user-interface of web-configurators becomes of the highest importance (Rogoll and Piller, 2004; Piller, 2004). On the other hand, ETO products are often hard to standardize to a degree that allows configuration, for which reason the knowledge-base design generally is one of the main challenges, when creating a configurator for an ETO company that becomes a standardized customizer (Sabin and Weigel, 1998; Hansen et al., 2003; Edwards and Ladeby, 2005).	KUMAR, A.,	2007
Supply Chain Management Definition	Claim of Value	Salvad`	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Supply Chain Structures	Claim of Concept	Product variety: For mass producers to move to mass customization requires that the customers are now allowed to choose different product components or properties, before the product is delivered. On the other hand, an ETO company normally creates a new product for each order, and the challenge when moving to mass customization is to predefine the elements of which the new products can consist, which, obviously, limits the options for the customer. In short, mass producers have the task of encouraging product variety while ETO companies have the task of limiting product variety	KUMAR, A.,	2007
Technically Skilled Employees	Claim of Value	The CODP can be used as a business level concept with strategic tactical as well as operational implications as the CODP impacts many aspects of the company	WIKNER J. and RUDBERG M.,	2005
Technological Constraint	Claim of Value	Gosling and Naim identify Domselaar et al (2001) stating advanced demand information, even if imperfect can help manufacturers in a project supply chain to reduce their supply chain uncertainty.	GOSLING J. and NAIM M.,	2009

Theme	Claim_Type	Claim	Journal Author	Journal Publication Date
Time Compression	Claim of Concept	Manufacturing costs: In this context manufacturing costs refer to all costs associated to fulfilling an order, including engineering design. Moving from mass production to mass customization implies that the manufacturing task becomes more complex by requiring more planning, a more flexible manufacturing process etc. However, when such tasks can be limited, product prices close to the ones of mass production can be achieved, i.e. what most define as mass customization. Obviously, the opposite is the case when an ETO company moves towards mass customization, in that this implies simplification of the manufacturing process and lower costs per manufactured product.	KUMAR, A.,	2007

B. Transcripts

B.1 Company A

Interviewer: Please give your name and position

Respondent: My name is [redacted] I am Operations Director of Supply Chain Strategy and Planning for Networking at [redacted].

Interviewer: Do you offer personalised products and services?

Respondent: Personalised? yes we do. So if you think about [redacted] products especially, if you think about products in the enterprise group space. You will see that our quantity lot size could be one or go up to many thousands and that why I say we have personalised systems because the customer can chose exactly the configuration he or she wants to have. So they can have a very unique set of requirements in terms of I want to have a server which just wants to have exactly that configuration and that exact configuration will never be ordered again.

Interviewer: Is the personalised inventory differentiated from the standard products?

Respondent: Yes but it is driven by the products that we have and depending on the customer requirements because you will never be able to have the customers product on the shelf but the customer will order and you will need something that basically allows you to make that postponement step if you want to call it or customisation step at the time the customer order comes in, which really means the that you may have a bill of materials that is customer specific almost. It could be the configuration but it also goes that far. It could be a customer that comes to [redacted] and say 'Hey [redacted] I want to have my asset label on my product already put on by you.' That's always a nice example which happens quite often. Customers come and say here is my specific asset label. If you want an example electronic arts, they brought for one of their big new games 2.5 thousand servers from me, 2.5 years ago when I was in Czech Republic; so that was a cluster, with many specific products. And they gave

us exactly there electronic arts label and we created one ourselves based on the art work we were provided. So we printed it and applied it to all their products that we shipped to them.

Interviewer: How would you describe the nature of your product architecture and how would you describe your products characteristics?

Respondent: So if you look at our product structure as such there is product which if you think about a [redacted] networking switch where is pretty much a fixed BOM and we sell it actually in a build to stock model. If you then go into the server and storage space, this would be as you said be very modular. You have building blocks you would call them. And if you look at a server which is the easiest example it typically would have a chassis and that chassis for one product family is the same where in the inside of the chassis you will have a PCA that PCA can then take module blocks then as well like a memory, so it can take many different memories, or it could take many different processes. It could also take many different IO cards so you can see there will be obvious which you have. To give you another example you have one server platform which has the same chassis the same PCA, but some of the modules, hard drive and memory can be leveraged across these two platforms. This is how you can mix and match between the different families and the two platforms. So if you think about the combinations you can do. I think the number of configurations which are possible are in the millions.

Interviewer: How would you describe how involved you are with the Engineering specification of the products you customers order?

Respondent: When you speak about Engineering do you speak of the developing of it or?

Interviewer: Yes in the development/manufacture and in the production?

Respondent: So with the development of it you have all ranges. So if you speak about networking, most likely 80% of a product which have are [redacted] designed and are [redacted] IP in there so there is a very unique science of the PCA gets designed by [redacted] so there is very deep

involvement with [redacted] and if you then walk along the product price-list which are exactly the opposite, so they are coming from an OEM, the OEM does the design of the products themselves based on specifications provided by [redacted]. So basically we will look at the product we will ensure it meets the quality requirements of [redacted] that it meets our specification in terms of performance but the real execution and engineering of the product will be done by an original equipment manufacturer. Okay and in between you will see various different mixes of that correct where some of the development of the product will be outsourced or done by someone else and some of it will be [redacted]. So you can basically find everything.

Interviewer: How would you describe your supply chain?

Respondent: So if you think about the supply chain for all of our products it probably ranges from [redacted] to [redacted] to [redacted] you will see that we have a multi tiered supply chain and that means that components come out of Asia then there will be sub assemblies built in Asia and these sub assemblies mirror some of the modules we talked about earlier, then they are done by a supplier then these sub assemblies will be moved to either [redacted] factories or [redacted] manufactures and they could be in a world wide location feeding all customers world wide or they could be sitting in a region and feeding the customers from there okay so and then what then happens as well is that sometimes that sometimes the regional manufacturers would feed a [redacted] factory too because there would be combinations of our products which makes a solution. So if you think about a data centre you will have a rack and a rack contains a server it contains a storage solution, and it might contain a switch. So all three of these products will come from different sources but the customer wants to have them integrated an cabled together. Okay so that's basically where you will see them, they will meet at sometime physically do the customisation to it and then give it to a customer.

Interviewer: So how are your suppliers distributed geographically?

Respondent: The suppliers I would say, depends how you wanna, it's mainly Asia based there is obviously exceptions to that, if you think about Intel which is one of our biggest

suppliers, they actually have factories in regions right here in the US. So they have factories that do these chips and then supply these chips and they obviously provide the chips to [redacted] in region.So it's actually very interesting to see that PCA's typically get built in Asia, hard drives processors and memories, The hard drives are done in Asia as well chips could be also in US but all of these high value parts will brought by the supplier into the region and only in the region will [redacted] take possession.

Interviewer: How would you describe the inventory profile?

Respondent: Okay So obviously we have A, B and C Parts X, Y and Z. What you will see actually is what you would expect A products and parts and the B products and parts. We do in high volume and typically they could be expensive or they could be rather cheap but we just do in many many units. Then we have the tail I would say, the tail is the C parts especially if you go into the potential configurations we have we actually sometimes have very unique requirements so in these C parts overlaying C with Z correct where you come to a corner. It becomes very difficult to have the part at the right place. The old days a lot of paper was used, So we had for example as [redacted] we had 20 thousand software products and these software products or parts would also include corresponding documentation so you would have documentation and you would have a DVD or CD at the time. Now obviously that has a very short lifecycle typically because as soon as you have transformation or a revision change, in the ideal case you immediately burn new CD correct and also have new documentation which refers to the latest features you have inside of the product. So that can actually be a challenge in that space and one of the points we had in our factories in region for many many years, we actually did what we call print on demand or replicate on demand or CD on demand, what we called it at the time, so maybe we had all theses flyers maybe it was a full book. The bits for the CDs/ DVDs we had them on file but we never had them on stock and we basically then printed them on demand so at the time when the server was built depending on the country and the customisation of the server and the software loaded we triggered a process in parallel which was inside of our factory to actually print and write the manual and write the manual on the CD and basically whilst doing that on demand it

basically reduced our requirement for excess and typically these things are cheap correct but the amount of them we had for variations up to 20 thousand and we have high or short life life cycle of three to six months basically that will cause quite some substantial excess because even if you just print 10 of them you will never get rid of them. So you are just scrapping them on an ongoing basis so that was a nice example i think were the very late creation of actual document and CD's helped us tackle that a lot to tackle that C part space which is that CZ space which is that very difficult one to capture.

Interviewer: How would you describe you inventory management practices and policies? Do you use advanced sophisticated analytics and technology to understand and manage your inventory?

Respondent: So do you mean to drive demand or to understand demand because that is a slight different question?

Interviewer: Both

Respondent: Yeah I think on the demand understanding I think that there is as part of our demand planning process. We have demand planners and others who will look at demand patterns in the past and see how future demand patterns profile will look like. This in my eyes is simple or simpler if you have volume based products where you do many many it's just a statistical question it becomes a very difficult piece if you have product with a very low run rate okay if you sell 10 times a quarter it is very easy to be 50% off correct? If all of a sudden you only sell 5 or 15 correct instead of 10. If you sell something 10 thousands it is very difficult to be 50% off okay because that will mean 5 thousand off okay because you see you are less dependent on a single customer buying something or not you have a smoothing effect so that's what we typically do. Do we use any sophisticated tools like big data engines or anything like that I would say no.

Interviewer: Would you describe your backend operation and your front-end customer interface is strongly or weakly integrated and what are the implications for the product supply chain?

Respondent: I would say loosely integrated. The best connection we have is in terms of understanding big deals where we basically have all our regions hold meetings with the regional sales force and accounting management team to understand big deals and promotions. The learning is as soon as we go down to country based forecast we will very much air of the upside as we are not measured or held accountable if anything does not happen we are typically concerned with hey do I have my stuff because we will not get measured on revenue sorry inventory or any other related cost thats why I say it is loosely coupled it's not really an integrated S&OP process.

Interviewer: How would you describe you ability meet the changes in industry?

Respondent: There is a couple of points, one is that obviously from a supply chain management perspective we have the products in place to fulfil the customers requirements when it comes in and at the same time do that at the lowest possible cost. Okay so then behind that you will then drive all kind of things. so understanding you demand as well will help put a supply chain in place that can cope with that. So have sufficient capacity but on the other side not have too much capacity because that also costs you something. Okay that how i would describe it at a high level.

Interviewer: How capable is your production environment of responding quickly to change?

Respondent: So if the change in the market is an uptick or down trend in demand our production gets challenged short term. If you think about our volume products maybe networking and IPG you have upside capacity but your limiting factor there will be your PCA lines because PCA lines are very expensive, they are not owned by [redacted] they are always done by our subcontractors people like: Foxconn, inventech and Jabil. And they will typically

have big ones, like IPG will have dedicated SMT lines but SMT lines are very very expensive and putting a new one in is not necessarily an easy thing you are talking about couple million dollars here. So your short term reaction is basically if it is not [redacted] SMT lines you will then basically. It is good and bad correct, if another customer is not going to get an uptick to get more out of your supplier. It could become a problem if another customer with the same supplier basically has an uptick too because then becomes an arm wrestling context with a customer vs minus customer correct. so that's one of the constraints and then typically you also see upticks on some of our commodities like memories or like hard drives there could be industry wide shortages correct and if you have that thats your negating factor you know when there was a flooding in Thailand a few years ago. Then you can see that it is a hard learning experience for the industry. Obviously as a supplier at that point in time have a facility somewhere else you could make a lot of money. You can also see right why making another hard drive facility is also not so much an easy thing because it is a multi million dollar investment. So I think this is one thing where you typically have your limits. I think where you are very flexible is our regional factories because typically we have buffer models in place to cope with our upticks. I think for[redacted]for example I think we should be able to handle up to 50% upside. Okay now obviously that is something we just try to get in there to respond to these short term upticks. If when your change in demand is really requiring, lets say the market shifts somewhere, then really the question becomes ooh do i need a new product or is really one of my products so flexible to meet the existing demand too.

Interviewer:

Respondent: I think there is a consideration which is done by R&D and marketing where you would basically analyse a market and market trends together with IEC and other research firms where you would see okay there seems to be. I will give you one example SDN is a leading technology where you basically decouple the network from the hardware. Correct and [redacted] is pushing that way very much because [redacted]v are going after CISCO. Correct so you can see that certain companies that want to attack certain market space will try drive

new market requirements to attack competitors.

Interviewer: Does the size of the organistation have an impact on the pursuit of personalisation and the ability to manage costs?

