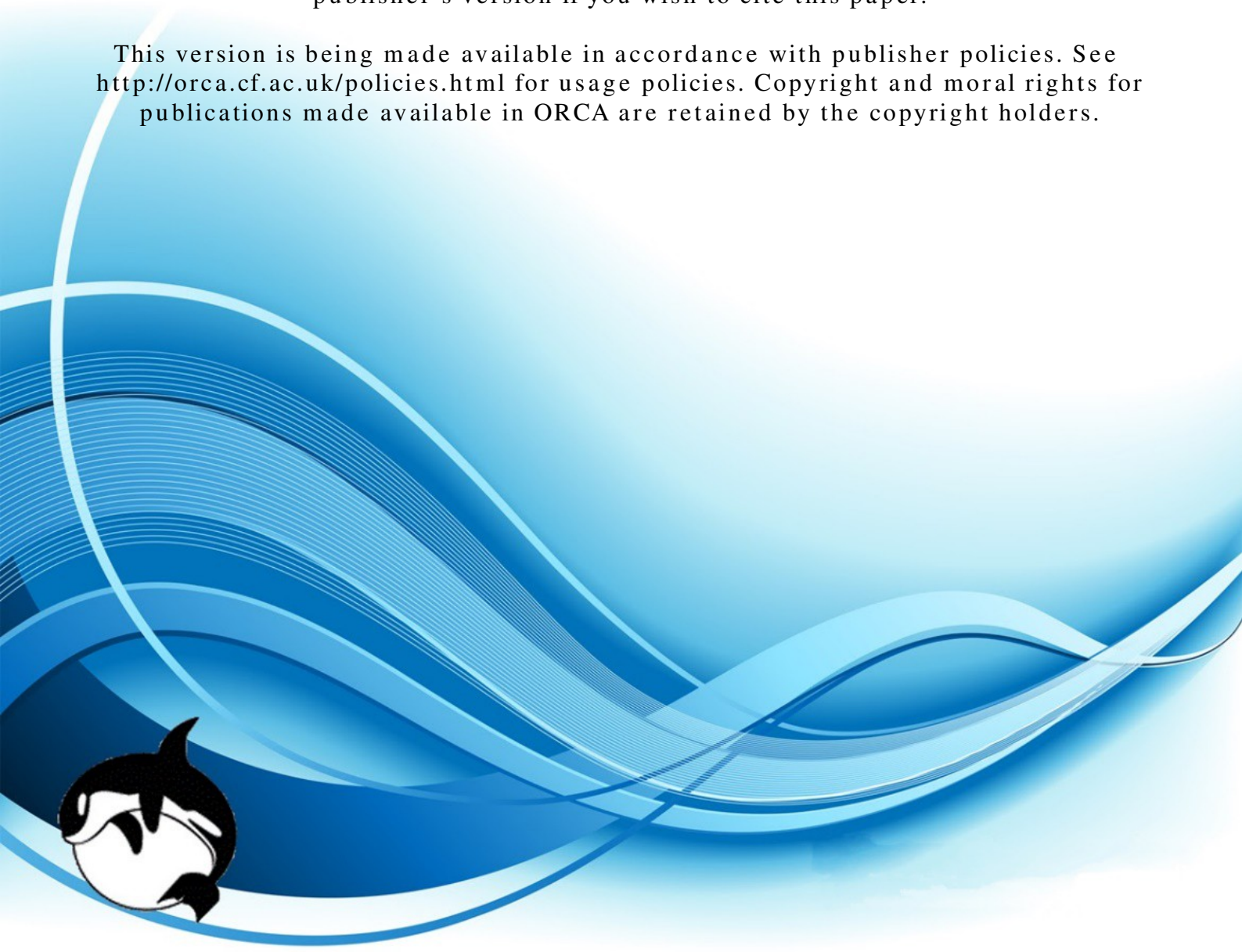

A SYSTEMATIC REVIEW OF RESEARCH INTO THE MANAGEMENT OF MANUFACTURING CAPABILITIES

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Abstract
Our study aims to explore the past and present knowledge related to the management of manufacturing capabilities and to assess the extent to which our knowledge of this field has developed. It places specific emphasis on the philosophical foundations of the field, while also providing a set of directions for future research. A systematic review is applied, covering 104 articles. The authors unfold a strong dominance of the positivist paradigm, and call for a more balanced and informed approach in philosophical and, more specifically, methodological selection by scholars. In terms of the research content, a strong bias exists towards measuring the impact that certain manufacturing capabilities, and various configurations of these, may have on key performance indicators, such as cost. Our review warns on the dangers of following a dominant paradigmatic stance and on the limitations of researching a limited area of the complex and dynamic manufacturing capabilities arena.

Keywords*:* Manufacturing capabilities, literature review, research philosophy, content analysis.

Introduction

The objective of this study is to investigate how research into the management of manufacturing capabilities has been conducted and what the main areas of interest have been. The intention is to explore the extent to which our knowledge of this operations and production management field has developed through the application of varying philosophies encapsulating elements such as research ontologies, epistemologies, methodologies and designs, as well the various directions in which it has been evolving.

Previous studies have argued that achieving sustainable competitive advantage for a firm results from building core capabilities (Prahalad and Hemel, 1990). These would include the organizational *modus operandi* that enables companies to meet basic competitive priorities, such as cost, flexibility, quality and dependability (Hayes and Wheelwright, 1984). In this context, superior manufacturing capabilities have long been associated with high performance and have been recognized as sources of competitive advantage for production systems (Wheelwright, 1984; Terjersen et al., 2011). Narasimhan and Schoenherr (2013), for example, investigated competitive manufacturing capabilities by focusing on their progression, or development, over time and emphasised how this process can influence improvements in manufacturing performance.

However, just possessing manufacturing capabilities, which can be related to technical issues (such as the use of advanced machinery), processes (such as flow-oriented manufacturing) and organisation (such as the use of independent manufacturing teams) will not automatically translate into high levels of performance. Instead, the performance outcome is dependent on how they are leveraged within the organisation, as well as across the supply chain. The not so recent now recent trends of outsourcing and globalisation have also emphasised the fact that, though manufacturing capabilities may still have a strategic role, they may no longer be confined within the boundaries of one organisation. Furthermore, the recent flat lining or, worse, decline of manufacturing sectors in the "developed" nations also calls for greater focus on understanding, acquiring, developing and sustaining manufacturing capabilities.

To present, there has been very little focus on assessing *what* the foci of the different research activities in the field of manufacturing capabilities have been. No known attempts appear to have been made either in order to understand the philosophical foundations that lie beneath the knowledge that has been generated in the field. This is particularly important, as the choice of a particular paradigm, for example, sets down the intent, motivation and expectation for a specific research endeavour and significantly impacts the knowledge that is generated.

The remainder of the paper is structured as follows. The next section provides a brief background to research into the management of manufacturing capabilities research. The subsequent section describes the reviewing method employed and classification framework used for the research papers identified. We then present the results from the classification activities. The final sections engage in the discussion of findings and puts forward a set of conclusions.

Background

The practical context which motivated our study's focus on manufacturing capabilities starts with the adverse socioeconomic challenges that have beset the most industrialised nations around the world in recent decades and the changing landscape of their gradually shrinking manufacturing sector. In the European Union, for example, manufacturing output and employment continue to contribute substantially to overall economic growth. In 2010, a total of 2.1 million enterprises employed 30 million people and contributed £6.7 trillion (Rhodes, 2015). US statistics portray a similar picture, with manufacturing accounting for 75% of private R&D investment, more than half of export earnings and most of the high wage blue collar jobs (Celasun et al, 2014).

However, the sector's relative decline within the total economy cannot be ignored (De Backer et al., 2013), with developed economies increasingly reporting on a trend towards 'deindustrialisation', where the relative share of their manufacturing is declining while the service sector is growing at a faster rate (Uppenberg and Strauss, 2010). The UK, for example, experienced a reduction in manufacturing employment at a faster rate than other developed economies, from close to 9 million people in 1966 to below 3 million in 2011 (Fothergill and Gore, 2013). While some authors argue that this reduction could be an indicator of increased productivity (McLaughlin, 2013), the wider view is that manufacturing sectors are losing jobs

due to loss in output triggered by an inability to compete in the global marketplace. The implications of these statistics and view points have facilitated further debates by stakeholders within different economic communities on how best to acquire, develop and sustain manufacturing capabilities. This was the practical motivation for our study.

