KES Transactions on Sustainable Design and Manufacturing II
Sustainable Design and Manufacturing 2015 : pp.242-257 : Paper sdm15-027

Developing sustainable manufacturing strategies through practice maturity assessment

Lampros Litos[1], Steve Evans[2]

[1]Centre for Industrial Sustainability, University of Cambridge, CB3 0FS
ll443@cam.ac.uk
[2]Centre for Industrial Sustainability, University of Cambridge, CB3 0FS
se321@cam.ac.uk

Abstract *A lack of consensus on the definition of eco-efficiency in factories has led to a wide range of assessment approaches in the literature available for practitioners. The growing number of such solutions has been supported to a limited degree by research into the process of improving environmental performance (EP) through technical and managerial practices. Following up from their research activities on assessments of the maturity of practices in manufacturing, through the lens of organizational capabilities and resources, the authors present early findings from their work. These results are represented in maturity profiles and this generates a discussion on the implications that the level of maturity of practice has on manufacturing strategy formulation. The authors develop a conceptual framework to interpret the implication of the maturity profiles on manufacturing strategy and conclude with a proposition of five sustainable manufacturing archetypes that enhance business performance.*

1. Introduction

A strong debate related to environmental performance (EP) in manufacturing facilities, expands to the challenge of eco-efficiency that the World Business Council for Sustainable Development (WBCSD, 2010) still carries in its 2050 vision. The WBSCD envisions a four to tenfold improvement in energy and resource efficiency in manufacturing through practices that enhance EP as well as business performance and are encapsulated in the phrase “doing more with less” or alternatively “co-efficiency”. However, practitioners remain troubled in their daily tasks in operations and production management as “doing more with less” is not instructive and multiple definitions of eco-efficiency in the literature do not clarify the objectives (Henri and Journeault, 2009). Measuring the effect of specific EP improvement actions, such as the energy savings from a one-off installation of a new air-compressor, can be quite straightforward as well as costly. In that sense, the request for “doing more with less” is not fully satisfied (Hellweg et al., 2005). In addition, one-off actions, that demand the expenditure of limited resources (capital), do not really reflect the continuity that “doing” implies.

In contrast, management practices are continuous in operations and production and these can offer business value when applied consistently and with passion for improvement. The value that EP improvements could be delivered through practice is explored through different research agendas that look into assessment methodologies, process improvement methodologies or even high-level manufacturing strategies. In table 1 the authors provide their understanding of practice performed (fourth column) in a collection of cases of EP and business performance improvement. The list indicates the breadth of options for improvement in manufacturing and potentially what that entails for the formulation of strategy today.

Table 1. Summary of Positive Links Between Environmental and Economic Performance – Authors' comments in 4th and 5th column:

			Additional considerations by the authors for discussion	
Business strategy	Circumstances making this possibility more likely	Example	*Type of practice (solution type)*	*Implication for manufacturing strategy?*
1) Better access to certain markets	More likely for firms selling to the public sector (construction, energy, transportation equipment, medical products, and office equipment) and to other businesses.	The Quebec government now cares about the environmental performance of all vehicles it buys, not only about the price.	*Product life-cycle management. Developing links with government authorities for guidance.*	*What do we need to change in product development and supply chain management?*
2) Differentiating products	More likely when there is: a) Credible information about the environmental features of the product b) Willingness-to-pay by consumers c) Barrier to imitation. Wide range of possibilities.	Toyota has announced that all its models will be available with hybrid engines in 2012.	*Corporate social responsibility and product life-cycle technologies*	*What is the level of information that we need to collect and manage about the product performance throughout its life-cycle? How do we communicate our manufacturing competence to our customers?*
3) Selling pollution-control technologies	More likely when firms already have R&D facilities	Alcan has patented a process to recycle its own spent potlining *(scrap recycling process)*, and that of other companies.	*Process recycling and business opportunity.*	*How do we secure that novel manufacturing technologies convert to competitive advantage? How do we engage best with new business partners in a local level?*
4) Risk management and relations with external stakeholders	More likely in industries that are highly regulated and scrutinized by the public, such as chemical, energy, pulp and paper, metallurgy, etc.	Statoil injects 1 million tons of CO2 a year beneath the seabed of the North Sea, thus avoiding the Norway carbon tax.	*Carbon-capture and storage is a bolt-on process to secure reduced CO2 emissions. A 30-year old practice re-surfacing due to legal pressures.*	*If CO2 emissions have not always been part of the core pollution control strategy, how do we adopt new technologies and capabilities in our manufacturing strategy? Reactive or proactive solutions?*
5) Cost of materials, energy, and services	More likely when: a) Firms have a flexible production process b) Firms are in highly competitive industries where optimization of resources is important c) Firms are in industries where market-based environmental policies are implemented d) Firms already have R&D facilities.	BP has reduced its emissions of GHGs 10% below their level in 1990 at no cost by implementing an internal tradable permit mechanism.	*Internal process re-configuration and incentives to improve through innovative reward schemes.*	*How do we change the way we communicate threats to our business to our manufacturing sites and personnel? How do incentives and reward systems address challenges in business level?*
6) Cost of labor	More likely for: a) Firms whose emissions may affect their workers' health b) Firms that seek to attract young, well-educated workers c) Firms located in areas where sensitivity to environmental concerns is important.	A 2004 survey of Stanford MBAs found that 97% of them were willing to forgo 14% (on average) of their expected income to work for an organization with a better reputation for corporate social responsibility.	*Reputation and political acumen drive HR practices and recruitment standards – see natural resource based view (Hart, 1995; Russo and Fouts, 1997).*	*Can we compensate cost of labor by evaluating and communicating the value that our manufacturing capabilities carry?*

In this study the authors demonstrate early findings from the application of an eco-efficiency assessment tool for manufacturing facilities. Eco-efficiency is defined as the ratio of economic value added per environmental improvement action performed. This definition is consistent with literature (Henri and Journeault, 2009; Huppes and Ishikawa, 2005), but since there is no standardized method to measure eco-efficiency ratios, this study is focusing more on the qualitative assessment of manufacturing practices and the environmental and economic benefits that these can deliver.

The assessment tool used is based on a maturity grid of practices developed by this paper's authors in previous work (Litos and Evans, 2015, 2014). The notion of maturity is used to address the level of organizational competence when dealing with externalities and is used by several authors to assess the performance of organizational capabilities in various subject areas (Maier et al., 2012). The results from the assessment are presented in the form of eco-efficiency maturity profiles and this visualization consecutively generates a discussion about the interdependencies between the maturity of practice and manufacturing strategy; an area of growing interest in the literature but yet limited in recommendations for practitioners.

In the following sections in this study, the authors present their motivation to study the implications of environmental challenges on manufacturing strategy and similarly the implications on management practice in manufacturing facilities (table 1). In section 2, background work and results from the use of an eco-efficiency maturity tool are presented. The results are presented as maturity profiles and an interpretation of these results is required to understand how practice maturity and organizational capabilities are effectively linked to strategic goals (table 1).

In section 3, the authors demonstrate a conceptual framework that demonstrates the possible interdependencies between relative dimensions of eco-efficiency and discuss (section 4) how manufacturing strategy can be the missing link in interpreting the results from the maturity profiles in section 2. Based on that discussion, a set of manufacturing profiles/archetypes is proposed following the structure of the maturity grid dimensions and relate this proposition back to business strategies from section 1. This set of manufacturing archetypes is part of on-going research.

In table 1, adopted by Ambec and Lanoie, the authors comment on the type of practice that led to improved EP in manufacturing companies while responding to business threats (Ambec and Lanoie, 2008). The table is provided here as it drives the discussion that follows on business strategy when it has to respond to environmental externalities and the implications this may have on manufacturing strategy and practice.