Respondent: That's a very interesting question because think about if you go to the server market because it's all about that cloud discussion correct, if you think what happened there people like amazon and facebook and google are the biggest IT customer on the planet. What they recognised wow my biggest costs, they only have two costs at the end of the day. One cost is that they have to develop the software if you think about facebook and google they don't need to do marketing correct and then the other biggest cost is the datacentre and that is huge. So they really early understood wow if that is my biggest on going cost next to my own development, i need to focus on the cost of it and that is electricity and that is the hardware. So what they start to do is they basically take cost out there and I give my example in the server side because I have seen what facebook has done they basically looked at the servers and basically stripped out what they don't need that is inside of a standard server. They basically left for example the chassis off and they just had you know the data server as a chassis they just have it sits on a shelf basically it's almost like an empty frame that could be up to 20 bucks a units.If I only have 25% basically the shell no sides no top make it a bit stronger but I can reduce it by 70% and if you think about it these guys buy a hundred thousand servers that's 50 million rights. How can I actually ensure that on one side I can protect my revenue stream so there is always a consideration you need to make, That is why other companies that start in that market don't have that baggae

B.2 Company B

Interviewer: Please state your name?

Respondent: My name is [redacted]

Interviewer And your position please?

Respondent: Operations Director for the UK subisidary of [redacted]

Interviewer: As I said before this will be a recorded interview. It will be transcribed and you will have the opportunity to redact anything that you do not like. I will start with the questions. Do you offer personalised products and services?

Respondent: Yes.

Interviewer Characterise your production and manufacturing environment? As in is it continuous production, mass production, jobbing, Batch?

Respondent: It is a batch. The card production is batch production so to get the cards made in our upstream supply chain locations of either Slovakia or Spain its very much a batch driven process. The constraint of card printing is the colour changeover process, so the technology spend is in terms of production control and production scheduling is all around sequencing of different colours through the different print machines. So that's a batch, that's a batch process. Once the cards are in the vault and you move to a different location, that then in my mind becomes another batch process but in this case we're driving our batches depending on the different service level agreements we have with different customers. We group work dependent on a day zero, day one, day two, six weekly SLA.

Interviewer What is the nature of your product variety? So as we spoke about before each of your products are personalised and once they have the individual customers details on it then totally unique. Is that the process for all the cards and services?

Respondent: We offer a range of services ranging from data handling, data enrichment, security, as well as the card production process. So we will accept for example files which will change the way the production batch is to be produced. We enrich the process during

the processing, So we have a thing called production IT operation which is very much a value add of the product itself. And we'll do IT related work prior to the actual print steps.

Interviewer How integrated is that, between the customer placing the order and the process itself?

Respondent: It is completely integrated and completely automated.

Interviewer: How would you describe the nature of the product architecture? So this question between modular versus integrated. Is the substrate and plastics and stuff and chips and stuff part of the pack before you personalise them or do have to actually manufacture how does the if your were sequencing it from a raw material point of view do you already have the raw materials here plastics here, how is the from the production cycle point of view.

Respondent: It is an assemble-to-order process for personalisation. There are a number of steps in that assembly which could be construed as print steps so we are able to put images on card for example but those cards would have been pre-printed so they have already come through a print and milling and embedding process where the chip has been put on to the cards and we will put further images onto the card, as well as the embossing and the data.

Interviewer: Is there a significant lead-time difference between the perosnlised with the images and standard?

Respondent: Yes our standard lead-time for card printing is 8 weeks, we are able to achieve day zero SLA for subsequent printing steps on the card.

Interviewer: Well you have commented on this but if you would like to add any more detail on to how you view the mode of order-fulfilment in for all your personalised cards so you said assemble to order was predominant do you have any aspects off engineer to order in any of your. Do you get involved in the milling process like for GSM for instance?

Ingterviewee: The print job is a manufacturing step, the insertion job is a manufacturing step, mail sorting is a manufacturing step, the card personalisation itself is a manufacturing step, mail sorting is a manufacturing step disguising the subsequent mail item is a batch function. In terms of the mode I don't know what you mean by the mode.

Interviewer: It is the same thing, I try to capture the whole assemble-to-order build-to-order thing in more straightforward language. It is exactly the same thing you said when you said is it either assemble-to-order, build-to-order or made to order-or-engineer to order.

Interviewer: I was just trying to establish how you would describe your whole production system?

Respondent: Ok. So on the extreme, we don't do any engineering-to-order for any of our customers our customers buy from a predefined set of available products that have already been developed. So they will chose a chip type profile, and we will then print their images on the chip card body profile.

Interviewer: On the set that you offer what is the range, for instance if you wanted to buy a pair of trainers combinatorial you may have hundreds or thousands. What are the maximum different types they can have.

Respondent: Because it is make-to-order every card print is to their design. We use a variant configurator here because of the complexity of the selectable options in terms of the production process. We calculated out recently out that to replicate out our configurator in a flat structure, we would have 400,000 combinations of variability in the production process. So for that reason the configurator is a very important part of our strategy to deliver our service and maintain the underlying master data related to the production process.

Interviewer It reduces your challenge?

Respondent: It reduces it tremendously. You could imagine having to maintain 400,000 lines that would be a tremendous over-head. Whereas now I only have to maintain each configuration once, and the configurator knows the relationship between the allowable configurations.

Interviewer And the configurator is manufactured by?

Respondent: SAP Which is a big ERP vendor and there are similar ones like oracle 11i have one in their oracle suite as well.

Interviewer: We've talked about your production environment. So the question is asking really is it capable of responding to changes in production.

Respondent: Yes!

Interviewer: And how does it do so.

Respondent: We scale for a maximum output day and we'll under capacity where demand is not received.

Interviewer: How responsive is your production facility towards changes in the market. This again your vision in terms of spends for production itemsinvestment in capital goods like you said before the HP asset and stuff like that strategy wise, how do you incorporate new technologies into your production line? For responding to market trends and stuff like that?

Respondent: In a number in a number of different ways. Our core manufacturing technologies are preselected from headquarters. In terms of responding to market demand, the product we produce is very restricted in terms of what we are able to produce. The cards and services we provide are strictly provided within certain guidelines we run under regulations that are driven under American express visa MasterCard PayPal etc. They do not give us

much leeway to work outside of the guidelines. As new products come to the market for example prepaid card is a new type of product, it has a different type of fulfilment option the rules are rewritten at that point but it is generally an industry driven set of rules and guidelines rather than a market driven set of rules and guidelines. I was just thinking about the marketing, the market responsiveness. We can enrich the offering so we can enrich the offering through lead time and of course price and of course quality, which are all important attributes. We cannot offer anything more than our day zero leadtime, because you cannot do better than that. We think we are very price competitive and our quality year on year, is very good in comparison to last year. We've come down to very high scores on our six sigma strategies.

Interviewer: Ok erm... describe the most advanced production equipment you utilise.

Respondent: Its specialist equipment for card production. So it takes a virgin card it has the IT and HSM so High security modules in it. It can unlock a chip, it can program a chip, lock a chip, test a chip, write the mag stripe, emboss all the characters on the card, colour the embossing characters on the card and then test it. It can read itself, it can print a carrier, attach the card to the carrier, collate other inserts with carrier, put it into an envelope and seal it. So its complete end to end and it's a highly specialised bit of equipment.

Interview: And is that just one bit of equipment?

Respondent: No that's an integrated platform that comprises of a printer a folder a card production machine and an inserter, all integrated into one platform.

Interviewer: Is your shop floor organised in cells?

Respondent: Cells!

Respondent: Where we have multiple platforms and different types of configurations. Different types of configuration producing the same output but in different styles

Interviewer: By different styles you mean?

Respondent: Different styles of operation. So we tackle different sizes of batches with different types of equipment.

Interviewer: How does personalisation effect your inventory profile basically how would you describe your inventory profile?

Respondent: A lot of the item we hold are considered free issue items. So that means our banks and our customers purchase those materials and provide them to us as free issue items . We provide logistics data a lot of the items we hold are held as free issue items. That means our banks and our customers purchase those materials and provide them to us as free issue items. We provide logistics data for them to make decision around restocking of those materials and we also provide rules around maximum stock holdings we would be prepared to hold – in terms of weeks or months coverage. We have our own MRP system which is based on the SAP platform and we run reorder point purchasing strategies on our own materials.

Interviewer: Is your planning based on forecast, how important is historical data in your forecasting ?

Respondent: It's probably only 60% of the picture. A large amount of the work we produce is project driven, so it is mostly to do with a reissue or a marketing activity that we would then provide for. So it's project driven logistics, so we would understand what the forecast would be for a specific campaign the materials are provisioned for that campaign the moment the campaign goes live. The underlying forecast is good for understanding standard daily type uptake. We have a daily cycle where people are losing their cards all the time, we've got a renewal cycle where cards come to the end of their life every three or four years and then we have got this marketing level where we have got campaigns which are dropping new customers into their business.

Interviewer: The planning for that is that separated as in by person? Do you have separate people responsible for the planning?

Respondent: We receive different plans from different people from different locations and we consolidate that into an overall demand picture on the available capacity.

Interviewer: How would you describe your supplier profile?

Respondent: It is a mixture of large scale printer operations and large scale card production operations.

Interviewer: Proximity wise how geographically dispersed are they to this facility?

Respondent: The majority of paper print is within the UK, all of the cards come from a mixture of Slovakia and Spain.

Interviewer: Describe how you manage your supplier relationship.

Respondent: So your priority suppliers your strategic suppliers, who you have a good close relationship with, maybe even have erm shared pallaning with.

Respondent: We do not have that type of close relationship, those relationships, because the materials are mostly free issue, those relationships are held within our customer and are stronger with our customer than they are with us. We'll do a call off of materials but the customers place their forecast and has their relationship with those suppliers more than we do. We behave like a better customer in that mode than some our customers in that mode, so we are aware of vendor management inventory in that sense for example at different Telcos. Even though it is a make to order product and we have personalised it with specific telephone numbers.

Interviewer: Interesting, ok you have sort of answered this before but it is more specific. How would you describe your fulfilment process this is in regards to do you utilise and web based platforms, data mining or recommendation engines and erm? I will ask the other part of the question later. So when you said that for instance when your customers place an order how do they place the order do they have to talk to a sales representative?

Respondent: No it is a mixture. 95% of what we produce here is based on an incoming file. We don't know the account numbers and we don't know the addresses until we are told them so that is the input to our

Interviewer: So how is that delivered?

Respondent: Overnight over a secure network...because all of our products are data driven some element of data transfer has to take place for the production to be initiated.

Interviewer: do you take any intiative to try and recommend products to customers.

Respondent: Yes we do so in terms of our speciality in this particular division we are talking about is card printing. We will do road shows to our different customers to explain the new types of inks, the new types of foils, the new types of underlays the new types of technologies available in the card printing process to give their marketing teams more of an insight and more of a scope to provide a differentiated product to their customers.

Interviewer: How would you describe your supporting logistics function, do you use different modes off transport to deliver your product?

Respondent: Do you mean inbound or outbound?

Interviewer: Both

Respondent: We are dealing with secure products and we're working out of a secure site and these bring challenges within their own right to move a secure product, you have got to imagine it is exactly the same rules as if you were moving cash. You require a secure truck, you require multiple truck people so multiple truck drivers, the team are never ever allowed to leave the truck at any time. In fact our deliveries never stop moving, they have a hot driving position one driver will move over the drivers will swap over the driver will reset the tachometer and continue to drive. The trucks are followed one truck follows another in case the cab breaks down so they can just swap the cab. So there is...

Interviewer: There is lots of redundancies

Respondent: Lots of redundancies and lots of additional costs in our supply chain model. It is very costly to move cards either by road or by air. We receive big batches, big deliveries, on a monthly or a weekly or bi-monthly basis and that is enough to supply us through the months of production.

Interviewer: and the cost of inbound is on your client and the cost of outbound is on..

Respondent: The cost of inbound is our own cost the cost of outbound is for our customers outbound postal accounts and we manage lots of different postal accounts for them. So as we print the {unknown word} on to an envelope or as we recognise a specific despatch method has gone to a specific royal mail HQ code we will register that and provide that information to the different postal services.

Interviewer: Could you describe the R&D process as you understand it for your cards?