From an academic perspective, the term 'capability' was introduced into the manufacturing strategy literature from general management following the development of the 'resource based view' of the firm (Corbett and Claridge, 2002). It relates to a firm's ability to deploy resources for a desired end result (Helfat and Lieberman, 2002), the efficiency with which a firm transfers available inputs into outputs (Dutta et al., 2005) or the exploitation of specific practices to attain performance gains (Dabhilkar and Bengtsson, 2008). Peng et al. (2008) further emphasised that capabilities should be seen as bundles of routines and therefore proposed a definition of capabilities as "the strength or proficiency of a bundle of interrelated routines for performing specific tasks". This is in consensus with Größler and Grübner (2006), who argued that the term 'capability' implied a firm's set of routines to achieve specific strategic objectives, for example producing with low cost.

The concept of capabilities as an embodiment of organizational routines (Dosi et al., 2008) can be, however, dated back to Nelson and Winter (1982), who in their evolutionary theory on economic change argued that "capabilities consist largely of the ability to perform and sustain a set of routines which may be regarded as a highly structured set of 'habitual reactions' linking organization members to one another and to the environment".

In this context, manufacturing capabilities are perceived as fundamental proficiencies that enable firms to achieve production related goals (Boyer and Lewis, 2002) which should align with the organisation's strategic goals (Taps and Steger-Jensen, 2007; Sum et al., 2012). Simply put, manufacturing capabilities reflect a production system's ability to produce and deliver their products, while competing along a set of performance objectives such as quality, cost, flexibility, delivery and innovation (Spanos and Voudouris, 2009). With the efficient and effective management of manufacturing capabilities having long been perceived as essential for long term economic growth and economic resilience, the literature in the area of operations management that addresses manufacturing capabilities has been steadily increasing. Debates in this area mainly centre on the Trade-off and the Cumulative models (Boyer and Lewis, 2002) for the management of manufacturing capabilities.

The Trade-off model addresses a question that has attracted a vast amount of interest: Can manufacturers focus on multiple competitive priorities simultaneously (or achieve strength on multiple capabilities) without sacrificing performance of another? The model was first proposed by Skinner (1969), who postulated that "a production system inevitably involves trade-offs and compromises, so it must be designed to perform a limited task well at the expense of others, with that task defined by corporate strategic objectives". However, later on, Da Silveira and Slack (2001), while exploring managers' cognition of the Trade-off concept using a case-based methodology, highlighted that the notion does not represent a main issue for the practicing managers, but more for academics. Research by Boyer and Lewis (2002) and Rosenzweig and

Easton (2010) further evidenced that manufacturers do not seem to report experiencing trade-offs among their competitive priorities.

The Cumulative capabilities theory (Ferdows and De Meyer, 1990; White, 1996; Rosenzweig and Roth, 2004) argues that high performance can be achieved in multiple capabilities simultaneously. Some authors proposed that this could be attained by developing competitive capabilities in a pre-specified sequence (Ferdows and De Meyer, 1990; Rosenzweig and Roth, 2004; White, 1996). This led to the development of Ferdows and De Meyers' (1990) "Sandcone model" and Roth's (1996) competitive progression theory. These models acknowledge, for example, that as a manufacturer invests in certain manufacturing capabilities in order to, say, improve its conformance to quality, the amount of rework typically decreases as a result, which allows for more stable production scheduling and subsequently more reliable delivery dates (Flynn and Flynn, 2004). Rosenzweig and Easton (2010) conclude that the sequencing that the law of cumulative capabilities appears to be most comfortable with is quality, delivery, cost and flexibility.

In keeping with the dominant logic of this literature stream, manufacturers are advised to set competitive priorities that are consistent with and supportive of their business strategy. Emphasis on such priorities should, in turn, guide a firm's pattern of strategic decisions or choices regarding the development of specific manufacturing capabilities (Hayes and Wheelwright, 1984; Vickery, 1991). As such, regardless of the fact that manufacturers focus on improving simultaneously along multiple capability dimensions or make particular trade-offs, they are likely to improve performance by centring on the development of specific manufacturing capabilities.

In view of the strategic importance of the topic both for the field of operations strategy as well as practice, it is important to synthesise the current knowledge on the subject (Gungor and Gupta, 1999; Ilgin and Gupta, 2010; Morgan and Gagnon, 2013). What also seems to be absent in this area of scholarship is an investigation into *how* research into the management of manufacturing capabilities has been conducted, from various methodological perspectives**.** The question that may be asked is: "with the near amorphous and multidisciplinary nature of manufacturing research and practice, what aspects of manufacturing capabilities have been explored and what methods and methodologies have been employed?" This question is even more abound as the boundaries between 'hard-core' manufacturing and the 'softer' social sciences are gradually eroding, especially with the current interdisciplinary nature of modern manufacturing systems, which includes issues and aspects of human factors, behavioural operations, technology, ergonomics and so on.

The discourse concerning issues related to the choice of paradigms, methods and methodology is not new to operations management research. Philosophical perspectives form the base for and influence complex research design decisions in management research (Morgan and Smircich, 1980). Continuing emphasis is currently placed on the importance of the move from instructional surface learning to deep structure or reflexive learning and independent critical thinking and analysis (Bates and Jenkins, 2007). This deeper discourse on philosophical foundations refers to the underlying ontological and epistemological beliefs involved in all

management research (Thomas, 2004; Bryman and Bell, 2007). These philosophical foundations are closely intertwined (see Figure 1) and influence the knowledge that is generated from research endeavours.

[Figure 1 near here]

In this context, Lakatos (1970) argues that knowledge growth derives from the competition between series of theories over time. Science is organised in research programmes, which share an irrefutable 'hard core' that is shielded by the 'protective belt' which aims for explaining arising anomalies. According to this viewpoint, knowledge development is a rational process where progressive research programs eventually supersede degenerating research agendas (Gold, 2014). As such, while the presence of a paradigmatic 'hard core' of a field is expected, conducting research exclusively within its boundaries carries the dangers of generating 'more of the same' knowledge. It is the protective belt that has the greatest potential of advancing a body of knowledge. Amundson (1998) further suggests that one core characteristic of mature scientific fields is the cumulative expansion of their knowledge at their frontiers, which prerequisites a broad prior consensus on one paradigm. This advances Kuhn's (1970) concept of scientific paradigms that promotes as ideal the stage of "normal" science, where research is productively guided by one dominant paradigm.

In operations management research, various scholars (Flynn et al, 1990; Meredith, 1998; Wacker, 1998; Coughlan and Coghlan, 2002; Voss et al, 2002) have dissected, theorised and called for the use of a diverse range of methodological approaches in order to further discover and answer the challenges that beset the field. Meredith (1998), Voss et al. (2002) and Ketokivi & Choi (2014), for example, argued against the continued proliferation of survey research and called for the adoption of more case study based research. Others, such as Westbrook (1995) and Craighead and Meredith (2008) called for more action research through research-industry engagement in search of practical and innovative solutions. Schmenner et al. (2009) warn that "real life problems and puzzling new phenomena, in particular, seldom map onto specific paradigmatic domains and thus, trying to understand a novel phenomenon using existing paradigms is akin to trying to play a new game with the old rules". If we then adhere to Kuhn's (1970) suggestion that researchers should propose more encompassing theories to find solutions to new challenges, there is an acute need for us to understand our methodological past and present in order to shape the future. Exploring the past and present knowledge related to the management of manufacturing capabilities, as well as its philosophical foundations, while also providing a set of directions for future research, is what our study aims to achieve.

Literature Review Method and Classification Criteria

Review Method

Systematic literature reviews employ a series of techniques for minimizing bias and error through exhaustive literature searches of published studies, while providing an audit trail of the reviewers' decisions, procedures and conclusions (Cook et al., 1997). Guidelines on conducting a systematic review of a literature base in order to ensure that an unbiased and valid evaluation is performed can be found in studies such as Tranfield et al. (2003), Rousseau et al. (2008), Seuring and Gold (2012).

In order to systematically review the operations management literature relating to manufacturing capabilities, the first step was to develop standards for including papers in the review. Papers for consideration included published peer-reviewed journal articles, which were not limited to particular journals, disciplines or sectors. Conference papers, textbooks, contributions to edited books, dissertations and theses were excluded. This follows David and Han's (2004) approach to ensuring only peer-reviewed, quality papers are considered. In addition, the review included only articles published in English.

