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Open Manufacturing: Impacts of Resource Based View and Servitisation

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Abstract
The environment of manufacturing has faced significant changes in the past decade. Meanwhile, the traditional focus of manufacturing strategy is also impacted by resource-based view and servitisation. Thus, no matter from a practical or theoretical perspective, it is time to rethink what kind of view we can have on manufacturing. In this paper, the literature is reviewed firstly to track the evolution of theories on manufacturing strategy and to investigate new views on manufacturing from a theoretical perspective. This is followed by three case studies, which are used to explore how manufacturing is used from a practical perspective. The usages of manufacturing are classified into three groups and their relationships are discussed further. Based on these findings and inspired by open source software (OSS) and open innovation, a new paradigm on manufacturing termed as "*open manufacturing*" is proposed in the combination of new views on manufacturing both from theoretical and practical perspective.

Keywords: Manufacturing strategy, resource based view, and servitisation.

1. Introduction

The environment of manufacturing has faced significant changes in the past decade. The most notable challenges are increased levels of complexity and uncertainty [1], coming from four aspects: 1) increased global operations [2]; 2) diversiform customer demands varying from manufacturing goods alone to service and knowledge associated with the goods [1]; 3) shorter product lifecycles and delivery times; 4) fast evolving technology [3]. In order to compete within these contexts, manufacturing can no longer be simply viewed as a "good corporate citizen" or "team player", which is therefore willing to wait for requests and directions from others [4]. Instead, as some researchers have pointed out [5], manufacturing is regarded as an important element of the company's knowledge base, thus contributing to redefine, and move beyond its traditional role of "transforming" materials into components or finished products.

Meanwhile, the traditional focus of manufacturing strategy, i.e. competing through manufacturing by aligning manufacturing capabilities with market requirements, is considerably impacted by two theoretical lenses: resource-based view (RBV) and servitisation [6]. On one hand, the development of RBV [7] brings a major influence on the way in which we have viewed manufacturing strategy. On the other hand, along with the servitisation of manufacturing companies [8], competing through manufacturing capabilities is rapidly evolving into competing through the manufacturing and service capabilities [6].

Therefore, no matter from practical or theoretical perspective, it is time to rethink what kind of view we can have on manufacturing and reconsider how to formulate manufacturing strategy corresponding to above challenges. In order to fundamentally understand these present developments on manufacturing, the literature is reviewed firstly in this paper to track the evolution of theories on manufacturing strategy and to investigate new views on manufacturing from theoretical perspective. This is followed by three case studies, which are used to explore how manufacturing is used from practical perspective. The usages of manufacturing are classified into three groups and their relationships are discussed further. Based on these findings and inspired by open source software (OSS) and open innovation, a new paradigm on manufacturing termed as "*open manufacturing*" is proposed in the combination of new views on manufacturing both from theoretical and practical perspective.

2. Literature review—Evolution of theories on manufacturing strategy

Until the early 1980s, most managers tended to accept "one best way" to design any manufacturing system and assumed that the key to low cost was standardisation and high volume, that work was done most efficiently when divided up and assigned to specialists, that managers and experts should do the thinking for workers, that every process was characterised by an innate amount of variation, and that communication within an organisation should be tightly controlled as dogma [4]. However, this assumption was disputed by a number of critics over the year and received its most effective challenge from Skinner [9]. Skinner [10] argues that companies could not achieve excellence on every manufacturing task. Therefore, there is a trade-off among all the manufacturing tasks. In his opinion, it is possible for companies to focus on certain key factors for certain market by using the focused factory and the plant within a plant. In this case, the paradigm of development of manufacturing strategy is essentially a contingent approach based on need to attain internal and external consistency [11] [12] [13] [14] [15] and dominated by the notion of strategic fit and focus [16]; that is, a company's manufacturing system should reflect its competitive position and strategy. Within the perspective of fit and focus the strategic role of manufacturing can be described by its location and contribution to the value chain of a company, following the ideas of Porter [17]. Failure to match with external business, product and customer factors can lead to mismatch with the market and consequently erosion of market share [18].