Respondent: Yes our customers are large institutions, they work collectively along with the different schemes to establish what attributes they'd like a specific card to have so do they want it to be able to incorporate lets say a transport network mechanism or do they want it to include an additional security feature or do they want it to include additional data around transaction you know storing transaction data for example. All this types of

requests will be joined collectively be passed through the schemes and we are effectively a supplier of recognised products to the schemes. As we become aware, so these are market driven requirements, we will then go into a research and development phase we will try and identify the type of chipset we need and the type of base plastic we need and then we will try and re-engineer a product to satisfy those customers' requirements it is more of an IT development and chip development function than it is a card production function.

Interviewer: How do you mitigate against the risk of cards going missing cards just, the whole safety aspect of the cards that you spoke about before how , from a business point of view not on individual batch going out, as a company mitigate against risk of technology basically so somebody finds away to. I remember last year there was an issue with the contactless cards so for example somebody calls off a whole batch or something do you simply write it off?

Respondent: No we go through a qualification process with our product and our product becomes released to the market once it is accepted to the different schemes so we always have to get a product platform underwrittn first before we release it to the market and it is through that qualification process that we are able to underwrite the risk of that data being handled within the chip.

Interviewer: Thank you very much for answering my questions today erm that concludes the interview so I will stop there.

Respondent: Sure thank you.

B.3 Company B Second Respondent

Interviewer: Could you please describe your organisations commercial activity and the products and services you provide?

Respondent: The global activity is a company that makes secure products chiefly bank notes, banknote paper security encryption products for the Internet and chip cards for the credit and payment and sim cards for phone and applications for digital techometers. [redacted] is a UK subsidiary concerned with payment cards, what they call mobile security, chip cards and credit cards and sim cards and the division I work for called banknote processing which is a division responsible for manufacturing and servicing machines to process banknotes anything from small desktop counters to very large factory machine up to 10m long which process million notes a day or a million pounds an hour. So my job as a global technical advisor is to assist on high level technical calls and help customers solve problems so I work in the UK but I report to the management of the customer service and support services in Germany.

Interviewer: Would you describe your role as providing a personalised service to your customers?

Respondent: Yes it is because we are the manufacturer of a very specialised piece of equipment, so yes every call is specific to every customer. We are the only people capable of supporting this product, and yes every call is specific to individual customers because these machines which cost up to a million pounds or euros each can have a whole range of problems and as they are used 24 hours a day everyday in production with some very valuable commodity i.e. banknotes. Anything that goes wrong in the course of a day's operation is taken very serious?

Interviewer: Do you customise or personalise the machine itself?

Respondent: The company is in the position to do that because bank notes believe it or not vary quite a lot. Most central banks build in level 3 features into the banknote, sort of machine readable features that only the central bank know about. So most machine, because 80% of them are sold around the world, because they are modular are available in a very large range of variations of different configuration, they run at different speeds, they are

different lengths, they have different sort of output pockets and they have different sort of sensors that pickup parts in the bank not the electronic signals from the banknote added to which the software although standard throughout the range is capable of being very highly modified to detect features which may be very important in one place over another. For example in Australia you have to pickup the defaults related to the polymer notes. In the UK they have very strict conditions on the fitness of the banknotes, which is different from the standards placed on it by the ECB or the Central Reserve Bank for example.

Interviewer: Are you constrained by your ability to manufacture personalised products?

Respondent: Well there are always limits, to the range of variations that can be programmed and solved but to a certain extent [redacted] would be inclined to developing new hardware and software for customers if it was economically viable and if it had an application and could be integrated into the existing machine set.

Interviewer: To what extent is cost a limiting factor?

Respondent: Well cost is always a limiting factor and it all depends on the type of contribution a client wants to make. For example if a customer wants to produce a banknote with a feature that is highly secret and only they know about, then it may be a very expensive thing to build into the banknote. It may only add a fraction of a penny to the cost of a banknote to the manufacturer but of course that feature built into a banknote is useless unless a machine can detect it. [redacted] might have to develop a special sensor to detect that special feature. Normally these things go hand in hand, and as [redacted] manufacture and design newer banknotes very frequently whatever is designed on the banknote side will be designed on the machine side. You will also get customers who will design features into their banknotes and that customer will also produce their own sensor then they will give that to [redacted] and we will put that into the machine. So there is a certain amount of negotiation and integration that goes on between customer and supplier, that goes on between customer and supplier.

Interviewer: How would you describe the dominant product architecture and would you characterise the machines as standardised or modular?

Respondent: Well there is a range of machines, the smaller machines tend to be physically standardised although they may have variants there may be three different models capable of doing plain counting a certain amount of fitness sorting and a high degree of fitness sorting. Right down at the bottom of the range there may be a very basic machine which is physically the same for every customer but the software inside will be different depending on whether you want to process Japanese yen or whatever. The software itself would be differentiated, the larger the machine go, once you get to the medium size the sort of table top machines you get variations in the modular design of the machine, so it can be fairly short with four stackers or it can go up to 20 stackers for a situation like for example in Scotland you might need more than 20 stackers to sort out all the different note all the different denomination and for all the different issuing banks The Royal Bank of Scotland, the Clydesdale Bank, The Bank of Scotland, The bank of Jersey. If all those need to be separated then you need more stackers. So the design family is standardised so they look they same and identifiable as a brand which is an important part of the offering, the machines are modular but they try to standardise on certain range and it is the software that is mostly configurable for the customer.

Interviewer: As such, would you describe it as being mass customised or mass produced?

Respondent: The mass customised sounds exactly where we are at. We are not talking about enormous quantities they've sold a total of 20,000 Numerons. And the total number of [redacted] that were sold since 1997, so over the last 17 years, was only 1,500 machines. 1,500 machines is not generally what you would refer to as mass production. So to a certain extent those big machines are almost bespoke products. But they are made to a standardised design.

Interviewer: Would you say that manufacturing and production activity of [redacted] resemble/reflect that, so length in time from specification to manufacturing to delivery?

Respondent: Yeah, generally speaking. You're looking for the big machines on a 6-month lead time and something like half that for event he smaller machines. So they tend to be built to order.

Interviewer: You just specifically answered the question that I was going to ask, apart from the second part which is how does it compare to the industry best in class? I'm talking about the lead time that you've just described, so six months. Is that the best in class or would you say that your competitors can do it quicker?

Respondent: I don't know. It's not something that is generally commercially known or available. I mean the reality of it is that an urgent or important order for a customer can always be brought forward. And, or somebody else has to go to the back of the queue. Because of priorities. I mean the problem with building a half a million-dollar machine is that you can't, nobody can afford to have them sitting around on the shelf.

Interviewer: Describe to what extent you are involved in the engineering of the product, so do you engineer all the components or do you have suppliers and OEMs that provide you with some modular parts?

Respondent: The machine are a bit like any large complicated machine. Are system engineered, in the sense that, large parts of it are bespoke designed in-house, and then manufactured out by specialist manufacturers who are selected by tender. And then certain parts will be bought off the shelf and they might, to a certain extent, have to be customised and so on, or built to specification. So, you know, just like in a multicar will have the battery or the alternator might well be made by Loops or the injectors might be made by Bush, and the electronics may be made by Siemens, but the car is badged up as a Jaguar or a Land Rover. But then the company themselves is responsible for integrating and putting together

those parts and working them up into a working whole.

Interviewer: You did mention earlier that you don't produce that many units of your flagship items, so what role does volume and throughput play in the production economics of fulfilling your orders?

Respondent: It's long-term in the sense that you are looking at a return on investment, R&D investment. That's probably more something like five years. So that, you know, a great deal of R&D goes in. Millions of Euros are spent in developing a new product. And it only really pays off once you've sold off several hundreds of units. I mean the total market for these things is only about 2,000 machines. [redacted] has something like 80% of the global market for these big machines, so you there's not like there's ever going to be a realistically huge market for them. So, the production of machines. So the questions was?

Interviewer: What role does volume and throughput play, as in, do you rely on the throughput. Or is it you're more reliant on your service contract to balance the cost of manufacturing?

Respondent: Right, yeah. Most companies across the subsidiaries all the way around the world, the daughter organisations from head office, for bank-note processing of course make their money mostly from service, because service is an income where you are earning every year. Whereas sales can up and down and it tends to be quite cyclic. So services is where you make the year on year money. And in terms of production on the machines I don't really know enough about it. I know they guy, and have had conversation with, they guy who I know is responsible for purchasing, so I do know that it's a very responsible job in taking the sales leads, every month from the salesforce from all around the world and asking them for their confidence in how many machines they think they might sell in three months' time, six months, times, a year's time. Because he needs that for the forward planning, forward strategic planning for the production schedules. Because the factory where the parts are made, or where the machine are assembled, they want to know

how many trained people they are going to have to put in place this September. And of course if the strategic purchasing says okay in the month of September we want to place an order for twelve machines, the he's got to be, well the company's got to be fairly confident that come the end of September, they're going to be able to sell those machines. So it's quite an involved and intricate process, so obviously it has pressures coming in from all sides. Some customers wanting machines much, much quicker than normal and others customers, other subsidiaries might well find that they were hoping to sell twelve machines to one customer and the sealed, the deal falls through at the last minute, so that's what I say. So it's in terms of the averages, in terms of the supply chain, you know, you can't rely on luck and pure guess work. You know there's a lot of work that goes into strategic planning.

Interviewer: How would you describe your supplier network and your level of integration with your suppliers?

Respondent: It's getting more organised all the time. The history of the company is that everything used to be manufactured in Germany. Although, all the product lines for the different types of machines used to buy stuff from all, or have always bought stuff from off the shelf and especially made in factories here, there and everywhere. None of that was especially standardised or organised. You probably remember yourself Kevin, that they had a big programme on sourcing all of their sheet metal gear from a single supplier. So five years ago, or something like that, a tender was put out for all the work, all the machines because you found that some of the smaller machines were getting it made in [redacted]. For another machine, it was all being made in [redacted]. For another machines, it might well have made all in India. Just simply because each development project grew up on its own without reference to the other product lines. So that sort of standardisation was quite interesting, and I think that is continuing more and more, as in common with other manufactures. A lot of this stuff is being outsourced to places like[redacted]. Although, most companies like [redacted] , probably wouldn't want to publicise that too much because many, many, customers value the made in Germany badge.

Interviewer: Of course. It's like the Swiss watches. You don't have to have it all made in Switzerland.

Respondent: Yes. [Laughter]. Exactly. Made in Switzerland, in small print assembled.

Interviewer & Respondent: [Laughter].

Interviewer: What are the critical factors and decision that have enabled your success in the UK, for the UK subsidiary?

Respondent: It was breaking in the market that was dominated by our major competitor, [redacted]. Who are also a global company with a very much, same sort of profile. And specifically set up as a service company, we won a big contract with the then [redacted] to sell 16 large machines and provide a whole bunch of service engineers to service those machines. Since then, we've gone on to get more than 50% of the market. And we've done that by being well organised and well-motivated. Service industry can only really function if it is well organised and well-motivated. Any business can – I guess. But with service, people are looking for a little bit more. So, the business has grown substantially and we've tried to break into other markets, and that's been difficult, so there's been some investment decisions that haven't always come off. But, it seems we're going alright now. So I don't really know where to attribute that to, except that hard work and a willingness to satisfy the customer's requirements.

Interviewer: And would you say that's the same for the global business?

Respondent: Yeah. I think they try to be very customer focused. Although, as you know, in Germany they are, in terms of service, a little bit isolated from that, because they don't have a very large home grown local service contract. For historical reasons. And that means that head office, as I imagine a head office have, a reputation for being rather aloof and away from all the action. But I think they are making great efforts to try to bridge that divide and to try to reach out and bring the culture, the company culture out to the subsidiaries, and

bring out any experience of the subsidiaries into the centre. So I think they are making great efforts to do that and are succeeding to a certain extent.

Interviewer: I guess this is a question for [redacted], but I have to ask everybody. Describe your supply chain management focus. So are you trying to be a lean company, an agile company? Does your market require you to even be agile? Because obviously, you are bound by the constraints by the Government and bureaucracy in terms of what you can and can't do with bank notes, and stuff like that. So what is your focus? Your supply chain focus?

Respondent: What's the Supply Chain Focus? [Laughter]

Interviewer & Respondent: [Laughter].

Respondent: Talk to [redacted]. I mean since, recent. Since you left, you probably got this from [redacted], is that there's been huge downward pressure on inventory. Because of the working capital project. And the way they did it, you know and I were working on a projects to do it very carefully and to do it in a very calibrated way, so as to minimise risk to the business, and then the management was under such pressure from head office to cut those costs significantly that everything that had not moved on a site for two years was just removed from every site with no ceremony and no exceptions.

Interviewer: Wow.