2. Background and results from

2.1 Environmental performance assessment in factories

Environmental performance (EP) measurement and management in factories has long been a central theme in the literature for sustainable manufacturing (Abdul Rashid et al., 2008; Bourne et al., 2002; Perego and Hartmann, 2009). Of particular interest for practitioners and academics is the common ground between environmental and economic benefits that occur through implementation of improvements (Christmann, 2000; Ciroth, 2009; Figge and Hahn, 2005). In pursue of achieving higher results in these two dimensions of performance, alternatively the eco-efficiency ratio (Huppes and Ishikawa, 2005), two approaches have been developed in the literature: quantitative and qualitative ones.

2.2. Quantitative and qualitative approaches of eco-efficiency

Understanding eco-efficiency in production and operations, through numerical evidence and composition of simple or even complicated indicators has been favored through access to data from monitoring measurement systems and surveys in industrial sectors (Abdelaziz et al., 2011; Bourne et al., 2002; Önüt and Soner, 2007; Singh et al., 2007; Zhou et al., 2012). In parallel, quantitative and semi-quantitative approaches have been used to assess the cost-effectiveness of environmental management systems like ISO 14000 (Barla, 2007; Newbold, 2006). Through these studies however, the practitioners may be receiving mixed signals related to the benefits of using quantitative methods to carry out eco-efficiency improvements. The reason for that is that measurement and monitoring systems need to be carefully designed in order to produce reliable data for performance improvement actions (Neely et al., 2005). In parallel, through assessing the effectiveness of environmental management systems, the importance of management practices is becoming noticed.

Management practice and organizational routines' effectiveness is not easy to assess quantitatively in terms of the energy and resource efficiency benefits (Bandehnezhad et al., 2012; Christmann, 2000; Henri and Journeault, 2009). Study of the success factors that enabled the delivery of EP improvements in organizations is paramount in understanding that impact. A growing body of literature is concerned with the impact of management practices on EP (Bocken et al., 2013; Despeisse et al., 2012; Litos and Evans, 2015). Various qualitative studies have demonstrated how this mechanism of improvement works through participatory research (Rothenberg, 2003; Yin, 2003). Several authors have contributed to the study of eco-efficiency through qualitative research methods (Claver et al., 2007; Hassini et al., 2012; Holton et al., 2010; Kerr and Ryan, 2001) and have made recommendations for manufacturing systems' design, operations, decision making processes, manufacturing strategy formulation or knowledge management.

2.3 Environmental performance and management practices

The findings implicate organizational resources and capabilities (Darnall and Edwards, 2006; Mills et al., 2002) and several theoretical frameworks have been proposed to link these with EP measurement and management practice as well as manufacturing strategy formulation (Sharma and Vredenburg, 1998). Perhaps the most relevant theory in that respect is the natural resource-based view of firm (Grant, 1991; Hart, 1995; Russo and Fouts, 1997).

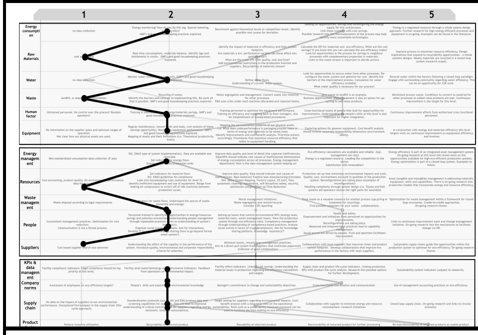
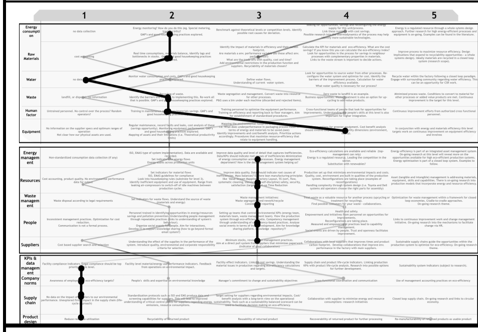
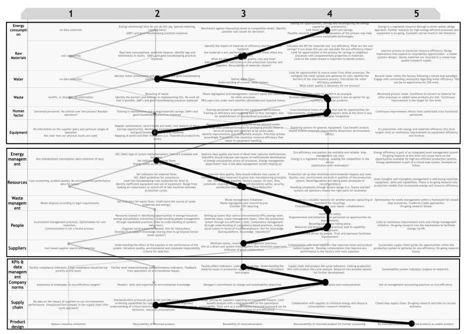
2.4 Eco-efficiency assessment in manufacturing