Figure 2 outlines the process undertaken in order to identify and filter the papers most relevant to our study. Key word searches were made through five databases: ABI/Inform Global Proquest, EBSCO, SCOPUS, Web of Knowledge and Google Scholar. These databases cover a wide range of peer-reviewed academic publications, as well as having a broad and multidisciplinary scope. Focusing on a wide set of databases also satisfies the recommendation that at least two but preferably more databases or journals should be searched (Thome et al., 2016). The keywords used included various combinations of "manufacturing capabilit*", "manufacturing competenc*", "production capabilit*" or "production competenc*". The reason both 'capabilities' and 'competencies' were used as search terms in our research is that in several studies the terms are used interchangeably (see, for example, Größler and Grübner, 2006; Dosi et al., 2008). The same applies for the terms 'manufacturing' and 'production'. Following an initial review of titles and abstracts, 946 studies were identified as focusing on the management of manufacturing capabilities across the five databases.

[Figure 2 near here]

For ease of manipulation, categorization and easy access, all identified papers were exported into EndNote. This process highlighted that the bank of 946 papers selected included a series of duplications. This was mainly a result of the fact that various combinations of search terms could return a paper more than once in the same database (for example, if an author used the term 'manufacturing competency' and 'manufacturing capability' in the same paper, the two separate search processes (for "manufacturing capabilit*" and "manufacturing competenc*") would both return the paper). Duplications could also arise from the fact that several journals are stored in more than one database and, as a result, a search for 'manufacturing competenc*' in Google Scholar could return the same paper as a search for 'manufacturing competenc*' in ABI / Inform. 422 duplications were eliminated once all papers were exported into Endnote. With a more manageable database of papers (524), the abstract, introduction and discussion /

conclusion sections of all papers were read to ascertain their relevance to this study. Two main inclusion criteria were used to select papers for full-text review:

1. The paper contributes to the development and understanding of manufacturing capabilities in the operations management field (this was particularly relevant for papers identified in engineering journals - if no managerial implications were discussed, and the article only specifically addressed manufacturing capabilities from a technical perspective, for example, specific tools or techniques, these articles were excluded) and
2. The research method / methodologies employed can be identified.

In total, 104 papers were selected and read in full. A further classification and content analysis of these papers was then undertaken, as presented in Section 4. In relation to the content analysis, one of the main challenges consisted in ensuring inter-coder reliability. According to Duriau et al. (2007) by involving several researchers into the content analysis, validity and reliability is believed to be highly enhanced. For our study, random selections were cross checked and confirmed in pairs by the three researchers.

Article Classification Criteria

In terms of understanding the philosophical foundations that lie beneath the knowledge that has been generated in the field, four main criteria were used for classifying the papers, adapted from Saunders et al. (2007): *Research Paradigm*, *Research Design*, *Research Methods*, *Data Analysis Techniques* (see Table 1).

[Table 1 near here]

Research Paradigm

The paradigmatic approach to any research endeavour should occupy centre stage in the research process. According to Guba and Lincoln (1994), a paradigm is defined as "the basic belief system or world view that guides the investigator, not only in choices of method, but in ontologically and epistemologically fundamental ways". Without the choice of a paradigm as the first step in a research project, there is no basis for subsequent selections regarding methodology, methods, literature or research designs (Mackenzie and Knipe, 2006). The choice of a particular paradigm therefore sets down the intent, motivation and expectations for the research.

While several paradigms have been identified in the literature, there are two major opposing philosophical perspectives: positivism and interpretivism. The positive paradigm generally adopts an objectivist approach, with ontological assumptions that believe an objective world exists, "with reality as a concrete structure" (Morgan and Smircich, 1980). Procedures and methods used in natural sciences are therefore the preferred research approaches with strategies such as experiments and surveys leading to analytical methods such as statistical techniques and mathematical modelling. These methods generate 'objective' knowledge and are devoid of any subjective or 'human' input.

Interpretivism, on the other hand, adopts a subjectivist approach, with core ontological assumptions that see "reality as a projection of human imagination" (Morgan and Smircich, 1980). Preferred research strategies include case studies, action research and ethnography, with data collection methods such as unstructured interviews and observations, which allow the researcher to focus on meanings and try to understand what is happening. Analytical methods focus on hermeneutics, an approach to the analysis of texts that emphasizes how prior understandings and prejudices shape the interpretive process (Denzin and Lincoln, 2000).

For some, beyond these two contrasting perspectives exists a third stream known as realism. This philosophical paradigm has elements of both positivism and interpretivism, where both qualitative and quantitative methodologies are seen as suitable tools (Healy and Perry, 2000) for researching the underlying structural mechanisms that constitute social systems, ideas, causes and effects. Two different realist perspectives can be found in the literature: the *critical realist* and the *positive realist,* which lean more towards qualitative (interpretivist) or quantitative (positivist) research, respectively (Laughlin, 2004). In the context of the realist paradigm, Kraus (2005) argues that methods such as cases studies and interviews are as acceptable and appropriate as statistical analyses and structural equation modelling.

Other similar classification frameworks that have been used to classify research outputs in management and social science research include that developed by Burrell and Morgan (1979), which refers to the four paradigms as functionalism, interpretivism, radical structuralism and radical humanism.

In line with the above discussion, four paradigms (Positivist, Positive Realist, Critical Realist and Interpretivist) were used in our study to categorize the 104 articles identified.

[Table 2 near here]

Research Design

'Research design' refers to the overall strategy chosen by researchers to integrate the different components of their study in an ordered, consistent and logical way, towards ensuring that the research problem is addressed (De Vaus, 2001). Advocating the importance of selecting appropriate research designs, Voss et al. (2002) state that "the research design in operations management should pay attention to what processes and systems are to be studied, the methods for studying them, and the operating data to be collected from them". Similarly, Westbrook (1995) argues that the quality of any research outcome depends as much on the management of the research project as on the research design or results analysis. Following similar classifications by Orlikowski and Baroudi (1991) and Bryman and Bell (2007), the research designs of the papers selected for our review were classified under: *Survey* , *Conceptual, Longitudinal, Case study, Experimental, Literature Review* or *Other* (the 'Other' classification was included to allow for any emerging new research designs).

Research Methods

Various options exist whereby researchers not only collect their data for their research, but also work towards answering research questions or satisfying research objectives, while also utilising some data analysis tools. Following similar classifications by Mentzer and Kahn

(1995) and Sachan and Datta (2005), selected papers were coded under: *Surveys, Interviews, Observations, Simulation, Mathematical Modelling* or *Other.*

Data Analysis Techniques

Regardless of the philosophical paradigm that is chosen for the research, data analysis is a critical and difficult phase where relevant details must be sorted from the mass of observations, comments, interviews and simulation runs (Stuart et al., 2002). To allow for capturing data analysis techniques for both quantitative and qualitative studies, papers were coded under: *Statistical, Modelling, Process Mapping, Content Analysis, Conceptual, Descriptive analysis techniques.*

Research Focus

The next step in our study was to identify 'what' have been the outcomes of the research in the field of manufacturing capabilities. We need to highlight here that at the outset no pre-defined frameworks, themes or codes were used, to avoid any bias of trying to fit the data into a pre-determined model. Hence, with regards to the content analysis and coding of each paper's contribution to knowledge, various steps were taken to achieve this task, using a modified version of Mayring's (2004) framework for content analysis as given in Figure 3. Phrases such as "*the paper proposes a model of the relationships among sources and outcomes of competitive advantage*" or "*in this paper, we provide a summary of the recent management theories by comparing their salient features*", were given adequate consideration as indicators to the content and argument of that paper. Following this deductive approach, an initial set of classification clusters emerged, captured at Level 3 (Bold) in Figure 5. These were then merged into several sub-categories (Level 2, Underlined)) and ultimately 3 main themes of *Technology*, *People/Attitudes and Process/Organisation* (Level 1, capitalised) emerged.

[Figure 3 near here]

Article Classification Results

The first stage of our analysis was to determine *when* the selected papers were published, as shown in Table 3. Based on the search criteria adopted, the first identified paper was by Whybark (1987). The author developed a Trade-off argument for manufacturing capabilities by arguing that management must set priorities on those manufacturing competencies most important for success in the market. After 1987 research on manufacturing capabilities has seen a steady increase in published papers, and is expected to continue to do so. A simple extrapolation of the number of papers identified between 2011 to date suggests that the interest in manufacturing capabilities will equal if not exceed the volume of research of the last decade.