Respondent: Actually, they wanted to do at a year, but [redacted] persuaded them that would be too much, too far, too quickly. So they did it for two years and reduced inventory costs enormously, so now, you have a situation where all the engineers complain that they simply don't have enough spare parts to solve problems diagnostically. You know, in the past, if you have a problem, then you could try that part, and then try that part, then try "D" and see if any of them worked, and if they didn't, rake them out and put them back on the shelf.

Now, they simply don't have those parts. So to a certain extent, on occasions, engineers had to put up with a problem until they order a spare in. And...

Interviewer: Has it had an impact on your SLA's at all?

Respondent: Some. But, not significantly enough to moan about. I mean I don't have the numbers for that, I mean the customer demand does seem to go up, in terms of they expect. If there had been impacts on the SLA, then they would have been addressed by putting certain numbers, you know, of individual spares put back on site perhaps but they are just as likely to be removed again soon after because it might just be a face saving exercise. I don't really know the details. I don't, for example know how much more we've spent on emergency couriers.

Interviewer: That was the balance that we were trying to make. All that information is pertinent to the ongoing activity, so...

Respondent: That's right. That's right.

Interviewer: They thought I was bad.so...

Respondent: [Laughter]. No they didn't think you were bad, but they, but there certainly have been many, many more emergency deliveries. And that has been expensive, but I think it was insignificantly small in compared the saving that were made by reducing the stocks. Having said that, of course, the problem was that the value, is the value. Whether that resides on the sites or back at Globe house. But I think they battered hard enough on the walls to get Munich to buy back the stuff...

Interviewer: Yeah, because you're putting more unreasonable requests on how the components were being sent back.

Respondent: Yeah, they wanted them like as completely as new and everything. So, I think to a certain extent they got some money back for that, and then they were, decide to take the leap and say, well okay maybe were not going to save any money now but the discipline will be good. And we will eventually run own those stocks because we won't need to purchase so much for Globe House. So, in the end you end up with a similar amount of problems and it just becomes even more stressful for the engineers, so I think that's what. That's my impression, of how it panned out.

Interviewer: I'm formerly going to ask this question but you've already kind of answered t. It's describe, the R&D process for your process. And who owns the R&D process, but you did mention earlier that sometimes your customers might produce the features. And then produce the features, and in a sense all you have to do is to integrate them in the machine.

Respondent: Yeah, that's not a very big part of the R&D process to be fair. Those sort of things, they will tend to be built as a black box, then they are supplied to [redacted], and then [redacted] will say right okay, you need to build that box in a particular shape, and the get it to deliver this signal. Most of the time it does, it'll be a yes or a no. Zero or a one. So integrating that is actually fairly simple. The research and development process is moving to a state where I think it's going to become less centralised. It was always the case that it was going to become les, that the head office tended to take the lion share and responsibility of all R&D, and there are certain subsidiaries, throughout, that are known as competency centres in the world. Some of the larger subsidiaries like in America and Russia and a joint venture with the people's republic of China, would have their own R&D departments. And, but whatever they developed tended to stay in their own, within their own area. And I think the company realised that could be optimised a bit more. So, I'm not sure how confidential that is actually. But the perception anyway is that R&D tends to be becoming more de-centralised, globally. But they do tend to put an enormous amount into R&D because everything about [redacted] being a security company, demands that you are ahead of the game, ahead of the competitors, ahead of the people who try and break that security. You know, gangs that try and break the counterfeit bank notes, or try to decrypt

the coding on chip cards, and on or whatever. Have to be ahead of the competitors, have to keep up with the customers and customer demands for all sorts of stuff. So the amount of R&D that goes into it is significant. I can't remember what it was, but it's certainly more than 10% of profit. Which, and I don't know how that compares to other companies. You know, probably less than pharmaceutical companies and probably more than TV companies in terms of turnover, because you are talking about a relatively small production base, but it significant. You know, it's the heart of the company, you know in the sense that [redacted] will always want to be at the cutting edge of technology for that kind of stuff.

Interviewer: How would you describe your order fulfilment process, [these are sub questions] do you utilise a web-based platform? And on the web-based platform [if it does exist] do you use any data-mining recommendation engines? And how integrated is your front-end with your back-end systems?

Respondent: Ooh. [Laughter].

Interviewer: [Laughter].

Respondent: Do you know what? I've hardly used SMS at all since you left, because it became largely a spare part management software, So although it started out (according to its name) a service management software, we very quickly found that, there was very little information, useful information that could be got out of that. You do have people working at head office collating that information and detail that's in there but it actually doesn't come to very much. So to a certain extent you have them coming to understanding that and with any luck, some of the lessons learned that will come out of the company fully integrate SAP as the replacement for SMS, which you know currently has a reputation for being, you know, as cumbersome as SMS was but, that sort of thing you've got to put up with when you are dealing with you know a hugely complicated teal-time data base. You know they're never going to make it easy, as easy to operate an Apple iPad. How well integrated the back-end is, historically, is not very good. I mean, as you know, SMS being a, you know the large

data, data-based system, was only really effective for some of the larger subsidiaries. So it was only really Munich, America and the UK actually used it. You need at the front-end, engineers with laptops. So although India was a much larger service organisation than us, without laptops, their engineers couldn't sign in, on it. Most subsidiaries use other types, I mean the in-house of systems used by Spain, was the one that some of the other smaller subsidiaries used and developed, and to a certain extent they do get [data] out of that. They know, what, you know, what their install base is, what it is doing and how hard it's working and they know much, much more now about spares usage and spares life and the mean-time between failures, than they ever did 10 years ago. When it would have all just been a cumbersome paper gathering exercise. Whereas now, all that stuff that you were involved in, and I and subsequently Mark Speakman, in terms of all that ABC-XYZ analysis, is now being done by everybody. And you could do that without the front and the back-end, you know, knowing what they are doing. So, given that, that got itself implemented with a great deal of work, I think that's looking back with as much as you can have expected out of it. 00:36:24 time stage of recording

Interviewer: Do you utilise a web-based platform [that was part of the question as well], so do your customers, when they initiate the whole purchasing either machine, or your service to develop bank note features or the bank note, do they use a web-based platform or is just conversation, an email? How…

Respondent: It's pretty much all face-to-face. A, because most of it is confidential. B, because so much of it is thoroughly bespoke, so, that if you try to have a web-interface with option one, option two, I mean you know, [redacted] do have a website but it's not a very interactive website. [redacted] are developing remote access software, so that service organisations will be able to dial in on a secure link over the internet, into machines to help resolve problems and to gather management information on performance and so on. But the idea of using a web portal for sales and service is still a relatively new concept. It's something that I know that [redacted] is looking at, and I think there's a lot of application for it across several different fields. But I doubt it's ever going to be used for part of the sales

process, because that's much more suited to Fast-moving-consumer goods, to quite a phrase that I learnt in your presence.

Interviewer: They're the devil's work [laughter].

Respondent: [Laughter].

Interviewer: How would you describe your supporting logistics function? So, do you use a mass approach, non-differentiated? Customised or is it all in the care of a third party? How do you... logistics for your inbound and outbound logistics foil for everything, BMPO?

Respondent: I wouldn't how to describe it.

Interviewer: Not that I need to know who it is, but is it like DHL, that's responsible for the inbound and outbound? Then is it your customer or is it you who's responsible for the inbound and outbound logistics?

Respondent: Oh I see! Right. Okay yeah. For the most part I think, they use DPD now for the most part. And then several small couriers for the emergency stuff. I don't know who Munich use. They did, as you probably know. Do you remember a guy called [redacted]

Interviewer: Yes. [redacted].

Respondent: [redacted] Yeah. He went to go find out if he could get a global deal with DHL and they just laughed at him.

Interviewer: [Laughter].

Respondent: [Laughter]. How much? How much stuff? We'll send a van. We'll send a man with a bucket. So, yeah. So I'm sure that most subsidiaries use a single carrier for most stuff. INTERVIEWER: It's definitely different across the world. Everyone uses different. Whoever's convenient?

Respondent: Yeah. You know the funny thing about DPD, is that suddenly you saw DPD vans everywhere on the streets. Just about the same time TNT vans disappeared. You don't know whether they all happened to be just repainted.

Interviewer: [Laughter]. I might try and find out. I don't know.

Respondent: [Laughter]. Well I certainly notice that when we use TNT, they were all over the place. You drive up and you saw TNT vans everywhere. Now you see DPD vans everywhere and you don't see TNT, and it happened about the same time. I mean, that would only be right in fair. And I'm sure they're not the same company. I'm sure it's just the way. But it would be interesting to know whether TNT made some disastrous strategic decisions, and whether DPD were in a position to suddenly take over, as in what would appear to be a UK leader. And indeed, whether they took over a large part of their infrastructure. Because we all get the same problems. You know trunking stuff involves, you know, taking stuff off a truck into a depot. And then moving it on into the trucks of course and making short journeys. And as you know, out of every 100 drivers, there will always be, you know, five of them, who are in the habit of throwing stuff. So the more stuff you, the more times you move it off a truck, and back onto a truck, the more chances are that your stuff will get lost or damaged. And that's why it's cheap.

Interviewer: Okay, almost finished. I don't know if you know the answer to this question but, could you describe the most production equipment you use?

Respondent: The advanced production equipment. Well. No, I don't really know, because we're not told 00:41:48 time of recording

Interviewer: Sorry, [inaudible word/advanced manufacturing] technology, sorry.

Respondent: Yeah, well we're not really involved in manufacturing. Cards would be, but you'll get more out of Ashly on that one.

Interviewer: To be honest, because he was talking about the cards in the production room. He told me about some big fancy piece of equipment. Yeah so...

Respondent: Yeah, each (and even that won't be too high-tech). You know, no, I don't know. Manufacturing processes? We're not a manufacturing process, we're not a manufacturer so I wouldn't really know. It's not as cutting edge, as some other stuff because the development and sales cycle is so long that a lot of stuff that comes out, even new machines, is relatively old technology. So, while the units are cutting edge, the technology in them isn't necessarily.

Interveiwer: You have answered this before, but what is the nature of your product variety? So, if you could just repeat what you said before that it's fine. 00:43:38 time on recording

Respondent: Okay, bank note processing machines. Are the commodities that [redacted] sells and while [inaudible word], companies services. So they a range of small single stacker desktop counters to great big machines that are 10 metres and a metre and a half high, which process notes at a rate of a million notes a day.

Interviewer: Okay thank you, that's fine.

Interviewer: The last question. Describe the implications of management of copyright and patent law on your activity. On your service and your production activity.

Respondent: It doesn't impinge on us directly too much. There've been a couple of examples where it has, and it largely involves American patent law. Which can be a little difficult because the US patent office has a reputation and a habit of granting patents to anybody for almost anything. And it can be so vague that one famous case, Cummings, have patented any machine that processes bank notes that has more than one output pocket. Which means that [redacted] hasn't sold the Numeron into North America since it was made. It's not that [redacted] think that it wouldn't win the court battle, because we're pretty sure that we would.

Because the way I understand it is that you can pretty much prove that it was a ridiculous thing to say that you own the exclusive patent rights on. It's a machine, for crying out loud. But US courts being what they are, it could cost you millions and millions of dollars in legal fees to actually get to the point where you've proved your case.

Interviewer: Because isn't that like one company saying that we own the patent of having a car that has four wheels?

Respondent: Yeah, it's a bit like that. But because they got in there so early, like decades ago. . . .and their lawyers will wave it in front of anybody who tries to import in, any of those kind of machines. So as far as I know, they pretty much enjoy a flat out monopoly. Which gives them a huge commercial advantage, in terms of sales and services, so anybody that did manage to challenge their patent, would still have a huge mountain to climb, you know, in terms of getting any market share. So, as they say there, you know, the view isn't worth the climb.

Interviewer: Fair enough.

Respondent: The other patent issue that I know about is header cards. You remember header cards? Did you know about the patent issue on those?

Interviewer: No. I assumed they were just barcodes, who owns. . .

Respondent: Well, no. [redacted] owns and patented a machine readable header card, for bank note processing machines that was used as a separator between deposits. And they put a patent up, and when [redacted] produced our header cards, which were of a different design and used a different technology. We used OCR, whereas they used a barcode, and they've use a barcode scanner in their machine. Whereas [redacted] used Optical Character Referencing Recognition by the cameras to read the numbers. [redacted] still threatened to take [redacted] to court. So in the end, [redacted] decided it was cheaper and more cost effective to licence the use of header cards from [redacted]. So even now, you will see in small

print on some [redacted] brochures the fact that the header card technology is licensed by a [redacted] idea. Again, I think it was an American company that had done it, but they had got it globally. [redacted] being a UK based company.