However, these theories were challenged by the performance of Japanese companies in 1980s. At that time, most Japanese companies were producing similar products to those offered by western companies, but at the same time they achieved lower cost, higher quality, faster product introductions, and greater flexibility [19] [20]. They often produced myriads of products for different markets in large and unfocused plants. Their success, evidently, was not built around notions of fit and focus [4]. The influential 1990 book "The Machine that changed the world" trumpeted the virtues of this approach, which it termed lean manufacturing [21]. Ferdows and De Meyer [22] argue that different competitive priorities are not necessarily in conflict with one another, but instead, they could even reinforce one another. Hayes and Wheelwright [23] provide the concept of world class manufacturing (WCM), and Schonberger [24] has adopted the term.

Apparently, according to Wheelwright & Hayes [25], previous research mostly focuses on the first three stages of the strategic role of manufacturing [26] [27]. Without being viewed as a source of potential competitive advantage, manufacturing deals with the question of how to pursue specific competitive priorities efficiently and effectively (through implementing best practice) according to changes in corporate strategy, market strategy and the internal and external environments [25] [28]. These reactive usages of manufacturing have been described by Hill's manufacturing strategy framework [11]. The consequence of restricting manufacturing's role in this way, however, is that it is forced to wait for others to give it direction and take the lead. Worse, as a result, manufacturing often is expected to compensate somehow for the delays and deficiencies resulting from the incomplete or flawed activities of these other groups [4]. It is less clear how much freedom manufacturing should have to develop competences that go beyond immediate requirements [29]. However, Wheelwright & Hayes [25] also indicated that there is still the fourth stage (externally supportive) of manufacturing to achieve, in which manufacturing is seen as providing the foundation for the firm's future competitive success and long-rang programs are pursued in order to acquire capabilities in advance of needs. Being creative and proactive, manufacturing needs to coordinate with other functions, as well as being regarded as an equal partner of other functions and expected to play a major role by changing the way in which the remaining organisation thinks about manufacturing and helping them see the world in a new way. These are also supported by more works, e.g. [5], [11] and [30].

During the 1990s, the problem of how organisations can deal successfully with unpredictable, dynamic and constantly changing environments has been a prevailing topic both in industry and academia. A new solution for managing a dynamic and changing environment emerged: agility, which is defined as the capability of manufacturing systems to meet the rapidly changing needs of the marketplace [31]. In this case, despite offering thinking about the nature of industrial competition, analysing specific competitive situations, and providing concepts and tools to translate competitive priorities into operations decisions, a contingent theory based solely on such static concepts as fit, focus and trade-off seems lacking in important respects. A more dynamic framework was needed for the rapidly changing global competition. The RBV provides potential solution to address this gap. RBV view has gained more importance since Prahalad and Hamel [32] emphasized the link between core competencies and competitiveness of an organisation and been developed further by others, including [7], [33]. The key assertion of this view is that companies succeed in long term primarily by focusing more on building basic internal operating *capabilities*. A dynamic capability is defined as the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments [34]. This more operations-based and dynamic view of competitive strategy has profound implications for manufacturing strategy, as it both elevates the importance of the operations function and raises new issues about the nature of its strategic management [4]. Thus operations management would not simply be a matter of structuring processes, but focus on making trade-offs in resource management determining the sustainability of the firm's competitive strengths [7].

More recently, another expanding context for manufacturing is the role of service. Manufacturers have several reasons to include more services in their total offering to: facilitate the sales of their goods; lengthen customer relationships; create growth opportunities in matured markets; balance the effects of economic cycles with different cash-flows; and respond to demand [35]. Naturally, the manufacturing focus is increasingly shifting from simply designing and selling physical products, to selling a system of products and services that are jointly capable of fulfilling specific users' demand [36]. This transition normally progresses through several stages: consolidating product-related services; entering the installed base service market; expanding relationship-based or process-centred services; taking over users' operations [37]. In summary, the evolution of theories on manufacturing strategy in past decades can be illustrated as figure 1.