[Table 3 near here]

Table 4 shows that 52 different journals were identified as containing relevant articles, with 13 journals returning two or more relevant papers. The wide spread of relevant journals indicates the interdisciplinary nature of the research in the field of manufacturing capabilities. This is expected to invite a broad variety of theoretic, methodological and epistemological approaches. However, as our study will reveal in the later sections, this is not currently the case.

[Table 4 near here]

A further classification of the identified papers was then undertaken, in order to determine the various methodological and epistemological approaches employed, as well as the main outcomes of the research reported on.

Research Paradigm

From Table 5, it is evident that the positivist paradigm has taken the dominant position in manufacturing capabilities research. 66.3% of all research contributing to this field did so by using so called objective, positivist approaches. 11 other papers (10.6%) were based on the interpretivist paradigm, which is "dependent on the ability to understand the way in which human beings shape the world from inside them" (Morgan and Smircich, 1980).

[Table 5 near here]

Furthermore, Figure 4 highlights that the positives paradigm has consistently dominated research into manufacturing capabilities across the years. This positivist philosophical stance, however, is not peculiar to manufacturing capabilities research alone. Other management disciplines such as the management of information systems (Chen and Hirschheim, 2004), logistics (Mangan et al., 2004), SCM (Burgess et al., 2006) and general operations management (Craighead and Meredith, 2008) all indicate the dominance of the positivist paradigm. This governance suggests that knowledge is being conceptualized as a rational function and investigated as a "science" (Burgess et al., 2006). However, Orlikowski and Baroudi (1991) previously warned on the dangers of an overwhelming dominance of a single research perspective in a field as being unnecessarily restrictive. Positivist studies are premised on the existence of a-priori fixed relationships within phenomena which are typically investigated with structured instrumentation. Such studies serve primarily to test (rather than generate) theory, in an attempt to increase predictive understanding of phenomena.

[Figure 4 near here]

An overwhelming proportion of the articles that fit into this paradigm focused on testing the relationship between the nature and / or the sequence of adoption of certain manufacturing capabilities on the performance levels achieved, as captured by either the Trade-off or the Cumulative models introduced in Section 2.1. In these articles, the positivistic approach focuses on developing deterministic explanations of the phenomena, with a particular emphasis on validity and control of the research procedures. Little emphasis is placed in these studies on the historical context of the firms, the wide environment in which they operate or, for example, the role of the employee participation in the decision making process. Rowan (1973) argues that such a posture is not conducive to the discovery and understanding of non-deterministic and reciprocal relationships and notes that "research can only discover one-sided things if it insists on setting-up one-sided relationships".

Furthermore, Benbasat (1987) argue that the positivist perspective has insufficient variety for multi-faceted phenomena under investigation, such as that of manufacturing capabilities. From this perspective, more interpretative research is called for in order to generate hypothesis for further investigation and to fill-in the knowledge gaps that positivist research cannot easily attend to, such as the contextual exigencies, the meaning systems and the interaction of various components of a system (Orlikowski and Baroudi, 1991).

Dominant Research Design

Table 6 highlights a strong dominance of empirical studies, with only 28 papers being conceptual in nature. This should be seen as a positive development. MacCarthy et al. (2013), for example, previously argued that in operations management research, where the main scholarly contribution is to identify, model, explain or otherwise categorize an empirical phenomenon, the corresponding concerns of the academic operations management field have primarily been about whether it was sufficiently focused on "real" managerial preoccupations (Wilson, 1995), hence calling for more empirical studies.

[Table 6 near here]

The research design classification also indicates, however, that in empirical studies the survey design dominates (55 papers, representing 72% of all empirical articles). This is not surprising, considering the dominance of positivist related research in the field of operations management, as identified in the section. However, as argued even as far back as 1993 by Meredith (1993), although the proportion of empirical research in the area is increasing, empirical research with a strong conceptual and methodological base appears less common. The dominance of survey design highlights that researchers have been preoccupied with building quantitative models, which scholars in most fields would classify as theory-testing rather than theory-building research. Furthermore, Meredith (1993) argues that such research has little relation to reality and offers little or no utility to managers. The same message was more recently reinforced by authors such as Ketokivi and Choi (2014).

A notable finding, though, is the relatively high presence of conceptual research designs (27%). These involve the use of conceptual research methods based on descriptive, empirical investigations and can significantly increase the external validity of research conclusions and, as a result, can increase their corresponding relevance to managers. Conceptual methods, building primarily on description and explanation, lead to a better balance between theory-building and theory-testing research. However, out of the 28 conceptual articles, 16 (representing 57%) belonged to the positivist paradigm, following a theory-testing approach based on quantitative modelling, simulation and laboratory experimentation.

Our findings also highlight noticeable absences from the *Other* research design choices in manufacturing capabilities research, such as action research, grounded theory and ethnography. Though grounded theory and ethnographic based studies may be less familiar territory for operations management researchers, scholars have long called for the use of action research, for example (Coughlan and Coghlan, 2002). Their argument is centred on action research being an approach that aims at making intervention, engaging in research that is interactive, conducted in real time and creating, rather than testing, knowledge. Similar arguments for the use of grounded theory in operations management, though scanty, are available (McAdam et al., 2008). Furthermore, Binder and Edward (2010) argued for more diverse, qualitatively led studies in the field, which will develop theories that help to explain current phenomena and the relationships between their relevant building blocks.

Research Methods

The options utilised in manufacturing capabilities research are given in Table 7. Unsurprisingly, in light of the previous findings, a strong bias can be observed towards quantitative research methods, such as surveys and modelling (67.3%), as opposed to only 32.7% of the papers reporting the use of qualitative, conceptual methods. Notable absences are observational and simulation based approaches. Again, while the former may be expected, the latter is surprising given the dominance of positivist research in the field. Conceptual or qualitative research has increasingly been highlighted as an essential form of scholarship for theory building and advancement of knowledge (MacCarthy et al., 2013), but its adoption in the field is still scarce. Another issue of concern is the relative lack of mixed methods being used. To achieve triangulation of findings and increase generalizability, it is generally recommended that a number of methods be used to address research questions (Wacker, 1998). The lack of mixed-methods can have an adverse impact on the development of a field that already appears to focus on theory testing approaches.

[Table 7 near here]

Data Analysis Techniques

Data analysis techniques employed in the selected studies are captured in Table 8. Again, unsurprisingly, due to the high number of positivist and survey based studies, statistical analysis emerges as the top choice, with modelling methods ranked third.

[Table 8 near here]

Content Analysis of Research into the Management of Manufacturing Capabilities

The result of our research content analysis can be found in Figure 5. The figure highlights that the majority of studies into the management of manufacturing capabilities are concerned with aspects related to *Processes / Organisation (*86 papers), compared to 14 papers focusing on *People / Attitudes* and only four papers addressing aspects related to *Technology* adoption aspects.

Technology Focus
Four papers clustered into this category, with a particular focus on the management of advanced technologies as a core manufacturing capability. Within these four papers, Chung and Swink (2009) investigate the relationship between patterns of Advanced Manufacturing Technology utilisation and manufacturing capability attainment; Terjesen et al. (2011) investigate manufacturing capabilities contributing to low operating costs and high product quality in the context of high technology new ventures; Zhang et al. (2006) and Spanos & Voudouris (2009) address the use of advanced manufacturing technologies as an antecedent to flexible manufacturing competence.

[Figure 5 here]

People / Attitudes Focus
The limited number of papers in the *People / Attitudes* category (14) also signifies a substantive gap, with only a single paper (Camuffo and Gerli, 2007) identified which relates manufacturing capabilities to personal, more tacit, knowledge and skills management within the organisation and emphasises the importance of human resource management (*HRM*) in this context. Within the *People / Attitudes* category, a further sub-category of 13 papers was identified, which focused on the importance of *Knowledge Management (i.e.* knowledge of the organisation*)* in developing manufacturing capabilities, though the human factor was not made as specific as in the *HRM* category. Within this sub-category,

- three papers emphasise the aspect of *Transfer* of manufacturing capabilities, either within the same organisation over time (e.g. Zander and Kogut, 1995) or from an external entity (e.g. Liao et al., 2011),
- seven papers propose *Models* for knowledge management in the context of manufacturing capabilities. For example, Paiva et al. (2002) address manufacturing capabilities from a knowledge based view of the firm
- three papers highlight the importance of the *Learning* organisation in this context. For example, Huang et al. (2008) investigate the role of learning in the development of mass customization capabilities.