Interviewer: The patent's global?

Respondent: Yeah, so header cards. Apart from that, every now and then, I do see some correspondence about, to and from the product development, (and I do get involved sometimes) where they ask me or I ask them whether there's a patent issue, and every now and then the questions are raised but it usually comes to nothing. But, intellectual property, that sort of stuff is always there in the background. And it consists of mostly, as far as I can see, as threats.

Interviewer: Empty gestures, and power gestures.

Respondent: Yes, except of course, you don't know whether the gestures empty until it hits you in the face. [Laughter].

Interviewer: [Laughter].

Interviewer: That's actually it. Thank you very much. You actually answered a lot of them even without me having to ask them, it's always good actually.

B.4 Company C

Interviewer: For the purposes of this interview can you please state your name and position.

Respondent: I am [redacted] and I am the founder of [redacted]and [redacted] is basically two things, I make VC an investment fund 100 percent dedicated to 3d printing. imakr.com which is the retail part.[redacted] is unique in that it has a physical store and is the largest store

to my knowledge dedicated to 3d printing. There are a couple of other stores out there. They are either very small with only one or two brands represented or there is a quite large one in new york but is only dedicated to one brand its quite large but only one brand even that one is said to be a third in size in comparison to this one. There is another one in london but that one is a pop up store it is not permenant.

Interviewer: How would define your method of production?

Respondent: Well the designers that we have are shared between the imager vc and the store, so obviously they make a lot of sense here because we want the people coming into the store getting a feeling for what it is we have to offer and what it is we do. We want to expose the finest and best printing things we can do and we want to push the machines to the limit. It is not obvious if having them all on the store will make a lot of sense economically but since we do have the both activities then they make a lot of sense.

Interviewer: How much input would you allow your engineers to have with a customer? How much effort would you allow your engineers to put in and where would the dividing line for copywriter?

Respondent: That is two questions. Well we published some PR today stating that we are going to do print on demand requests. So from today ou can come and give your 3D file and we gonna print it. The fact that you bring it in means we will expedite your print first. Give you feedback and if it is good we will print that for you for a small cost. So on that part of it if your file is a STL file, Blender file, or Maya file whatever file. Having access to whatever expert designers having knowledge of each and everyone of these softwares may help. It's obviously not their main task, they are not dedicated to that, but again if needed. In fact we have done that already. In fact a gentleman came "I have this printer" I won't tell you the name but I can't get it working on my files can you guy help and he gave us the file. The file was an STL file and the file was huge, just a massive massive file. The level of detail was like probably derived from whatever movie activity where they need to a very high level of

detail, you should match the machine you have. The STL file was way more detailed than needed. So what we did is we went back to the original file and exported the file again at the right resolution and then it printed smoothly on most machines. This is an example of when it is beneficial to have those designers in house. Another one is when gentlemen come in and they are designers themselves and they want to hear about this or that and ask "hey what are you doing?" "hey you know I am doing this." It's so handy to have them here. That is one of our targets here not a retail store making business but be the flagship store for the maker community in London.

Interviewer: It's one of the reasons you chose this location, I guess?

Respondent: Yes this location and this size of shop, because if you are just selling printers you can have a shelf. Another shelf have tons of Objects and then you conduct business online and you come in you pick you go. You know we wanted to people to have space, we wanted people to come in and enjoy.

Interview: So formal training will be part of your commercial activity?

Respondent: Yes because we realise that people need that, some of them come in with no knowledge at all most of them or a lot of them just read something or watch something on youtube and we definitely recognise that if somebody where to come in and have some training for maybe 2 hours 2 and a half hours, dedicated to beginners.

So we definitely realise that if somebody comes, maybe with ketchup installed, we will install the others in the class if we need it. They come in with no knowledge at all, and we demonstrate how to create the simple object within sketch-up and how to export that in the appropriate STL format. We not only demonstrate but they try themselves and they learn how to chose the proper parameters and they leave with a printed object. They do it form the very scratch down to I have got it in my hand, and they get to leave with that for an affordable ridiculous price. There are chances that from that they are going to buy a machine. We may have a situation where if you buy a machine, then you get the training or

if you if buy the training at the end of the training you get a voucher valid for maybe one week. If you make a commitment to buy the machine in the next 7 days then the training is redeemable. So that is something we are working and you can expect that raining is currently going to open late may, late June. We are also looking at the same thing but for expert people. We recognise that there is an expertise specific to 3d printing we have a couple of designers, they are experts in a specific software, the guy has been using blender for year he has a degree with blender, he is a PhD in blender but he has always been using blender for rendering so he can make beautiful renders, using light and thing which do not apply to 3d printing. We will teach them through more expert courses specific skills like size, angles and support. The good thing is again with our designers in house, we cover the wide range of software come in and I have got one engineer at least as good as you are.

Interviewer: How do you help people select the right machine?

Respondent: Well that depends on what you plan on printing with it he target is that you come in with no knowledge at all and you bring your laptop with something like sketch up you know. We demonstrate how to make the simple object within sketch up, how do you export that with the appropriate STL format. They practice, they practice and leave with a printed object.From that we hope that they are hoping to purchase a machine. Obviously we are going to have a deal where if you buy a machine the training is included. We also have if you buy the training first and at the end of the training voucher you get to redeem against a purchase within some days. We are also hoping to cater towards people who are specialists in one specific software. Different machine mean different specifications. Differentness machines have different uses it is not dependent on what software you are proficient in. If you are doing jewellery, you do want precision and detail, if you are an architect then you probably want to make larger pieces because you want to make models for competitions and things. Perhaps you are interested in using a machine that can deal with a couple of colors, running white transparent and PVA for the support, polycarbonate for the windows and you have a beautiful looking model. The machine is bigger larger probably more expensive but it fits your needs. Imakr is all about helping you guys come into 3d printing properly.

Interviewer: How much time would you invest on a customer?

Respondent: However long it takes?

Interviewer: Really, well the economics of this and the time?

Respondent: Well you are definitely right saying this and we have not yet calculated this. Some customers have done their research before they come in, they have been googling etc. The only thing they are bothered with is the delay. When you go to a manufacturers website and you want to buy a machine you cannot always buy a machine you may have a 4-8 week delivery. If you come in store you have a 0 lead-time for the product. If you are not in store you can have same day delivery in London or next day in Europe.

Interviewer: Do you use third party logistics?

Respondent:

yes we use third party logistics providers?

Interviewer: Do you use inventory management systems?

Respondent: Yes we are looking into best filament and best machines and sourcing. There are two important things we have to consider when sourcing, One is the cost and the other is the technical functionalities ABS and PLA are very good but you probably want to have more colors. You know about the glowing in the dark materials and there are the new materials like rubber type filaments. So we are looking into a number of promising.

Interviewer: Do you have a supplier network that you are actively maintaining?

Respondent: We contact the manufacturer to make sure t they are reliable as of the time delivery and quantity just incase their product will be successful with us, we don't want to be stocked too quickly. We do not use any specific software or system or technology, it's is still early days for this technology.

Interviewer: What is the most advanced technology you are using?

Respondent: Well if you think about it from a cost perspective then the most expensive printer is the Quebec trial. It's is rebranded by 3d systems is the world-wide leader in 3d printing. They make consumer grade machines so there is the cube

Interviewer: What is the nature of the product architecture?

Respondent: The products are all unique in that they are one offs for the customer if they are using this service.

Interviewer: What are the unique considerations for building a personalization focused business?

Respondent: Well the other participants can significantly influence the cost of your operations. Which companies will be around now and which will be around in the future. This consideration has implications for what to purchase, who to deal with etc.

B.5 Company D

Interviewer: Please state your name and position.

Respondent: My name is [redacted] and I am the business unit director of [redacted] which is a business unit of the larger company [redacted].

Interviewer: Do you offer Personalised products and services?

Respondent: Well definitely as something unique most of the products we print for people are one off prints for people who make something and people who we make a 3D print of these designs. Is this customisation, not completely I would say in my opinion customisation is when you have something existing that you adapt to your tastes or to your needs. So some of the products we provide are customised but a majority of the work we do are just unique products made by individuals.

Interviewer How would you characterise your manufacturing and production environment? Would you consider yourself continuous production or mass production? Do you get involved at the fabrication stage?

Respondent: Yeah as a matter of fact we print on many different types of machine. So they are all located in other rooms because each technology has its own requirements of the conditions of that room; air temperature, humidity and things like that. So it is not one big space where everything is located in, the technology doesn't allow for that unless you are only producing one technology and then you don't have that problem. And then everything needs to go to other locations where parts get finished or where assemblies are made and from that division it goes to shipment where we can have the white labelling, for sending it to the customer that ordered it and batch production is also done for the customised goods for instance, if we are talking phone covers, we gather all the phone covers in one production batch, to optimise the load of the machine and we print all individualised phone covers it is one technique and then it goes to that one shipping department.

Interviewer: How do you treat your outbound logistics, do you consolidate loads or expedite as and when orders are ready?

Respondent: Most of the time the covers are all... most of them are white label meaning that the company order them the company gathers their orders and send the orders as a batch to [redacted] . [redacted] then send it to the individual people who ordered it not to the company who ordered it.

Interviewer: Do you design products for market by getting the specification of newly released products?

Respondent: We are a 3d printer that is our strength. Our strength is not in designing something for this you have the billions of designers all around the world who can do a much better job of that around the world. We try to stay to our core strength and hat is making good 3d prints.

Interviewer: How would describe the nature of your product architecture and how would you describe your products characteristics?

Respondent: Yeah, for some parts, well some print we have to assemble we would source parts from elsewhere for instance if we sell a lamp okay the light bulb of course is something we will have to get from elsewhere the electrical wiring its also normal you don't print these type of things or the switch, these are all components which we have to assemble. On the other hand we do make functional parts which are kind of assemblies but where the components are printed at the same time together with the rest of the parts. The functionality is printed with the part for instance, if you have a box with a lid you can print what we call a living hinge So that there is a connection element with the lid and the box. So that you can open and close after the print. We have done very nice stools which are foldable chairs which can connect that make it foldable are part of the printing process. It requires some attention and some skills when you are printing the product people do not think about this always.

Interviewer: How would you characterise your production environment?

Respondent: Well I think we are quite flexible because we very rarely print something twice so we have to change constantly. We do not have a real setup of standard goods that we move through our warehouse and through our production facility. So that gives us also the possibility of changing everything always when needed. We are no production company.

If you have to print or to make millions of the same product a day then yeah you are bound by the restrictions of that product, But because we even don't know what the product of the day will be so we have to adapt constantly.

Interviewer: How do you manage to turn a profit? I assume this business is profitable [laughter]

Respondent: That is because we have already been in the business for 23 years now. So it's quite a lot of experience and in the beginning of [redacted] I am not talking [redacted] I am talking materials we also had to look at how we could manage this and how we could become profitable. It is trying and error and after those years you know what you can and cannot do.

Interviewer: So would you say that the success of [redacted] was contingent on the parent company?

Respondent: Absolutely if you had to do this with [redacted] on its own life would be much more difficult. We had suddenly access to 60 machines it was the same machines that car bumpers are printed on or parts or parts of one of the new navigation tools. So all the tools are in use for industrial and medical applications we can simply use them as well. If you have to start a business and start buying these machines then the situation would be completely different.

Interviewer: Describe the most advanced production equipment you utilise?

Respondent: What are the most developed machines we have Well I would say these are the [redacted] which were developed in house. Which are over 2m in length meaning, we can produce large products without having to cut them in several places and the spread them over several machines and then assemble them again. This has really given us a lot of advantage in the 3d printing world and it is also a benefit it also a benefit that we don't want to share with the others. We don't sell these machines we use them in house to

provide the service that we want to give but we are not going to sell these. They also are fantastic they do what they have o do but they do not look fancy [laugh] they do what they are meant to do. We are not a machine producer, a machine producer would put a nice cover around them and put a nice brand on it. For us these are purely technical machines doing their thing.

Interviewer: Describe your supplier profile. How geographically dispersed are they?

Respondent: In Europe you can get everything everywhere, several of our companies are American suppliers but they have a European base. Europe is small and in a day you can have Everything close by. Interviewer How would you describe your inventory profile? Interviewee We try not to stock to many raw materials, there is always an estimation of what we think we would use. I would try to keep that amount available but we don't try and keep a large number of materials and by materials I mean nylon powders or acrylic resins or ABS granulate. That is a material that we use and that we have a limited amount of stock. But no huge warehouse full of stock.