Three lessons can be drawn from above literature review. First, in contrast to abundant literature on reactive usages of manufacturing, research on proactive roles of manufacturing is still on its infancy. Most of studies on this aspect are still on the conceptual level; conclusions are normally obtained conceptually; and proactive roles of manufacturing are only predicted theoretically. Second, it is evident that RBV has had a major impact on our view of manufacturing strategy and provided a new and strong theoretical grounding for the area [6]. However, this is still an area ripe for research, with many unanswered questions including how to formulate manufacturing strategy derived from RBV, etc. Third, even the trend of servitisation has been identified, but such transition constitutes a major managerial challenge as services require organisational principles, structures and processes new to the product manufacturer. Not only are new capabilities, metrics and incentives needed, but also the emphasis of the business model changes from transaction- to relationship-based [37]. In a word, facing above theoretical challenges, a redefinition of our understanding of manufacturing and its contribution to the overall competitiveness of companies is therefore necessary. Furthermore, various theories indicate new directions for the development of manufacturing, but less discussion rooting from the practice has emerged of how to orient it towards goals proposed by theories. This is not enough especially to operations management as which is normally treated as an "Empirical Science" [38]. Ever more works derived from practice investigating how the real world responds to above theoretical predictions and how to use theories to direct operations in practice are the need of the hour.

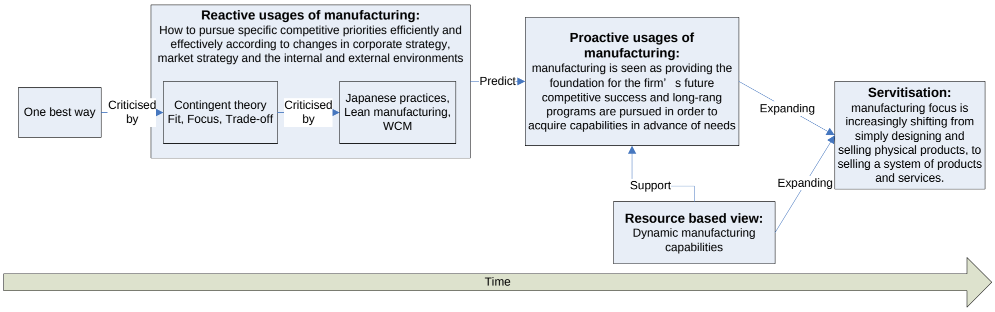

Figure 1: The evolution of theories on manufacturing

3. Methodology

For the purpose of exploring how manufacturing is used and what kind o role manufacturing is playing in practice, this paper selects the case study as the primary research method for its relevance in answering *how question* [39]. Furthermore, it has been decided to choose the cases in a cross-sectoral manner. However, to minimise complexity, three Danish firms are selected mainly according to accessibility (willingness to participate), but they all have identified manufacturing as an important element in their competitive strategy. Multiple-case designs enhance external validity [40]. The case companies differ in size and represent different industries and, thus, a range of products, processes, types of served markets, technological intensity, industry structure, global shifts and competition. These differences serve to seek anomalies and establish the validity of the theory [41]. See Table 1 for details of each firm.

The research relies on extensive use of triangulation (from company reports, interviews, and observations) and protocols to enhance the validity and reliability of the research outcome [42] [43]. A four-step approach is used for data collection. First, secondary sources such as annual reports, press releases, presentation materials to customers and stakeholders, and media materials were analysed to help us learn more about the backgrounds and the operations of the companies. Second, two researchers spent half a day or one day visiting the companies and met with top management. Multiple interviews spanning 1 to 2 hours each were conducted with CEOs and/or operation managers. Third, researchers visited Danish subsidiaries and manufacturing facilities of each company. Again, multiple semi-structured interviews were conducted with factory managers, production managers, and engineers. Fourth, based on document reviews, interviews, and observations, case reports were written and returned to companies for verification. After several rounds of correcting, final versions were completed.