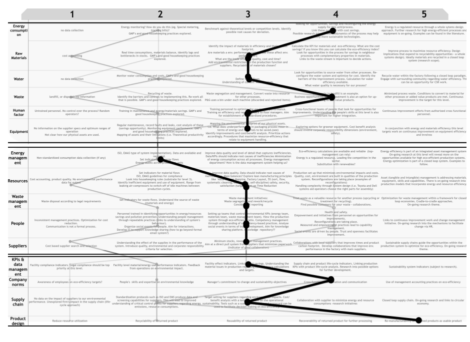
The authors in this paper, developed and presented in previous study a qualitative eco-efficiency assessment tool based on the natural resource-based view of the firm (Litos and Evans, 2015). The tool is in essence a maturity grid that follows the definition of maturity and design principles that Maier et al., have identified (Maier et al., 2012). The tool has been tested for eco-efficiency self-assessment in factories, workshops platform and as a semi-structured interview guide for case study research. In this study, the authors report their results from its use in the form of self-assessment maturity profiles after using the tool with practitioners in four different manufacturing sectors (anonymized in this study): automotive, construction materials, optical systems and packaging materials.

This maturity profile analysis (table 2) is inspired by the work of Baumgartner and Ebner and seeks to understand the link between the maturity of practice and sustainable manufacturing strategy (Baumgartner and Ebner, 2010). However, the academic discussion on environmentally sustainable manufacturing strategy has been growing over recent years and has produced limited and variable results. The variety of approaches of sustainable manufacturing strategy can be attributed to its elusive nature, as it has to be aligned with the corporate business strategy and this amplifies the discussion ground (Brown and Blackmon, 2005). On that note, the boundaries of the discussion around sustainable manufacturing strategy may extend from corporate social responsibility (Hahn, 2013; Schaffel and La Rovere, 2010; von Geibler et al., 2006) to de-materialization of products and product life cycle management (Ball et al., 2009; Jenkins and Yakovleva, 2006; Saling et al., 2002) or process re-configuration (Ball et al., 2009). An internal dimension of manufacturing strategy is its embedded degree of pro-activity that has been found to relate positively with environmental risks and externalities (Aragón-Correa et al., 2008; Holton et al., 2010; Sharma and Vredenburg, 1998). To summarize, there is a clear signal that the sophistication and proactivity levels of management practice are related to manufacturing strategy, which is further affected by the business strategy. The way that this system interacts will be part of the analysis to follow in this study.

In section 3 the authors present their framework of analysis, that links manufacturing strategy, organizational capabilities and resources and practice maturity and guides this study at high-level. This study contributes to the body of literature related to sustainable manufacturing strategy formulation (Abdul Rashid et al., 2008) by seeking to translate the maturity profiles collected into meaningful recommendations for strategy practitioners. The study is concerned with linking the natural resource based-view of the organization with eco-efficiency. A conceptual framework is produced (section 3) that links the maturity assessment work and results (table 2) with manufacturing strategy. An attempt to analyze 5 differentiated manufacturing strategies based on this framework is presented in discussion as part of the authors on-going research efforts (table 4).

Table 2. Results in the form of maturity profiles for four manufacturers. In each case, the top segment relates to practices at process layer (6 dimensions), the middle segment to practices at facility layer (5 dimensions) and the bottom segment to practices at top-management layer (4 dimensions).