Interviewer: How would you describe your order-fulfilment process? Does it utilise a web based platform, data mining, recommendation engine.

Respondent: Sorry do we use data mining to...?

Interviewer: I know that you have a web presence and that is how you customers communicate with you but I was wondering whether you use their online behaviour to analyse trends and understand them so you can solicit more business from you customers? Interviewee Well we use the standard analytics tools so see where the customers come from where they go to and understand how they navigate on the page etc but that's standard in the layout of or website. Do we solicit our customers? we have a community manager and that person tries as much as possible to be in contact with our customers and our contacts and now and again we also do or she does all sorts of surveys however it is not like we have a team's

sitting here constantly doing structured marketfing research, that is not something that we do.

Interviewer: How integrated is your front end and backend system?

Respondent: Very much because we developed it all in house.

Interviewer: Describe you supply chain management focus is it lean or agile?

Respondent: Its leans and its agile of course but that is also the nature of the business we can do this we can do this I mean as a 3d printer this is possible I think most of the 3d printers can act in the ay that we do its just the nature of the technology. Interviewer What is focus of you manufacturing and marketing strategy?

Respondent: It is all heavily related to the technology. There are a lot of players trying to enter the business nowadays as the business 3d printing is a booming business. But many get stuck because of the technology also the ones that make the most noise saying, we are entering the market well after a very short time they need technology. It might seem very easy print something but as I said to you we have conditioned rooms for the different technologies and there is such a big influence of where these machines are located to have nice prints. That means that you cannot put them in one or another supermarket and think that the perfect products will roll out. You can put these printers at home and you can put these printers in a supermarket but then you get what comes out. It is fun but it is no business product absolutely not.

Interviewer: Thank you for participating

Respondent: You are very welcome. Next time we know you have to put on the headset Interviewer [Laughter] yes that would help. thank you again and have a nice day

Respondent: Have a nice day bye.

C. Naive Bayes Classifier

C.0.1 NBC Application

C.0.1.1 Requirements and Overview

Implementing an NBC requires a capable programming language of which there are several to choose from. Some langauages such as Pyhton even provide a sentiment analysis package in this case the Natural Language Processing Tool Kit (NLTK). Ultimately time constraints and profficiency in a langauge were contranining factors on the choice.

Initially Visual Basic for Applications (VBA) was employed to test the validity of making a NBC. The language although capable is not a true object orientated languge due to the omission of Object inheritance. The language is part of Windows office applications and was employed in Excel because of the spreadsheet capabilities that are useful. In the initial application the main constraint became the single threadedgeneral.

C.0.1.2 Implementing NBC

The NBC application was implemented twice. The first implemetation was an application based on Microsofts Excel using visual basic for applications (VBA). Figure C.1 illustrates the main application interface. details the code required for the functional elements described in figure C.3

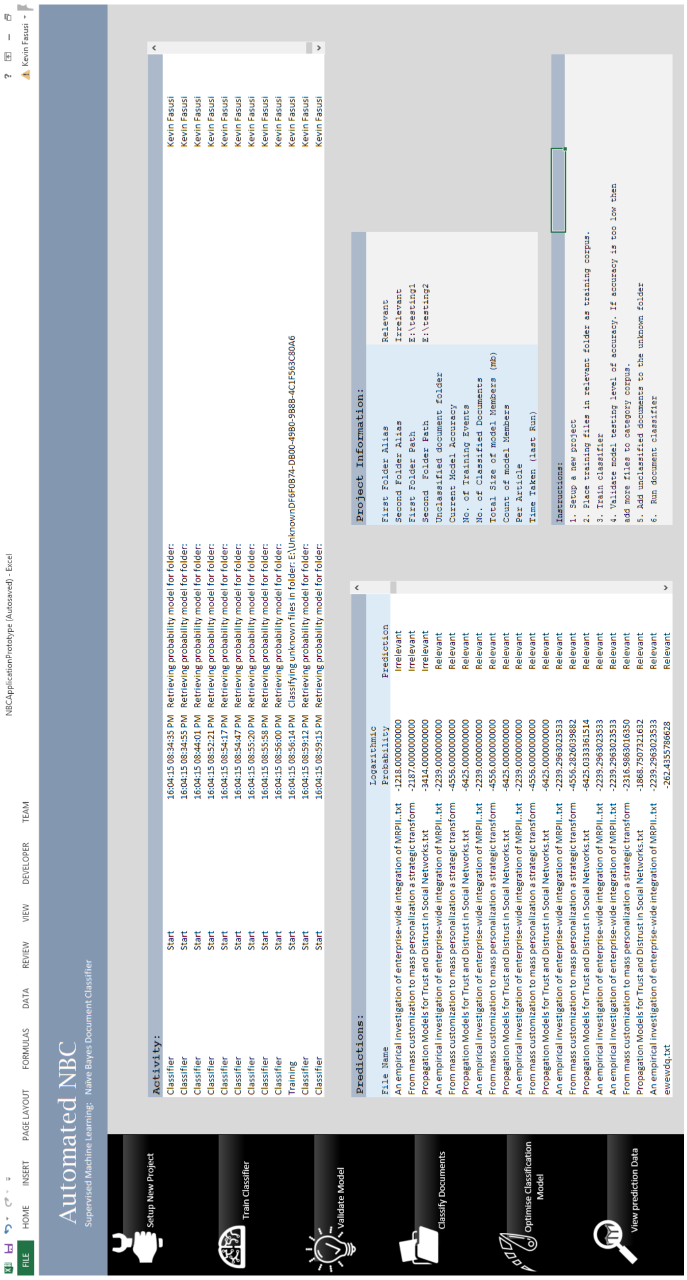


Figure C.1: Naive Bayes Classifier Application(VBA)

The process was as follows:

Create a new project, creating folders to hold the abstracts of the journals that have been manually classified.

- fill each folder with manually classifed text as training corpus.
- train classifier
- validate model
- classify unknown abstracts.

The process is straight forward and provided satisfactory results in all areneas except speed. Modern computer processing unit (CPU) architecture provides multiple cores. The increase in core count is so ubiquitous that it is uncommon to find a consumer grade computer without a 64bit multi-core processor. The multi-core architecture can accomodate multiple concurrent processes, if an application is written to take advantage of this capability. Excel is a single threaded application and as such does not take advantage of multithreading. A more mature development framework wuld be necessary to build such an application. One was a available in .net framework, VB.net and C# are both .net languages that utilise the .net framework and are capable of multithrading. However using this platform means forgoing the spreadsheet presentation layer afforded by excel and instead use an alternative presentation layer framework. Windows presentation framework (WPF) as of the time of development was the standard method of providing a graphical user interface (GUI). Alternatives such as windows forms exist but this technology is being deprecated (coming to the end of it's life).

The choice between VB.net and C# was a straighforward decision. Since the preliminary application had been written in VBA, the quickest option to port the application from VBA was to use VB.net. In some circles the assumption is that C# is a superior programming language to VB.net. This is a vestige of the old perception of visual basic (VB) and visual basic for applictaions (VBA), which are not true object orientated languages (OOP). VB.net however is a fully realised OOP language and in fact compiles to the same intermediate

language (IL) as C#. This means that there is almost a trivial difference between the two languages at compile time and the only real difference is in the syntax during the coding of the application. That being said C# is the more popular language used in industry and as such has more prolific support, extentions and portability. For an application that is only required to perform for the purposes of this immediate thesis, these slight differences make little material difference and subsquently speed of development is the main criteria for the selection of VB.net.

Figure C.2 show a screenshot of the imporved application with multithreading. Appendix has the performace details outlining the imporvement over the intial implementation.

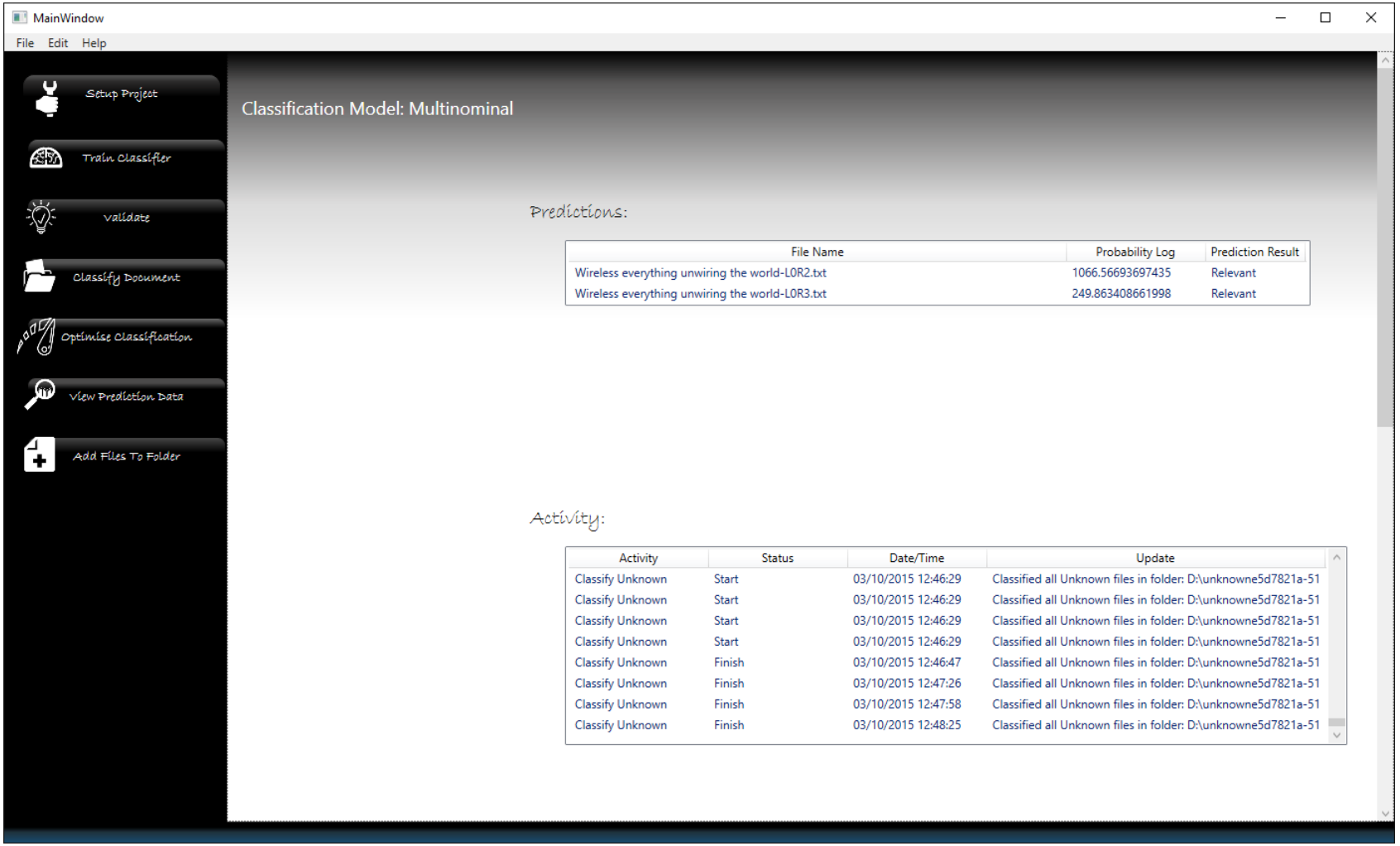


Figure C.2: Screenshot of NBC Literature Review Classifier

application

C.0.2 Supervised Document Classification

C.0.2.1 Multinominal Naive Bayes Classification

A naïve bayes classificlation software was developed to assist in sorting of journal articles into relevant and irrelevant classifications. The implementaion of this application is detailed below, however a detailed explantation of the internals are to be found in Apppendix as they are not deemed the core of this research. Before explaining the application and its outputs, it is necessary to explain what naive bayes classification (NBC) is and why it was an appropriate tools to aid in the task of classifying documents.

C.0.2.2 What is Multinominal Naive Bayes Classification?

Multinominal Naive Bayes Classification (MNBC) is a form of Machine Learning (ML) and Artificial Intelligence (AI) (Barber, 2012). ML is the use of a computer (machine) to extract an algorithm for evaluating unknown data. The algorithm generalises from known data, to create a model that represents a process. In this research the process that requires representation is the exclusion criteria and the classification of articles as relevant or Irrelevant. An algorithm can be trained to discern between the aformentioned classes objectively and consistently. This process can be automated and orders of magnitude faster than the manual alternative.