Table 1: Backgrounds of case companies

Company	Company A	Company B	Company C
Size	1250 employees	450 employees	One of five production business units of an energy company
Product	Lighting products and solutions	Plastic/metal components and solutions	Towers for windmills
Operation characteristics	Customer specific, innovative, high-tech products	Customer-specific product; high flexibility; quality; short delivery time	Benchmarking; supplier selection; knowledge accumulation
Manufacturing footprint	In 3 countries; two plants in Denmark	Most in Denmark; one plant in Poland	10%-12% of its manufacturing in Denmark

4. Case studies

4.1 Case A

Case A is a supplier of dynamic lighting products and solutions, smoke machines, and controllers for entertainment, architectural, and commercial applications. In order to provide attractive product to customers continuously, case A adopts the stage-gate model which divides the whole process of its new product development (NPD) into five stages. Manufacturing joins the new product development as very beginning, but plays different roles in different stages. In stage 1, R&D people normally come to manufacturing people with their drawings and ask for suggestions about the feasibility of their ideas. Manufacturing, to some extent, can be viewed as laboratories to R&D people, with helps of which, they can enjoy freedom to experiment with new ideas. From stage 2, NPD team is organised, in which manufacturing is responsible for providing production-related information. In stage 3, the main contribution of manufacturing is to produce prototypes. Again, R&D and manufacturing people work together on the production lines in order to control and improve the prototype processes. In stage 4, the main aim of manufacturing is to optimise manufacturing processes for new products. Standard operational procedures (SOPs), work instructions (WIs) and other documents can be prepared for future ramp-up and mass production. On the basis of prototype productions and close location of R&D and manufacturing, it is easy to realise ramp-up of new products at the same plant in stage 5. By ramping up small quantities of new products, on one hand, customer demands for minor orders of new products can be satisfied. On the other hand, experience can be accumulated which in turn leads that all the monitored factors can achieve pre-decided targets gradually.

Besides supporting NPD, manufacturing also play significant roles in other three ways. First, Manufacturing is used to support management system prototypes. Case A has acknowledged the importance of securing good communication between managers and workers on the workshop level. Therefore, it attempted to abolish the offices and move managers into the assembly. The idea about "abolishing" offices was first tested at the plant in Denmark, and improved gradually. When positive results were shown and experience about the new system was earned, the new management system was transferred to plants in UK and China. Second, together with quality management department, manufacturing provides benchmarking service to strategic purchasing department to help it monitoring price level of sub-suppliers; having an overview on the structure of suppliers; and finding new suppliers. Third, case A encourages partners, customers, and the curious to visit facilities which present an industrial back-stage look to the visitors, and house their product demonstration facilities as well as a stunning product showroom. As the plant manager points out, "*the … factory … presents a dynamic environment, where factory floor, fully-automated logistics, an open office environment, and social and recreational spaces join together to create a seamless whole*". In this context, manufacturing plants are used more like showrooms to provide direct impressions on manufacturing abilities and innovation of products to customers.

4.2 Case B

Case B focuses on developing and manufacturing customer-specific components and total solutions in the area of plastic and metal solutions. All its products are customised and need to be produced according to customers' demands, which also leads that case B has no fixed product. In case B, manufacturing has close relationships with other functions, which is realised by an integrated database. This database is open to all the employees, but with different permissions. Manufacturing staffs are allowed to record and update all the manufacturing-related information, including set-up time, process time for different processes, etc. Meanwhile, it is also possible for people from other functions to access all these information. Normally, the operation starts from the sales department as it handles direct contacts with customers. Visiting the database to choose proper processes makes it possible for sales people to formulate a master plan for a specific product based on customers' demands. There are more than 10000 template articles stored in the database, which have been accumulated and standardised from past operations. Once processes are decided, delivery time, quality level and other process-related factors can be seen. Sometimes, because of new demands of customers, not all the information can be found in the database. Thus, sales people need to ask for help from development and manufacturing functions, which means that product development does not happen behind closed doors in a single department. By having dialogues between three different departments, the master plan could be decided. Afterwards, a corresponding template article will be prepared and used for future manufacturing. A more complicated procedure is that customers come to the company only with ideas of having no clear descriptions. Then, manufacturing can provide suggestions about how to realise these ideas and help customers on defining the needs and desired characteristics of the products. By doing so, case B ensures, firstly, that the customers' demands and expectations of the product are complied with and secondly, that the developed products are manufacturable.