Process / Organisation Focus

The *Process / Organisation* category is by far the largest (86 papers), and four sub-themes emerged: *Strategy (60), Evolution (13), Outsourcing (2) and Measures (11)*. The large number of papers in the *Strategy* sub-category (60) is perhaps unsurprising, considering the fact that manufacturing capabilities have long been perceived as having a strategic role in the firm, contributing to competitive advantage and performance improvement in terms of both operational efficiency and efficient product development. The majority of these papers follow the Trade-off or Cumulative theories highlighted in the earlier literature review. Within the papers in the *Strategy* sub-category, five main themes emerged: *Performance* (23), *Competition* (8), *Configuration* (22), *Networks* (3) and *Innovation* (4).

The *Performance* theme is the largest Level 3 cluster identified across our content analysis, with 23 papers focusing on ascertaining the impact that the adoption of certain manufacturing capabilities may have on key performance indicators (flexibility – e.g. Fawcett et al., 1996; customer satisfaction – e.g. Rosenzweig et al., 2003; financial performance – Vickery, 1991), with some also highlighting certain contextual variables that might mitigate the effect. Within this sub-category, a strong emphasis on positivistic research was apparent, with 96% of the papers, as expected by the strong focus of these studies on measuring the impact that the adoption of certain capabilities might have on performance.

The *Configuration* theme (22 papers) includes papers that focus on understanding the way manufacturing capabilities should be configured within an organisation. For example, Ward et al. (1996) develop strategic configurations which describe commonly used paths by manufacturers to achieve competitive advantage, while other papers refer to the strategic arrangement of capabilities, in particular forms or combinations, giving rise to ether the Trade-off or Cumulative theories (Avella and Vasquez-Bustello, 2010; Sarmiento and Shukla, 2011). The *Competition* cluster (8 papers) particularly discusses manufacturing capabilities in the context of ensuring competitive advantage (e.g. Linden et al. (1998) examine capabilities that Asian 'second movers' such as Korean and Taiwanese firms adopted in order to build globally competitive advantage, in competition with Japanese firms, which were thought of as the leaders in the then regional production hierarchy).

The *Innovation* cluster (4 papers) emphasises the role of manufacturing capabilities in supporting product and process innovation, especially with reference to external market forces. For example, Bozarth and Berry (1997) present a methodology for evaluating the congruence between market needs and manufacturing plant capabilities while Corbett and Campbell-Hunt (2002) examined how the operations of six manufacturers responded to the turbulence in their business environments. The *Networks* cluster (3 papers) captures the importance of competitive priorities being grounded not only in the development of internal manufacturing capabilities but also in the design and management of the supply chain. The relative small number of papers in the *Networks* category is even more surprising considering the fact that, particularly in the developed world, there is an increasing trend towards management of manufacturing being no longer confined to an individual firm but outsourced to global locations. As such, the role of the supply network in managing outsourced manufacturing capabilities appears as a notably

under-researched area. That is, of course, not to say that there are only three papers in the body of operations management literature currently addressing the role of SCM in managing suppliers which manufacture a variety of goods or services. It is the particular focus on the management of manufacturing capabilities, through appropriate integration mechanisms, that is missing in this context.

Evolution of manufacturing capabilities (13 papers) was the second largest Level 2 sub-category in the *Process / Organisation* category. 4 of the papers focus on *Co-evolution Modelling* of various capabilities within the firm (e.g, AlGeddawy and ElMaraghy (2011) hypothesize that the evolution and co-evolution of products and the machines used to manufacture them is akin to that observed in the adaptation of biological species and they proceed to study the symbiosis between products and manufacturing capabilities using real examples). 8 papers concentrate on aspects related to *Development* of manufacturing capabilities *(*e.i.. Gavronski et al. (2011) propose a model for factory resources leading to the development of green manufacturing capabilities and global sustainable manufacturing competencies*)*. One paper discusses aspects related to manufacturing capabilities in the context of *Firm Growth* (Zhai et al., 2007).

Overall, papers in the *Evolution* sub-category specifically highlight that, as products and markets change over time, the role of manufacturing capabilities should change too. Thus, when making strategic decisions regarding manufacturing capabilities, it is important for firms to take into account their dynamic nature. This concept is referred to in some of the strategic management literature as "*dynamic capabilities*", defined as a learned and stable pattern of accumulating experiences through which organizations systematically generate and modify their operating routines in pursuit of improved effectiveness (Macher and Mowery, 2009), but without making specific consideration to manufacturing capabilities, which was the focus of our review.

The *Measures / Dimensions* Level 2 sub-category (11 papers) within the Process / Organisation category focuses on quantitatively assessing certain manufacturing capabilities. Wu and Pearn (2006), for example, propose a Bayesian approach to provide numerical measures on whether a process is capable of reproducing products which meet the manufacturing specifications, while Wu (2007) developed a capability testing procedure to enable practitioners to make reliable decisions for determining whether their processes meet the pre-set capability requirement for production control planning. Similarly, other researchers, such as Hsu and Shu (2008) present a fuzzy inference to assess whether a process conforms to the defined manufacturing capability prerequisite. Again, perhaps unsurprising, as the focus of these papers is the measurement of certain variables, there is a strong bias towards the adoption of a positivistic stance in this category (8 out of 11 papers, representing 73%).

The *Outsourcing* Level 2 sub-category (2 papers) specifically explores the dynamics associated with outsourcing manufacturing capabilities. As was the case of the *Networks Level 3* theme (3 papers) under the *Strategy* sub-category, the lack of focus of research on managing manufacturing capabilities beyond the boundaries of the focal firm is of particular concern, in view of the globalisation and fragmentation of today's supply chains.

Discussion

Our study investigated 'how' operations management research into manufacturing capabilities has been conducted, including detailed insights into the research paradigms, research designs, research methods and the different analysis techniques used. The study also addressed 'what' the foci of the different research activities in the field have been.

Our findings revealed that, in contrast to other disciplines, such as medical science and psychology, where more even distributions of research paradigms, designs and methods are in play, the manufacturing capabilities field is dominated by a positivist 'hard core' (Figure 6), led by quantitative research methods such as surveys and modelling. This is, perhaps, unsurprising considering the fact that the field is grounded in the operations management discipline, which has strong influences from operations research, management science and engineering. However, while research at the core resembles research in a unified discipline and is more likely to focus on the 'historical root interests' of the field and establish consensus on appropriate methods to use, it is also more likely to generate 'more of the same' knowledge. Orlikowski and Baroudi (1991) have, for example, previously argued that the dominance of positivism limits what aspects of a phenomenon researchers can study, as well as how these are studied. This has implications not only for the development of theory and our understanding of various ways in which to manage manufacturing capabilities for the competitive advantage of firms and nations, but also for practice. The findings of manufacturing capabilities research should ideally filter into the practitioner community and be used as direction for action. Restrictive research, thus, has far reaching consequences.

Further confirming this trend, the majority of data in the selected studies was collected using questionnaires. This is a tool mostly used in survey research designs, where the researcher is mostly detached from the participants and the research is based mostly on preconceptions from previously established research outputs. Most of this research, thus, is therefore positivist oriented and the implications of this are profound. The paradigm was claimed to reduce people to mechanistic systems and only account for the rich and unpredictable complexity of human interaction by means of a few isolable variables, thereby reducing complex human dynamics to simplistic patterns (Schrag, 1992). According to our findings, data collection methods such as qualitative case studies and interviews, where the researcher is actively engaged with the participants, are not widely used. This is despite a plethora of academics, such as Craighead and Meredith (2008), previously arguing for the field of operations management to evolve toward more interpretive research and analysis based on natural observations of reality, thus increasing its relevance to practice.

[Figure 6 here]

However, our research also identified the emergence of a 'protective belt' (Figure 6), with 33% of articles adopting a critical realist, positive realist or interpretivist paradigm and employing more qualitative research methods. We argue that research at the 'protective belt', which appears more exploratory in selecting suitable theories and methods for addressing identified

gaps, borrowing from the general management discipline, is where the main opportunities lie in terms of advancing the field of manufacturing capabilities.