Self-assessment maturity profiles *Maturity levels left to right (1->5) and results* *Management layers: Process (top), facility (middle), top-management (bottom)*		Authors comments and considerations for leverage to support decisions for manufacturing strategy formulation
	2 1 2 1 2 2 2 1 2 2 1 2 2 2 2	**Automotive** External assessment on manufacturing practices in the automotive sector. The assessor provided her view on the maturity of manufacturing practices in the automotive factory that she had formerly worked for. The authors allowed this assessment to be part of this study as it demonstrates that a third-party assessment is one of the possible applications. Particularly, when the assessor has spent time consulting or advising factory managers for best practice. In this case the results indicate low or business-as-usual practice implementation across most of the EP dimensions of the maturity grid.
	2 2 1 2 2 4 3 3 3 3 3 1 1 1 1	**Optics** The production manager of a large manufacturing facility of optic systems assessed the maturity of practices they implement across the organization. There is a clear signal that top-management is not supporting implementation of energy and resource efficiency practices, even though his assessment suggests that middle manager's competence at facility level is much better. A gap exists further at the maturity of practices at process level, with the attention given to equipment performance to exceed other areas of EP. Middle management competence could be key to communicating EP issues to strategy level.
	4 3 2 4 4 2 2 3 4 4 3 3 4 2 5	**Construction materials** The production manager from a construction-materials company in the UK touches on multiple maturity levels (ML) across their organisation. The assessment indicates that there is a clear interest across all organizational layers to deliver improvements on energy and resource efficiency. The authors note that the product's nature allows for re-manufacturability and this can be considered as an catalyst for certain types of practices, particularly in the area of waste management (achieving maturity levels of 3 and 4 in the grid). It could also be key to supporting EP improvement initiatives at strategy level (i.e. life-cycle design).

	4 3 3 4 3 3 2 3 3 3 3 3 4 3 5	**Packaging materials** The technology manager of a packaging solutions manufacturer demonstrates that his company is already working on energy and resource efficiency and most of the EP dimensions of the maturity grid include practices in levels 3 (10 out of 15 areas) and level 4 (3 out of 15). There is an inconsistency of maturity of practices related to energy consumption at process level (ML 4) and energy management (ML 2) which calls for further investigation. In addition the authors note that the product (metallic) allows for re-manufacturability (ML 5) and this is reflected at process waste (ML 4) – internal re-cycling and collection of returned/re-called products or recycled products, zero-waste to landfil.
***Note to the reader**: the maturity profiles in this table represent the perceptions of managers in each company and are subjective. As this study is concerned with the long-run interpretation of these profiles and their link to manufacturing strategy, further analysis on the maturity profile and EP that each company exhibits is not part of this study.* *As these results are part of on-going research into the maturity of practice in manufacturing and EP, the authors will be collecting more maturity profiles from each of these companies in this table in separate case studies.*		

3. Conceptual framework for analysis and results

In figure 1, table 3, the authors present a generic conceptual framework that combines 3 knowledge disciplines that have been found to have significant impact on EP improvement actions and planning in manufacturing. The purpose of this framework is to clarify the boundaries of the area of knowledge that the authors would like to contribute into (area B in figure 1). However, in order to provide more context and further references for the reader, table 3 provides a list of sources that reflect on the impact of the strategy, resources and practice on EP and the areas in between A and C.

The body of literature represented by area B is quite limited. Through their previous study using the maturity grid of practices and organizational capabilities the authors seek to understand the implications for manufacturing strategy formulation. The research tool developed provides a 5-level maturity assessment of practices in manufacturing. It is broken down into three cascading management layers (process, facility and top-management). Each layer is broken into certain dimensions of EP and it is populated with examples of practices drawn from the literature that demonstrate clear EP improvement potential. Overall the framework consists of 15 rows/dimensions of performance split in 3 organizational layers of management and 5 maturity levels (columns). The grid is populated with examples of practices in each dimension with a sequence from left to right of growing maturity (Litos and Evans, 2015).