As a sub-supplier, co-operations with customers become extremely important to the company. Under this background, "partner innovation" project is introduced, which allows customers to work with the company as active collaborators in the new product development. Correspondingly, case B also gains advantages in such project by absorbing new manufacturing technologies, materials etc. from customers as well as their external knowledge centers (e.g. universities). This knowledge can be made for good use to improve the company's products and contribute on accessing to potential markets. Moreover, case B also establishes specific production groups and allows them to have direct connections with specific customers (e.g. IBM and Hannibal). Therefore, on the one hand, orders from customers are automatically given directly to the production unit, which can subsequently start the production; on the other hand, once customers face production related problems, consultants will be provided, and problems will be solved through a kind of trial/error process.

4.3 Case C

Case C is one of five production business units in an energy company. Mainly due to political and logistic issues, case C follows the strategy that it only holds 10%-12% of its manufacturing in Denmark while the rest is outsourced to local suppliers. Following such strategy, case C only has 2 plants in Denmark currently. Treated equally to other suppliers, they are responsible to produce towers in certain quality level and deliver them on time. The purpose of this in-house manufacturing is, on one hand, set as a benchmarking. Based on this mini version of operations of partners, advanced knowledge about how to produce towers can be accumulated within the company, making case C have knowledge bases to select proper suppliers and help them to improve their performance. In order to facilitate knowledge transfer with suppliers, case C mainly relies on documents and “supervisor corps”. Once external suppliers face different kinds of manufacturing-related problems, experienced craftsmen (e.g. welders and CNC-operators) are sent to suppliers, assisting them to solve problems on the basis of expertise from benchmark manufacturing in Denmark. Meanwhile, the “supervisor corps” also brings back manufacturing knowledge derived from co-operations with suppliers to the Engineering and Manufacturing departments in Denmark. On the other hand, two own plants with volume of 300 turbines per year can be viewed as good complementarities to local suppliers as in-house manufacturing can be controlled more directly, making quality more stable and deliver time shorter. Instead of being sensitive on changing demands, holding only 10% to 12% of manufacturing activities makes case C enjoy the flexibility on its manufacturing volume, simply by telling suppliers to produce more/less towers.

5. Findings and discussions

Without abandoning traditional/reactive view on manufacturing, i.e. pursuing specific competitive priorities efficiently and effectively according to changes in corporate strategy, market strategy and the internal and external environments, manufacturing is used variously in the cases (table 2):

- Not only interact/cooperate with R&D and marketing, but also other functions (e.g. procurement, service, and sales), suppliers and customers;
- Not only operate for NPD, but also for other purposes;
- Provide different feedbacks/suggestions to other functions, suppliers and customers according to different purposes.

By following above three points, manufacturing has the potential to play a much stronger role than those of implementer and “fixer” [4]. This implies a deep shift in manufacturing’s role, in its self-image, and in the view of it held by other functions [25]. Thus, transforming from reactive to proactive, manufacturing can become so proficient that it is able to generate new opportunities for itself and other functions. In the process of identifying and exploiting such opportunities, manufacturing is able to participate in or even instigate a reformulation of company strategy and help drive suppliers, customers and other functions to react to its initiatives [4].