As such, in order to develop the field further, considering the findings above, our paper calls for more 'applied' research with the adoption of what were previously called 'heretical' research methods, towards finding new channels through which to obtain organizational insights (Daft and Lewin, 1990). These heretical methods and methodologies within operations management research may include those abhorred, and least used, such as those belonging to ethnography, grounded theory, action research and other observational based data collection approaches. Currently, these appear not to be used at all in the area of manufacturing capabilities.

A second aim of our study was to explore the specific focus of research into manufacturing capabilities. The main findings highlighted an uneven distribution across the discipline. Definitions of manufacturing capabilities as "the strength or proficiency of a bundle of interrelated routines for performing specific tasks" (Peng et al., 2008) imply that these competencies are a combination of both soft and hard resources, which should include people, skills, processes, machines, technology. However, the majority of articles selected particularly address the impact that the adoption of certain manufacturing capabilities may have on key performance indicators (as reflected by the *Performance* cluster of articles, with 23 studies) and the various ways in which these could be configured within an organisation, as mirrored by the Trade-off or Cumulative theories (the *Configuration* cluster includes 22 papers). Within these clusters, a strong emphasis towards positivistic research, aimed at theory testing, was apparent.

More notably, the impact and importance of the behavioural / human factor aspect, as well as the technology contributions, seem to have been particularly under-researched. Some exceptions do exist. For example, Camuffo and Gerli (2007) looked at the relationship between HRM and manufacturing capabilities and delved into how manufacturing capabilities can be grounded on peoples' skills and competencies. This research collected extensive data though behavioural events and interviews. Other research, such as Huang et al (2013), looked at the effects of learning capabilities on manufacturing competencies, while Liao et al (2011) looked at external competence transfers but mainly used purely statistical methods.

A further particular area with limited research conducted to date relates to the role of the supply chains and their various coordinating mechanisms in managing geographically dispersed manufacturing capabilities. The two clusters containing papers that address this aspect, from different perspectives, are the Level 3 sub-category of *Networks* (3 papers) and the Level 2 cluster of *Outsourcing (*2 papers*).* Krause et al. (2014) argue that only by understanding how well-selected and well-implemented operations initiatives (involving cross-functional or supply chain capabilities) can truly enhance overall competitive advantage, operations management researchers will be better positioned to influence top management strategic planning within organisations. The interdependencies and intersections across functions and the supply chain are indeed potentially fertile research areas, where considerable insights into implementation challenges can be sharpened (Krause et al., 2014). Thus, in order to bridge the gap between

manufacturing capabilities research and practice, what we also really need is to focus more on 'how' than on 'what'.

Conclusions

Given the strategic significance of the area, our study set out to explore the extant body of knowledge published on the management of manufacturing capabilities, both in terms of how research in the field has been conducted as well as what the focus of research has been. Through a systematic review covering 104 articles published from 1980 to 2014, we unfolded a strong dominance of the positivist paradigm, and a strong bias towards measuring the impact that certain manufacturing capabilities, and various configurations of these, may have on key performance indicators, such as cost. The majority of these studies adopt a survey approach.

In terms of research focus, the majority of studies appear to address process / organisation aspects, at the expense of people / attitudes and technology adoption. As a result, our findings indicate opportunities for the advancement of manufacturing capabilities research. As shown in Figure 5, these may be achieved through the investigation of manufacturing capabilities in relation to human resources management, outsourcing and technology, particularly in terms of the emerging advanced manufacturing capabilities. Better still, the application of 'heretical' methods such as grounded theory and ethnography, may provide opportunities to produce novel theories in a field that appears to be dominated by theory testing studies. The amount of operations management research in the field of manufacturing capabilities is steadily increasing and there is a high risk that, if the same patterns are followed in terms of both paradigmatic choice and research focus, we will keep producing more of the same knowledge and carry on missing out on the opportunity to make a real difference in terms of practice.

Though the discourse concerning issues of paradigms, methods and methodology is not new to the field of operations management and strategy (see, for example, Flynn et al., 1990; Meredith , 1998; Voss et al., 2002; MacCarthy et al., 2013) , up to date no known comprehensive attempts appear to have been made in order to understand the philosophical foundations that lie beneath the knowledge that has been generated in the field of manufacturing capabilities, with a focus across the four aspects of: paradigmatic choice, research design, research methods and data analysis techniques. In terms of academic contributions, our study's findings should be seen as a warning on the dangers of following a dominant paradigmatic stance, but also as a cautionary note on the limitations of researching a limited area of the complex and dynamic manufacturing capabilities arena. Using Lakatos (1970)'s model, we were able to identify the field's 'core', as well as its protective and heretical belts, and highlight the fact that most of the research into the management of manufacturing capabilities adopts a theory-testing, rather than theory-building approach. Such research is at risk of having little relation to reality and offers little or no utility to managers (Meredith, 1993; Ketokivi and Choi, 2014). Thus, as well as providing directions for future research, the authors call for a more balanced and informed approach in the choice of both research focus and philosophical selection by scholars. The paper also offers a foundation for developing research streams where aspects particularly related to people /

attitudes and advanced manufacturing technologies are further integrated into research on the management of manufacturing capabilities.

Synthesising current knowledge is important for academic researchers, but also for practitioners (Gungor and Gupta, 1999; Ilgin and Gupta, 2010; Morgan and Gagnon, 2013). They can benefit from this present study as it generates a knowledge base accumulated from a range of primary studies conducted in the industry (Thome et al., 2016). Furthermore, with the worrying recent statistics on the trend towards deindustrialisation of developed economies generating debates by stakeholders within different economic communities on how best to acquire, develop and sustain manufacturing capabilities, our study is particularly relevant. It highlights the fact that, in an effort to develop and sustain manufacturing capabilities, firms should adopt a balanced approach in addressing not only process / organisation related factors, but also aspects related to the management of manufacturing technologies and people. This more balanced approach will enable stakeholders to be better equipped in their fight towards sustaining competitive advantage. At the same time, the importance of managing manufacturing capabilities beyond the boundaries of the focal firm, in view of the not so recent now trends of outsourcing and globalisation, is particularly relevant. This, however, requires 'systems thinking' which is underpinned by the assumption that the whole differs from the sum of its parts; practitioners should aim to look beyond the function and firm level in their quest to effectively manage manufacturing capabilities. Furthermore, from an academic perspective, Sachan and Datta (2016) also warn that positivist methods are not able to address a system holistically, with the knowledge generated being in danger of having little relevance to practitioners.

Further research should aim to inform managers as to how to build effective and efficient manufacturing capabilities for global competition by enabling them to better understand their current capabilities, across the technology / process / people aspects, identify capability areas of strategic importance and restructure their global operations to achieve desired capabilities (Zhang et al., 2016). Further research should also seek to address the blurring boundary between manufacturing / service capabilities in a supply chain context.

Several limitations of our study should, however, be highlighted. One relates to the fact that only a failry limited number of peer reviewed articles were selected, using a narrow string of search terms. Second, despite the fact that inter-coder reliability was checked for, the selection and coding of articles could be influenced by the article's authors and their perspectives. Furthermore, researchers were sometimes limited in their ability to code studies because of the often limited description of research settings in the original articles. Any systematic review is also constrained by the nature and scope of the original studies on which it is based.

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Figure 1: Interrelationships between building blocks of research