In this research, MNBC is used to builds probablistic models for two mutually exclusive classes for relevant and irrelevant journal articles. The models use the logarithmic proabilities based on the frequency of the a word appearance in each class. Each class is built using a selection of preclassified articles retrieved using the manual exclusion criteria discussed in .

Articles preclassified as relevent or irrelevent are tokenised resulting a *bag or words* representing $A \neg B$ where. A Naive Bayes model for each class specifies a distribution of the number of occurrences $p(x_i|c)$, where x_i is the frequency count of the number of times

$word_i$ appears in documents of type c (Barber, 2012). The model is then used to predict the class of unknown documents. Unknown documents are compared against each models to ascertain the probability of the document fitting into either class. MNBC is a popular machine learning method despite unrealistically assuming all the words used are independent (Kim *et al.*, 2006).

Naive Bavyes Calssification (NBC) has several forms, however the most popular is the MNBC (Kim *et al.*, 2006), as such for the rest of this thesis the MNBC will be refered to as the NBC.

C.0.2.3 Why was Naive Bayes Classification Necessary?

Manually applying exclusion criteria to thousands of articles is a slow and cumbersome process. A prohibitive amount of time would be required to appraise the relevance of all the papers returned by the search strings used to interrogate the journal databases. A structured literature review is required to be exhuastive, implying coverage of all available and accessible literature relevant to the field. Therefore implicitly all pertinent literature, has been appraised and either included as part of the corpus or excluded for specific and consistent reasons. The use of the naive bayes classifier adds a systematic and consistent method of discerning between relevant and irrelevant articles. The details of the classification process and how the model was trained and deployed is discussed next.

C.0.2.4 Training set

Training the classifier required a set of articles retrieved using the manual exclusion criteria. For each search 100 articles were read and classified as relevant or irrelevant. The results for compiling the training set are shown below. A list of the publications that comprised each training set are listed in appendix xx. These articles were used as the training set for

C.0.2.5 Feature Extraction

The feature extraction process involved:

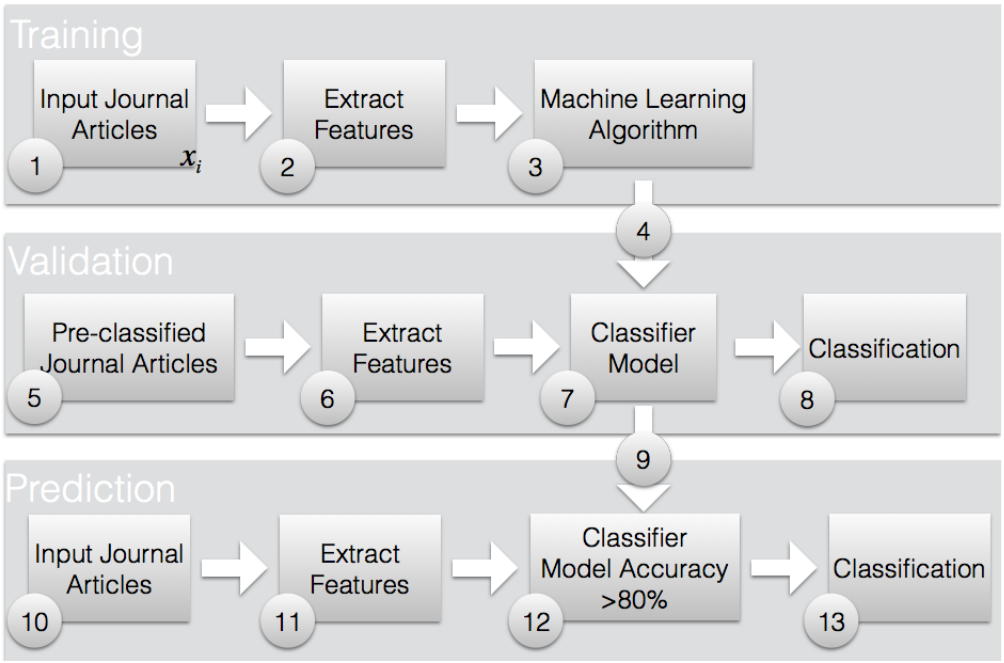


Figure C.3: Summary of Multinominal Naive Bayes Classification

Token	Count	Normalised Count	Probability	Logarithmic Probability
winter	1	2	0.0002414001	0.0001206928|
production	47	48	0.0057936029	3.8501501698
operations	45	46	0.0055522028	3.806665172

Table C.1: Example model output

1. Removing extraneous punctuation from each document.
2. Chunking the document into sentences.
3. Tokenising the sentences splitting sentences into words (tokens).
4. Counting the unique tokens and calculating the probabilities of their occurrence.

The most common way to tackle the problem of deciding which class (relevant or irrelvant) a document belongs to is by using a *bag of words model* (Foreman, 2013). A bag of words converts a documents into a collection of unordered words.

C.0.2.6 Tonkensing Text and Removing Punctuation

Removing tokens from a document creates

$$p(x,c) = p(c)\prod_{i=0}^{D} p(x_i|c)$$

For example the following extract from an abstract:

> "Recent approaches to text classification have used two different first-order probabilistic models for classification.."(**?**)

can be represented as a collection of words or tokens{"Recent","approaches","to","text"...}. Each word in the bag of words extracted from the corpus is a feature variable $(x_1, x_2, x_3 \ldots x_n)$. The

Table C.1 is an example of the output generated by the feature extraction process.

D. Transcript Interview Protocol

D.1 Interview Agenda: Exploring order-fulfilment and supply chain design for mass personalised products and services.

This interview agenda is designed to be answered by senior management in organisation's that provide personalized products and services. The interview will be recorded and transcribed. The data collected will be held securely and confidentially; no individual participant will be identified. Data will be used for academic research and academic publications.

The interview agenda is divided into 2 parts both comprise the comprehensive agenda and are qualitative in nature. The questionnaire aims to address the following issues:

- To describe mass personalisation as a set of supply chain and order-fulfilment process and differentiate between customisation and personalisation.
- To identify the implications of the mass personalisation of products and services, for the supply chain and order-fulfilment.

D.2 Interview Agenda

Company Name:	
Company Address:	
Respondents Name:	
Position:	

D.2.1 Section A – Manufacturing Strategy, Information systems, Order-fulfilment:

1. Describe your organisations commercial activity and the services and products it provides?

2. Explain the dominant characteristics of your products architecture (integrated or modular)?

3. Explain the lead-time for fulfilling an order and the specificity of the product architecture?

4. Explain your inbound and outbound logistics (Mass approach non-differentiated, customised, care of a third party)?

5. To what extent you are involved in the engineering of products that you fulfill orders for?

6. Describe you supplier network and your level of integration.

7. Explain the critical strategic decisions that you have operationalised to achieve personalisation?

8. Explain the implications of variations in volume and throughput for you production economics and ability to fulfill orders?

9. Describe your supply chain management focus (lean or agile)?

10. How would you describe your order-fulfilment process?

    (a) Does it utilise a web based platform, data mining, recommendation engine?

    (b) How integrated is your front end and backend systems?

11. Explain your strategy for utilising advanced manufacturing equipment?

D.2.2 Section B – Mass personalisation, Mass customisation:

1. How would you describe the dominant mode of production for your flagship product? Is it mass produced, mass customised or mass personalised? Please explain your reason for your choice.

2. Explain the extremity of configuration/personalisation possible for the most personalised product you offer.

3. Explain your companies capability of providing personalised products?

4. Explain your mode of order-fulfilment (e.g. engineer-to-order, make-to-stock, etc.)?

E. Themes and Descriptions

Category/Theme	Description
ETO Description	Statements and claims defining engineer-to-order.
Mass Personalisation	Statements and claims defining Mass Personalisation
Postponement	Statements describing Form or logistics postponement.
Strategy	Statement about operations, logistics and supply chain strategy.
Supply Chain Structure	Statements and claims about supply chain typology, topology and geography
Flexibility	Statements or claims regarding any compnent of the supply chain and flexibility.
Time Compression	Statements or claims regarding the shortening of lead-times or the contraction of the supply chain.

Table E.1: Themes and Descriptions

Category/Theme	Description
Supply Chain Integration	Statements and claims discussing the interface between supply chain components.
Information Management	Statements discussing the intergration of ERP and or MRP to facilitate personalisation.
Leagile	Statements or claims about the application of Leagility in the supply chain
Cost efficiency	Statements discussing cost: reduction, efficiency etc
Mass Customisation Definition	Statements defining mass customisation and constraints.
Product Design	Statements about product architecture
Manufacturing	Statements about advance manufacturing technologies, manufacturing systems and general manufacturing technology

Table E.2: Themes and Descriptions (continued)

F. Search Strings

Search	Search Strings
1	((Engineer-to-order) OR (ETO)) AND ((“flexible manufactur*”) AND(“supply chain design*”) OR (“supply chain strate*”) OR (“supply chain architectur*”) OR (“supply chain manage*”) OR (“supply chain plan*”) OR (SCM) OR (SCS) OR (“supply chain manag*”) OR (“supply chain typolog*”) OR (“supply chain classi*”) OR (“Supply chain taxonom*”))
2	((Engineer-to-order) OR (ETO)) AND (“flexible manufactur*”) AND (“mass personali*”)
3	((Engineer-to-order) OR (ETO)) AND (flexible manufactur*) AND ((mass customi*) OR (customer co-design*) OR (customer co-creation*))
4	((ETO) OR (engineer-to-order)) AND (flexible manufactur*) AND (personali*)
5	((ETO) OR (engineer-to-order*)) AND ((supply chain design*) OR (supply chain strate*) OR (supply chain architectur*) OR (supply chain manage*) OR (supply chain plan*) OR (SCM) OR (SCS) OR (supply chain manag*))AND ((mass customi*) OR (customer co-design*) OR (customer co-creation*))

Table F.1: Results Literature Search

Search	Search Strings
6	((ETO) OR (engineer-to-order*)) AND ((product develop*) OR (product design*) OR (product engineer*) OR (product architecture*)) AND ((supply chain design*) OR (supply chain strate*) OR (supply chain architectur*) OR (supply chain manage*) OR (supply chain plan*) OR (SCM) OR (SCS) OR (supply chain manag*))
7	((ETO) OR (engineer-to-order*)) AND ((product develop*) OR (product design*) OR (product engineer*) OR (product architecture*)) AND ((mass customi*) OR (customer co-design*) OR (customer co-creation*))
8	((ETO) OR (engineer-to-order*)) AND ((product develop*) OR (product design*) OR (product engineer*) OR (product architecture*) AND (flexible manufactur*))
9	(("3D print*") OR ("additive manufactur*") OR (fused deposition modelling) OR (serioligraphy) OR ("Rapid manufactur*")) AND (("supply chain design*") OR ("supply chain strate*") OR (supply chain architectur*) OR ("supply chain manage*") OR ("supply chain plan*") OR (SCM) OR (SCS) OR ("supply chain manag*"))
10	(("business strateg*"))AND ((“supply chain design*”) OR (“supply chain strate*”) OR (“supply chain architectur*”) OR (“supply chain manage*”) OR (“supply chain plan*”) OR (SCM) OR (SCS) OR (“supply chain manag*”) OR (“supply chain typolog*”) OR (“supply chain classi*”) OR (“Supply chain taxonom*”)) AND ((Engineer-to-order) OR (ETO))
11	Branching

Table F.2: Literature Search Results (continued)

G. Journal Database

First create a search like in Figure by selecting *add new search*

Selecting the coding *content button* in the navigation panel illustrated in figure G.3 navigates to the form for reviewing journal papers (*Review Journal Paper* button) also illustrated in Figure G.3. Figure G.2 illustrates the form for adding codes to database for content higlighted in an article. The process simply requires browsing folder directory for the copy of the article, higlighting the section of text from the article on the right hand side of the form and entering this data into the database by selecting the log claim form and fiilling in the details on the right. This is an automated data capture form. The database is populated as shown in Figure G.2. The finer details for using the database application are explained in Appendix ...