The practitioners that took part in the self-assessment exercise were asked to reflect on the practices that they currently implement in their facilities. The self-assessment exercise was not strict, in the sense that the authors were interested in gaining insight into the system's behavior by examining the maturity profiles. This is the reason that the contents of the cell were populated with descriptive examples of practices (Fraser et al., 2002) rather than with numbers of performance (i.e. percentage of energy saved in each level). The practitioner would consider these as headlines to a certain type of behavior (i.e. reactive or proactive to externalities) and relate to that if applicable.

Table 3: A conceptual framework of interactions between manufacturing strategy, organizational resources & capabilities and practice maturity. In the left column there is the list of literature sources that influenced the framework and reflect on the impact of strategy, resources and practice on EP and the areas in between A and C

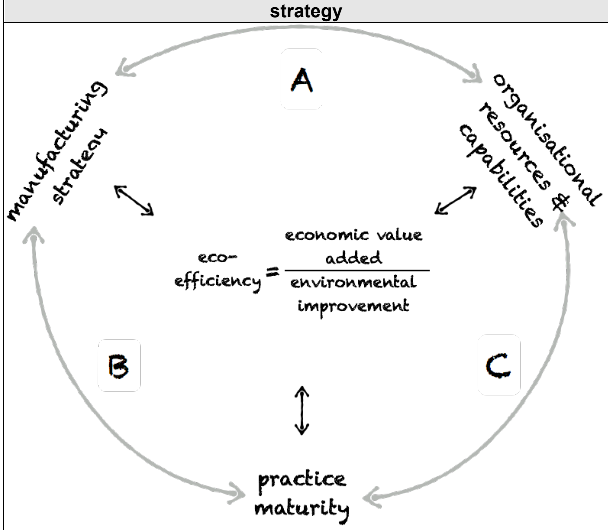
<table>
<tr><th>Framework of practice maturity, organizational capabilities and strategy</th><th>Supporting references:</th></tr>
<tr><td rowspan="6">

Figure 1. Conceptual framework for eco-efficiency
Definition of eco-efficiency provided by Huppes and Ishikawa, 2005</td><td>Manufacturing strategy & EP
(Abdelaziz et al., 2011; Abdul Rashid et al., 2008; Bereketli and Erol Genevois, n.d.; Grant, 1991; Sharma and Vredenburg, 1998)</td></tr>
<tr><td>Organizational resources and capabilities & EP
(Cagno and Trianni, 2012; Crick et al., 2013; Farris et al., 2009; Hart, 1995; Russo and Fouts, 1997; Trianni et al., 2013)</td></tr>
<tr><td>Practice maturity & EP
(Baumgartner and Ebner, 2010; Litos and Evans, 2015; Ngai et al., 2013; Ormazabal and Sarriegi, 2012)</td></tr>
<tr><td>Interaction area A
(Aragón-Correa et al., 2008; Brown and Blackmon, 2005; Elliot, 2011; Grant, 1991; Russo and Fouts, 1997)</td></tr>
<tr><td>Interaction area B – limited literature
(Abdul Rashid et al., 2008; Dangayach and Deshmukh, 2001; Baumgartner and Ebner, 2010)</td></tr>
<tr><td>Interaction area C
(Fraser et al., 2002; Maier et al., 2012; Păunescu and Acatrinei (Pantea), 2012; Subic et al., 2012; Witcher et al., 2008)</td></tr>
</table>

The results of that exercise are demonstrated in table 2 along with comments about the manufacturing strategy and practice maturity. The profiles are compared between organizational layers of the same company not between the same layers (i.e. process maturity) of different companies. The comparison between companies on the same organizational layer is part of the discussion about manufacturing strategy in the following section.