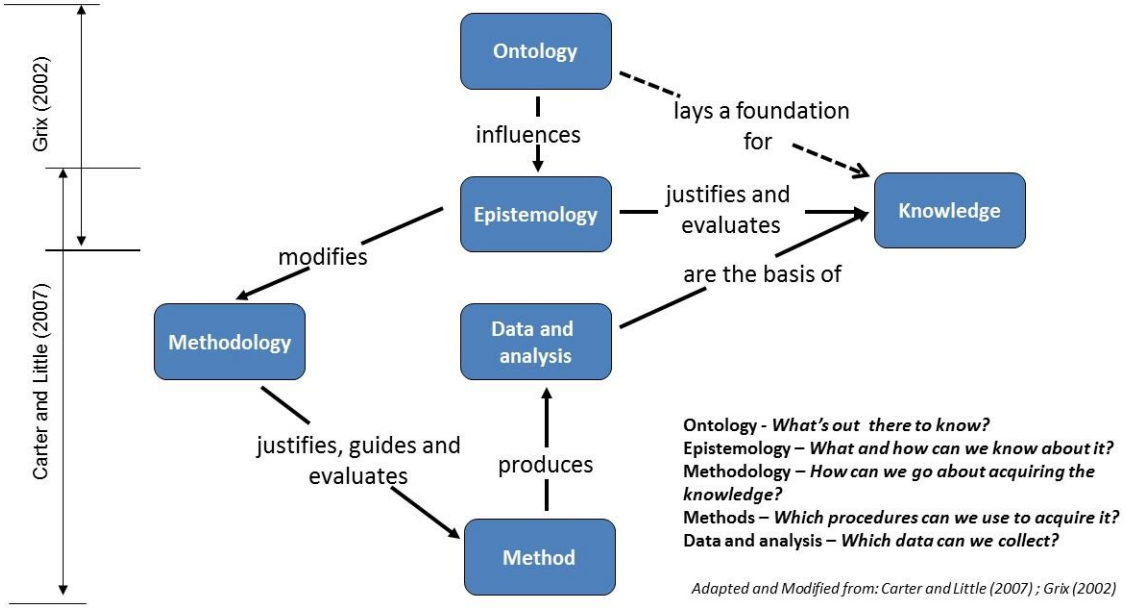


Figure 2: Selection process for the 104 reviewed papers

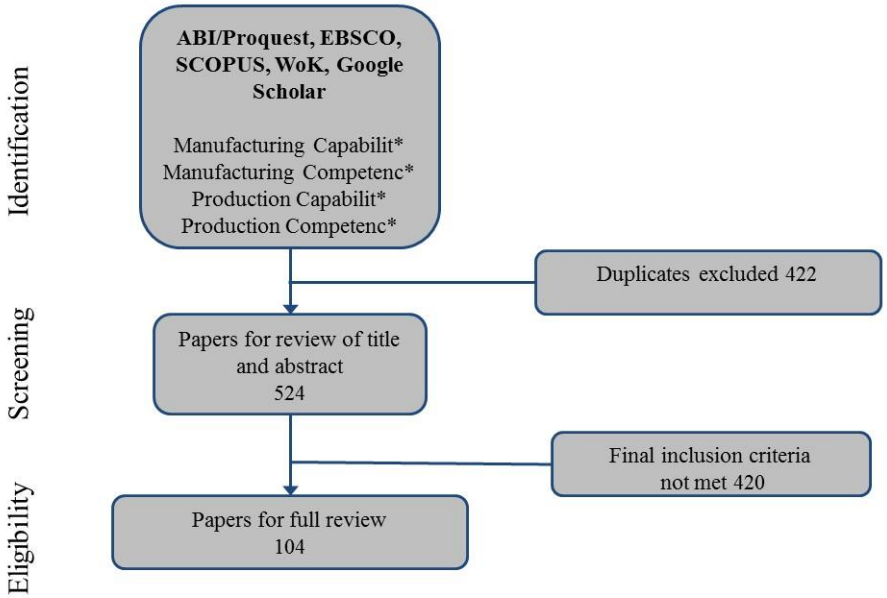


Figure 3: Flow-chart of procedures for qualitative content analysis

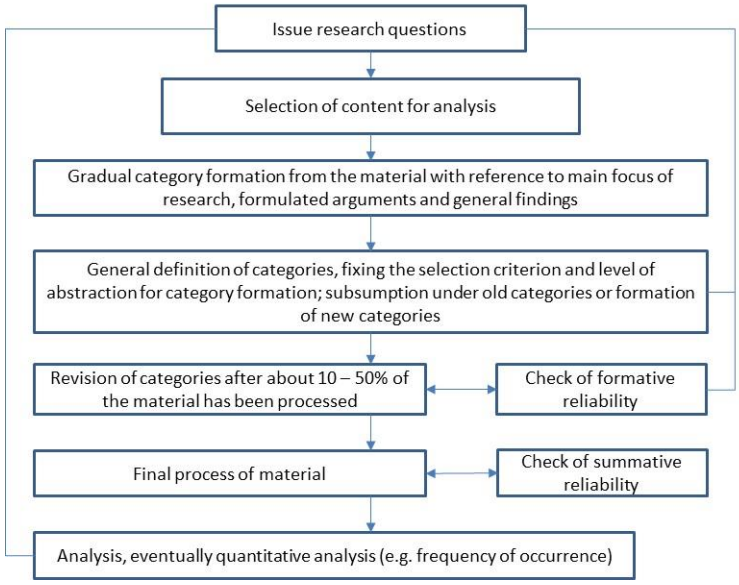


Figure 4: Timeline for the Distribution of Research Paradigms

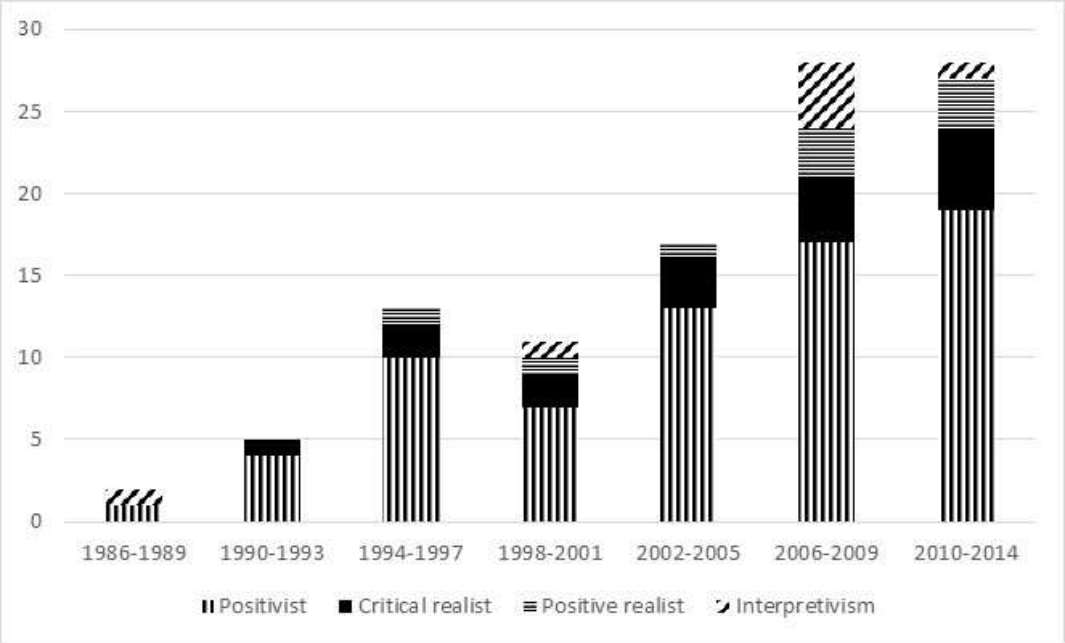


Figure 5: Content analysis results and emerging themes from manufacturing capabilities research