Figure G.1: Adding New Search

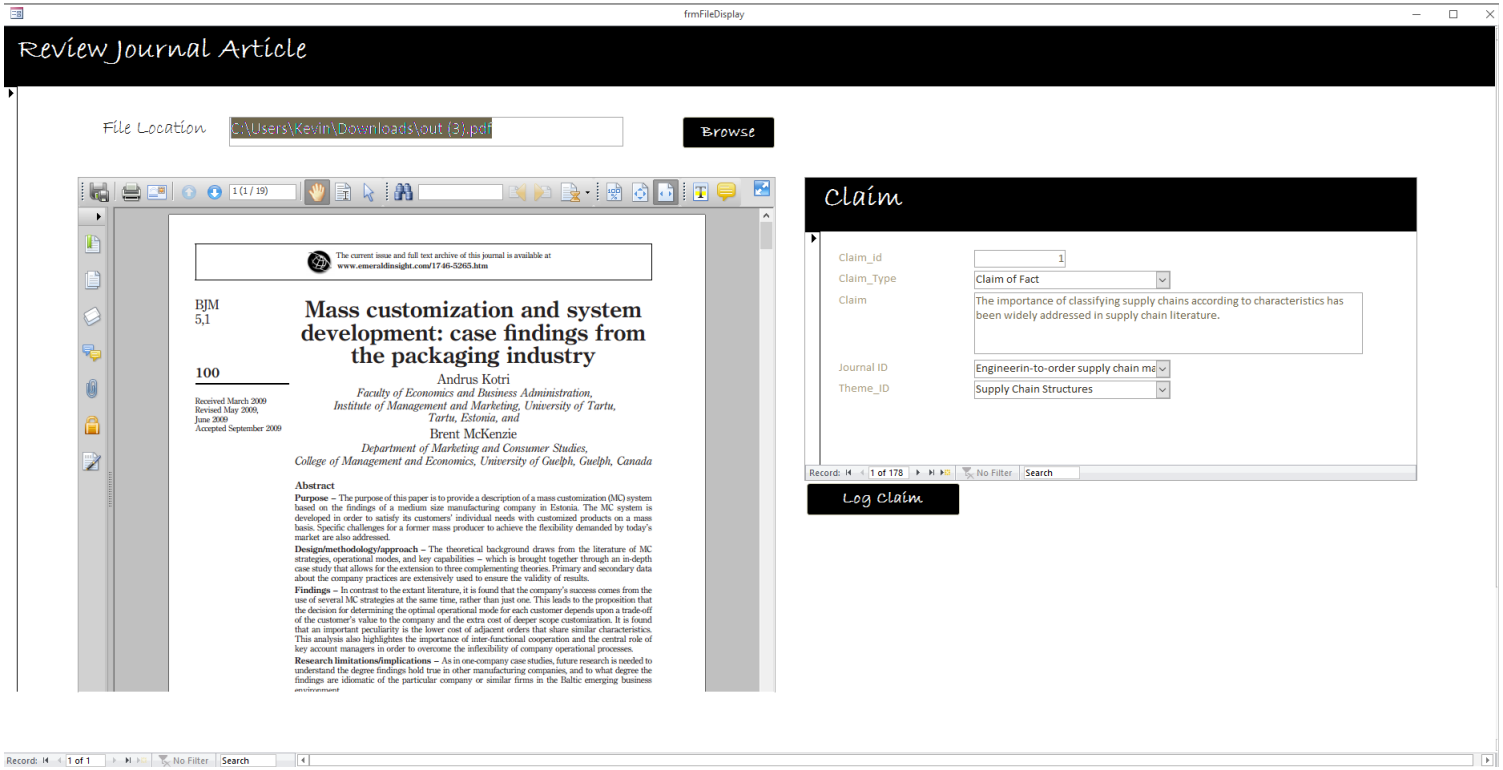


Figure G.2: Reviewing Journal Aricle

Figure G.3.

The referential integrity enforced by this system allows for later querying of the database for similar themes and claims by category across publications. This facility asissts the write up process by providing a filter allowing for the comparison between themes across the literature and the field data. The data is then held the claim table as illustrated in Figure G.4.

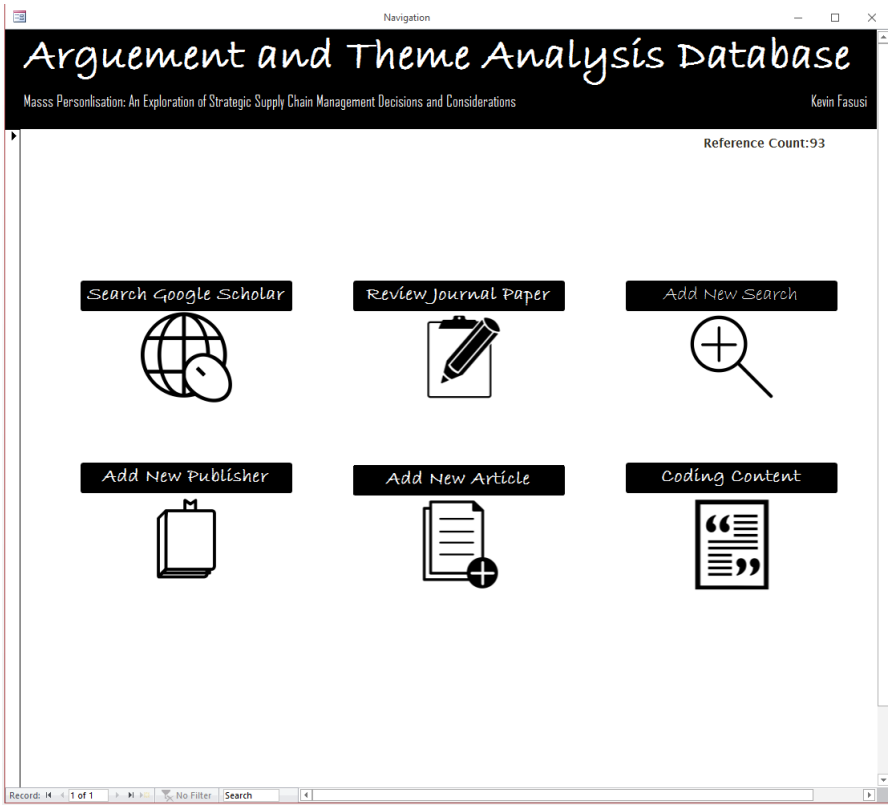
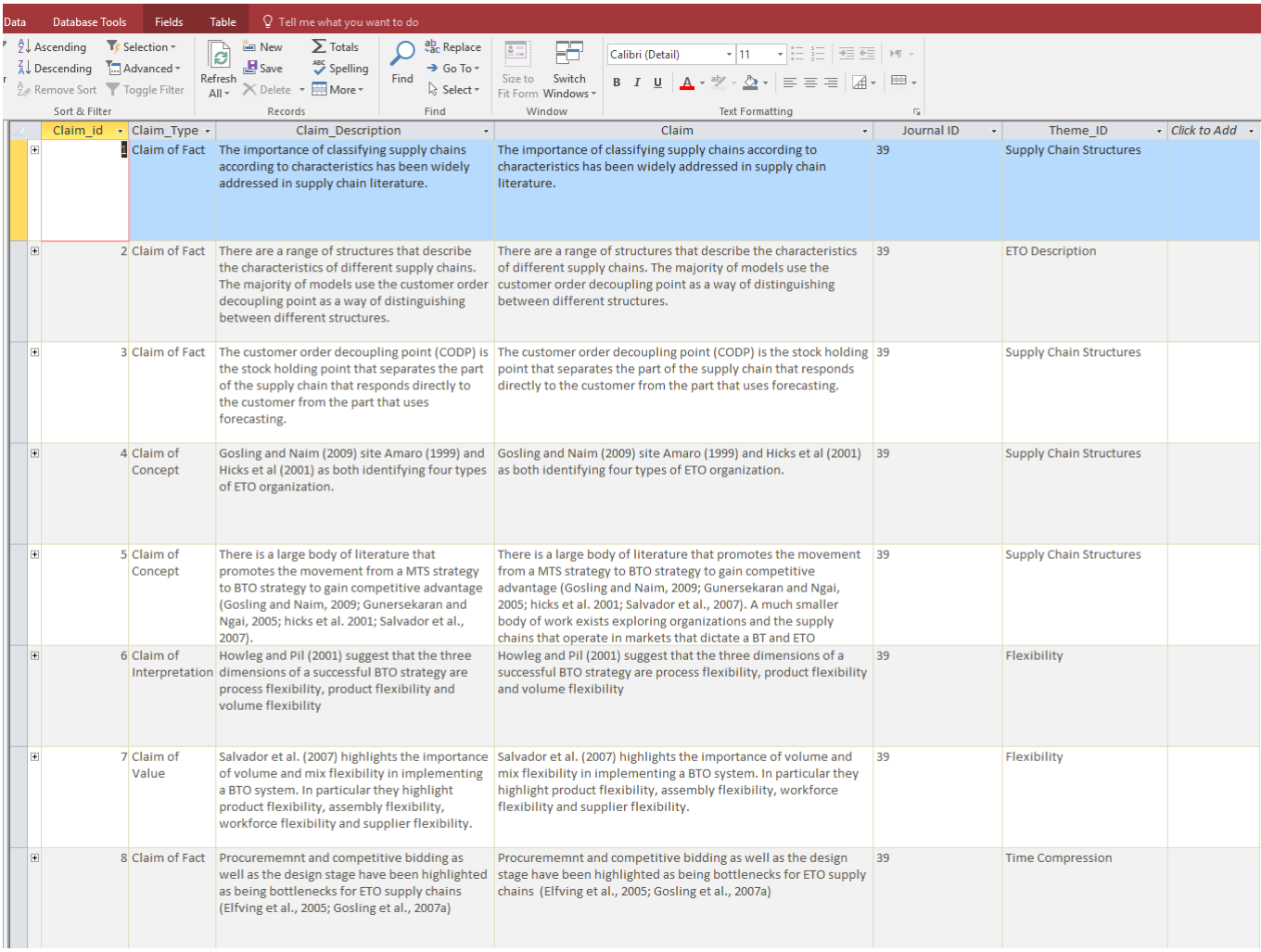


Figure G.3: Content Analysis Database



Claim_id	Claim_Type	Claim_Description	Claim	Journal ID	Theme_ID	Click to Add
1	Claim of Fact	The importance of classifying supply chains according to characteristics has been widely addressed in supply chain literature.	The importance of classifying supply chains according to characteristics has been widely addressed in supply chain literature.	39	Supply Chain Structures	
2	Claim of Fact	There are a range of structures that describe the characteristics of different supply chains. The majority of models use the customer order decoupling point as a way of distinguishing between different structures.	There are a range of structures that describe the characteristics of different supply chains. The majority of models use the customer order decoupling point as a way of distinguishing between different structures.	39	ETO Description	
3	Claim of Fact	The customer order decoupling point (CODP) is the stock holding point that separates the part of the supply chain that responds directly to the customer from the part that uses forecasting.	The customer order decoupling point (CODP) is the stock holding point that separates the part of the supply chain that responds directly to the customer from the part that uses forecasting.	39	Supply Chain Structures	
4	Claim of Concept	Gosling and Naim (2009) site Amaro (1999) and Hicks et al (2001) as both identifying four types of ETO organization.	Gosling and Naim (2009) site Amaro (1999) and Hicks et al (2001) as both identifying four types of ETO organization.	39	Supply Chain Structures	
5	Claim of Concept	There is a large body of literature that promotes the movement from a MTS strategy to BTO strategy to gain competitive advantage (Gosling and Naim, 2009; Gunersekaran and Ngai, 2005; hicks et al. 2001; Salvador et al., 2007).	There is a large body of literature that promotes the movement from a MTS strategy to BTO strategy to gain competitive advantage (Gosling and Naim, 2009; Gunersekaran and Ngai, 2005; hicks et al. 2001; Salvador et al., 2007). A much smaller body of work exists exploring organizations and the supply chains that operate in markets that dictate a BT and ETO	39	Supply Chain Structures	
6	Claim of Interpretation	Howleg and Pil (2001) suggest that the three dimensions of a successful BTO strategy are process flexibility, product flexibility and volume flexibility	Howleg and Pil (2001) suggest that the three dimensions of a successful BTO strategy are process flexibility, product flexibility and volume flexibility	39	Flexibility	
7	Claim of Value	Salvador et al. (2007) highlights the importance of volume and mix flexibility in implementing a BTO system. In particular they highlight product flexibility, assembly flexibility, workforce flexibility and supplier flexibility.	Salvador et al. (2007) highlights the importance of volume and mix flexibility in implementing a BTO system. In particular they highlight product flexibility, assembly flexibility, workforce flexibility and supplier flexibility.	39	Flexibility	
8	Claim of Fact	Procurememnt and competitive bidding as well as the design stage have been highlighted as being bottlenecks for ETO supply chains (Elfving et al., 2005; Gosling et al., 2007a)	Procurememnt and competitive bidding as well as the design stage have been highlighted as being bottlenecks for ETO supply chains (Elfving et al., 2005; Gosling et al., 2007a)	39	Time Compression	

Figure G.4: Claim Table