4. Discussion

Environmental performance in factories has been studied through literature on benchmarking between factories and production processes. Through an investigation of manufacturing practices with a positive environmental impact (Litos and Evans, 2015) the same authors design a 5-level maturity grid for EP improvements that spans across 3 layers of management: process, facility and manufacturing as business unit (top-management). The maturity grid is used as a self-assessment tool with four companies and the results are represented in maturity profiles, inspired by the work of Baumgartner and Ebner (Baumgartner and Ebner, 2010). Baumgartner and Ebner conceptualized the various options for manufacturers in the form of strategy profiles along a set of sustainability dimensions, similarly based on a triple-bottom line maturity framework (Elkington, 1997). The scope of their study is quite wide as it covers the business area (customers, technology, market position etc.) as well as the manufacturing area (health and safety, pollution, governance etc). However, their profile study is not supported by empirical data and is mostly based on literature reviews. The discussion on sustainability strategies however remains interesting and this study adds more light into developing a process that supports sustainable manufacturing strategy formulation.

The scope of this study is narrowed down to the manufacturing area and particularly the economic and environmental performance in factories (Ehrenfeld, 2005; Ekins, 2005). The framework's purpose (figure 1) is to help the practitioner understand which areas of knowledge are combined. It focuses on the interactions between the three key concepts presented: manufacturing strategy, practice maturity and organizational resources/capabilities. The common ground for these areas is EP improvement in manufacturing facilities (centre). The surrounding knowledge disciplines (framework constructs) and their relationships with environmental performance in factories (figure 1, bold centre-oriented arrows) have been documented in the literature to some degree and are not the main focus here. Through this study the authors seek to understand the interdependencies between these constructs (figure 1, grey circular arrows) and add detail to a growing body of literature related to environmental strategy formulation and management practices.

The relationship between manufacturing strategy and organizational resources and capabilities has been studied extensively in the literature and particularly within the resource-based view theory (Aragón-Correa et al., 2008; Darnall and Edwards, 2006; Grant, 1991; Hart, 1995). One of the key ideas that this study intends to highlight and support with evidence, is the opportunity for companies to build up on existing capabilities in order to address certain challenges that sustainable manufacturing brings (WBCSD, 2010). For instance, companies that have been working along the ISO 9000 standards find it easier to adapt to environmental management protocols such as ISO 14000 or similar as the tools and techniques used are already familiar to them (Claver et al., 2007). More specifically, the company under investigation, had an implemented certified quality management system in place and Claver et al., observed that, as pollution prevention is similar to total quality management in terms of employee involvement and continuous improvement practices, the synergies derived from the knowledge and experience accumulated through practice in the quality area could be further extended to other areas.

Table 1 links results achieved in companies under specific circumstances through implementation of practices with environmental and financial benefits. It is not always clear though what the practice that best suits in each case is or what resources the organization has to employ in order to achieve eco-efficient results. From a contingent perspective, two firms with similar resources (similar physical assets, technologies, and human skills) may develop different environmental strategies and/or obtain differential levels of competitive advantage with similar environmental strategies (Aragón-Correa and Sharma, 2003).

Table 4. Proposed set of strategy archetypes along the dimensions of EP (same dimensions and grouping as in the maturity assessment grid (Litos and Evans, 2015))