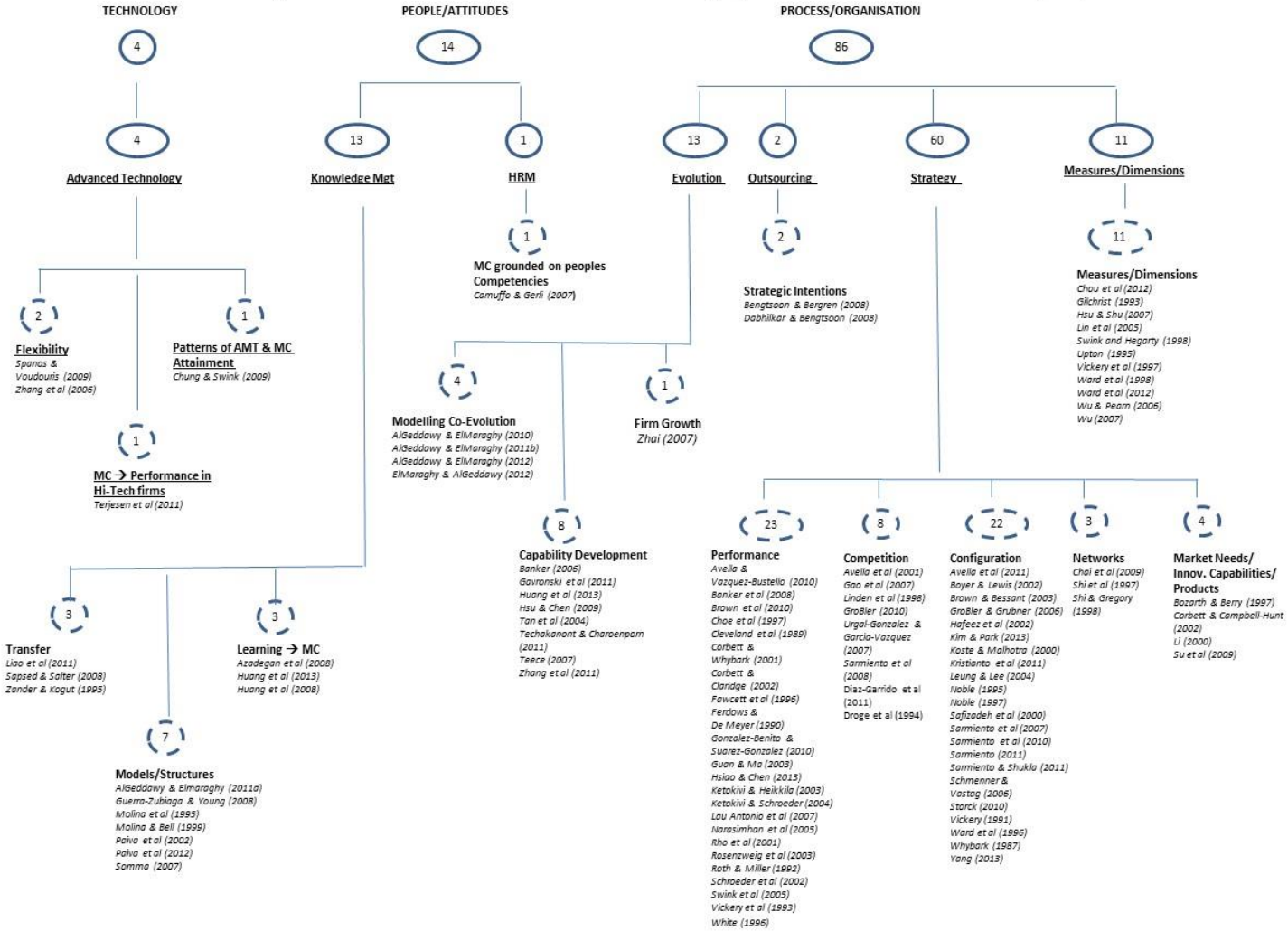
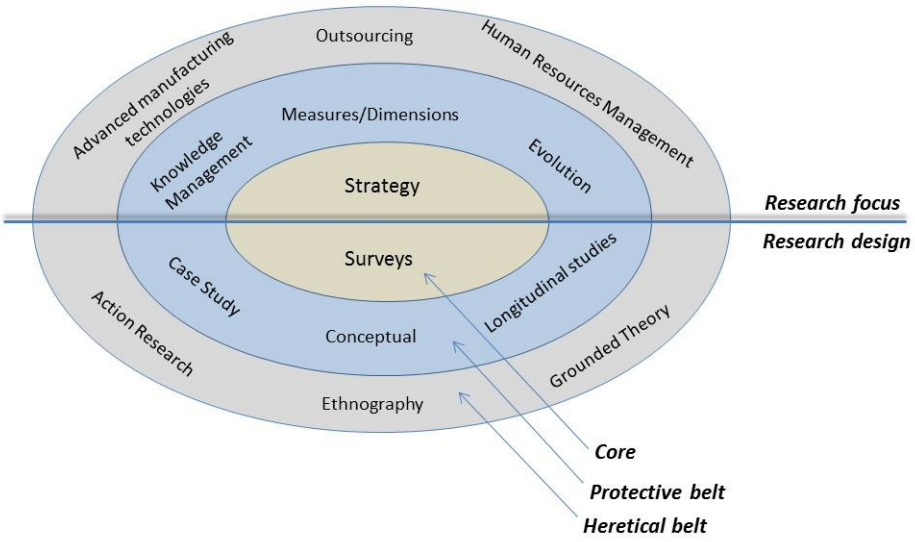


Figure 6: The focus of manufacturing capabilities research



Classification	*Categories*	*Examples of previous references using similar classifications*
Research Paradigm	Positivist / Interpretivist / Critical Realist / Positive Realist	Morgan and Smircich (1980); Denzin and Lincoln (2005)
Research Designs	Survey / Conceptual / Longitudinal / Case study / Experimental / Literature Review / other	Orlikowski and Baroudi (1991); Bryman and Bell (2007)
Research Methods	Surveys / Interviews / Observations / Simulation / Mathematical Modelling	Mentzer and Kahn (1995); Sachan and Datta (2005)
Data Analysis Techniques	Statistical / Modelling / Process Mapping / Content Analysis / Conceptual / Descriptive	Stuart et al (2002)

Table 1: Classification framework

Research Paradigm	***Selection Criteria***	***Examples of Methods Used***
Positivist	• Utilize natural science methods in social world • Objective approach devoid of 'human input'. Researcher detachment • Search for correlations between different social facts using statistical, mathematical or numerical evidence • Human behaviour described in terms of cause and effect	Surveys Questionnaires Statistical methods Math. Modeling Deductive
Positive Realist	• Utilize natural science methods in social world • Adopt more positivist approaches rather than critical realist. More likely to look for generalisations • Recognize the possibilities of human perceptions about the real world impacting upon their actions	Case studies Interviewing May have surveys May be contextual Participant observation
Critical Realist	• Reject the view that the world is created solely by the minds of human observers (Interpretivists). A mind-independent reality, which has its own order, exists • See things as being the case whether people recognise them or not (i.e. objectivity) • Causal explanation aiming to identify objects, structures and mechanisms that connect them that cause events to occur • Retroductive analysis of data i.e. take an outcome and try to explain it	Case studies Contextual Interviewing Participant observation Action Research Grounded Theory
Interpretivist	• There are no situations other than those which individuals create through their activities • Interested in people and trying to understand how their actions and their view of the world is structured • Researchers want to interpret these structures	Interviewing Observation Ethnography Discourse analysis Action Research Grounded Theory

Table 2: Research Perspectives

Year of Publication	***Frequency***
1980 – 1990	3
1991 – 2000	25
2001 – 2010	57
2011 – Date	18

Table 3: Year of publication

Most cited Journals	*Number*	*ABS Classification*
International Journal of Operations & Production Management	12	OTM
International Journal of Production Research	10	OTM
Journal of Operations Management	9	OTM
Decision Sciences	8	ORMS
International Journal of Production Economics	8	OTM
Institution of Mechanical Engineers Part B – Journal of Engineering Manufacture	3	N/A
Production and Operations Management	3	OTM
Omega	2	ORMS
Strategic Management Journal	2	M
Industrial Management and Data Systems	2	IM
CIRP Annals – Manufacturing Technology	2	N/A
Journal of Manufacturing Technology Management	2	OTM
Others	40	Management / Business (22); Operations Management (13); N/ A (Engineering / Technology focus -5).

Table 4: Most cited journals

Paradigm	*Frequency*	*Percent (%)*
Positivist (P)	69	66.3
Critical Realist (CR)	13	12.5
Positive Realist (PR)	11	10.6
Interpretivist (I)	11	10.6
Total	**104**	**100**

Table 1: Dominant Research Paradigms in Manufacturing Capabilities Research

Research Design	*Frequency*	*Total Frequency*	*Percent (%)*
Survey	P(53), PR(2)	55	53
Conceptual	P(16), I(4), CR(6), PR(2)	28	27
Case Study	I(4), CR(8), PR(4)	16	15
Longitudinal studies	P(1), I(3), PR(1)	5	5
Total		**104**	**100**

Key: P (Positivist); PR (Positive Realist); CR (Critical Realist); I (Interpretivist)

Table 2: Research Design in Manufacturing Capability Research (based on Guba and Lincoln, 1994)

Research Methods	*Frequency*	*Percent (%)*
Questionnaires (Surveys)	56	53.8
Interviews	18	17.3
Mathematical modelling	14	13.5
Conceptual (Thought pieces)	13	12.5
Literature review	3	2.9
Total	**104**	**100%**

Table 3: Research Methods in Manufacturing Capability Research

Data Analysis Methods	*Frequency*	*Percent (%)*
Statistical Analysis Methods (*Bayesian, Meta-analysis, regression, t-test, ANOVA*)	60	57.6
Conceptual/Descriptive	22	21.2
Modelling *(Cladistics, AHP, SW, Mathematical)*	14	13.5
Process Mapping	6	5.8
Content Analysis	2	1.9
Total	**104**	**100**

Table 4: Data Analysis Methods in Manufacturing Capabilities Research