Dimensions of EP as presented in the **maturity self-assessment**	Manufacturing strategy options and EP Reactive--------→Proactive				
	Legal compliance –customer standards	*Productivity and cost*	*Reduce resource intensity*	*Product stewardship*	*Lean and Green*
Supporting literature →	*(Foster et al., 2000)*	*(Hellweg et al., 2005)*	*(Abdul Rashid et al., 2008)*	*(Bereketli and Erol Genevois, n.d.; Kerr and Ryan, 2001)*	*(Rothenberg et al., 2001)*
Dimensions of eco-efficiency	**Process level (priority degree: Little | Some | A lot)**				
Energy consumption	*Some*	*Some*	*A lot*	*A lot*	*A lot*
Materials consumption	*Little*	*A lot*	*A lot*	*Some*	*A lot*
Water consumption	*Some*	*Little*	*Some*	*Some*	*A lot*
Process waste/pollution	*Some*	*Some*	*Some*	*Little*	*Some*
Human factor impact	*Little*	*Some*	*Some*	*Little*	*Some*
Equipment performance	*Some*	*A lot*	*A lot*	*Some*	*Some*
	Facility level				
Energy management	*Little*	*Little*	*Some*	*A lot*	*Some*
Resource management	*Some*	*Some*	*A lot*	*Some*	*A lot*
Waste management	*Some*	*Little*	*A lot*	*Some*	*A lot*
People (HR)	*Little*	*Some*	*Some*	*Some*	*Some*
Supplier relationships	*Some*	*Some*	*Some*	*A lot*	*A lot*
	Business-unit (top-management)				
KPIs & data management	*Little*	*Little*	*A lot*	*A lot*	*Some*
Company norms	*Little*	*Some*	*Some*	*Some*	*A lot*
Supply chain	*Some*	*Little*	*Little*	*A lot*	*A lot*
Product development	*Some*	*Little*	*Some*	*A lot*	*Some*
Related examples from table 1	*1, 6*	*5*	*3, 5*	*2, 4, 6*	*2, 5*

Following up from a body of literature related to strategy process formulation (Mills et al., 2002; Platts, 1993; Platts et al., 1998) the authors don't focus on setting goals to drive EP. They propose the development of a process that connects the relative business priority on certain dimensions of EP (drawn from the maturity grid) with sustainable manufacturing strategy archetypes. The set of strategy archetypes and the relative degree of focus on EP dimensions is demonstrated in table 4 for guidance only (at this stage of the research).

The argument behind table 4 is not to suggest that strategy A is better than strategy B. The authors propose that different manufacturing strategies, aligned to business strategy, have different impacts on the resources available for EP improvements and the types of practice that can support these. However, practice maturity can also be an indication of the efficiency potential across various dimensions of EP. The level of maturity in each dimension can highlight more options for managers and help them make coordinated improvement actions with other business stakeholders.

The archetypes provided in table 4 are sorted from left to right in regards to the element of pro-activity that these embed. Proactive manufacturing strategies have been found to have a more positive effect on EP than re-active (Aragón-Correa and Sharma, 2003; Buysse and Verbeke, 2003) however, the authors acknowledge that certain options require additional organizational resources. In that respect, adding more complexity in manufacturing systems may not be the best way forward and priority should be given to dealing effectively with legal or customer requirements.

In parallel, one of the arguments that this table proposes, is that advanced and more proactive environmental manufacturing systems are less selective in the areas that benefits can be pursued. As Ferdows and Thurnheer suggest in their study of a generic improvement and change program (in terms of quality, safety etc.), multiple dimensions of performance are found to improve when a company embarks on such initiatives (Ferdows and Thurnheer, 2011). Similarly, the authors here, project that notion through table 4 and suggest that as production systems become more proactive, more dimensions of EP become important or that dimensions of EP (i.e. process waste/pollution) are enhanced as correlated to other improvement actions (i.e. product development and re-manufacturability).

5. Conclusion and future agenda

This study focuses in the interdependencies between management practices and manufacturing strategy and their attributes to energy and resource efficiency actions in production facilities. The authors present the maturity profiles from four manufacturers in the UK. Managers from each company provided their self-assessment based on the maturity framework previously developed by the authors. A conceptual framework of interactions between practice maturity, organizational capabilities and manufacturing strategy is developed to translate the maturity profiles into meaningful recommendations for practitioners at various organizational positions. The analysis leads to a proposition of sustainable manufacturing strategy archetypes that reflect on the environmental performance dimensions set in the maturity assessment framework. The proposed archetypes demonstrate the link between dimensions of EP and practice maturity in the formulation of the manufacturing strategies. More data however are essential to generate a robust framework that practitioners can follow with confidence in strategy formulation and it is the intention of the authors to continue collecting and analyzing maturity profiles of management practices through their work on eco-efficiency.

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