Besides, manufacturing is not just a question of aligning operations to current competitive priorities but also of selecting and creating the operating capabilities a company will need in the future [29]. Thus, it is necessary to stress the importance of developing dynamic capabilities on manufacturing, defined as the ability to “integrate, build and reconfigure internal and external competencies to address rapidly changing environments” [34]. For example, in case B, it is believed that the manufacturing abilities can not be accessed in the market by being imitated but should be developed over a period of time, and in a path dependent and cumulative way. It is expected that development of a unique manufacturing capability is not only currently strategically important, but will be particularly significant in the future for enabling the company to distinguish future opportunities as the absorption of newer and more complicated technologies is required existing manufacturing activity for its assimilation process [44]. Derived from the cases, manufacturing capabilities can normally be obtained from three sources: self-accumulation (case A and B), suppliers (case C) and customers (case B).

Table 2: How manufacturing is used in Case companies

What manufacturing interacts with	*What purposes manufacturing operates for*	*Feedbacks/suggestions manufacturing provides to other functions, suppliers, or customers*	*Corresponding Case Companies*
Manufacturing and R&D:	The laboratory for experimenting and testing new products, technologies and ideas;	Experiment results about products, processes, and technology for analysis and improvement	Case A and B
	Facilitating new product development by experimentation and prototype manufacturing	Product prototypes for analysis and improvement	Case A
	Integration between R&D and manufacturing for manufacturability and concurrent product and process development; Consultant service to R&D	Information, knowledge about the manufacturability of products	Case A
	Preparations of SOPs, WIs and other documents for future mass production	SOPs, WIs and other documents	Case A
Manufacturing and marketing/sales:	Supporting marketing strategy and corporate strategy by ramp-up	New products matching customers' demands	Case A
	Enabling to customise products according to changed user preferences		Case B
	The showroom to demonstrate manufacturing competence, no matter about product or process	Impressions of manufacturing competencies to partners and customers	Case A
	Providing open office environment, and social and recreational spaces join together to create a seamless whole among partners, customers and the company	Opportunities for socialising and co-operation and new ideas for future development	Case A
	Supporting strategic location vis-à-vis customers and market	Close to markets to protect the market position	Case B
	Consultant service to sales by providing manufacturing-related information and supporting them to decide product specifications	Manufacturing-related information and knowledge to sales people	Case B
	In-house productions can be controlled more directly, quality can be ensured more stably, and deliver time can be managed more accurately	Carefully controlled manufacturing to protect and strengthen the market position	Case C
Manufacturing and suppliers (procurement):	Supplier benchmarking service to strategic purchasing department	Foundations for supplier selection and experience for supplier improvement	Case A and C
	Supplier selection, inspection and control		
	Preparations of SOPs, WIs and other documents for suppliers	SOPs, WIs and other documents for suppliers	Case C
	Providing a frame of reference, technical and manufacturing-related consulting to partners and helping them to improve	Documents, experience and knowledge for helping suppliers improve	Case C
	Avoiding being sensitive on changing demands and achieving higher flexibility by telling suppliers to produce more or less towers for the control of manufacturing capacity	Manufacturing orders to suppliers	Case C
Manufacturing and customers:	Providing technical and manufacturing-related consulting to customers	Manufacturing related-information and knowledge to customers	Case B
	Supporting customers to understand, describe and identify their demands and desired characteristics of the product	Purchase agreements with clear product descriptions	Case B
	Platform for provision of after-sales, which provides customer-specific service to ensure higher customer satisfaction	Direct productions and customer-specific service after sales	Case B
Manufacturing and infrastructure:	The laboratory for new management system Source of management system innovation	Manufacturing system models for analysis and improvement	Case A

In summary, manufacturing roles identified from cases can be classified into three groups. To a certain degree, they are inter-related as illustrated in figure 2.

- Reactive role--working with other functions as a seamless system for producing products efficiently and effectively through pursuing specific competitive priorities;
- Proactive role--providing various service to suppliers, customers and other functions in terms of feedbacks, suggestions and other forms;
- Self-evolution--accumulating, absorbing and creating manufacturing knowledge for future operations and preparing capability foundations for above two aspects.

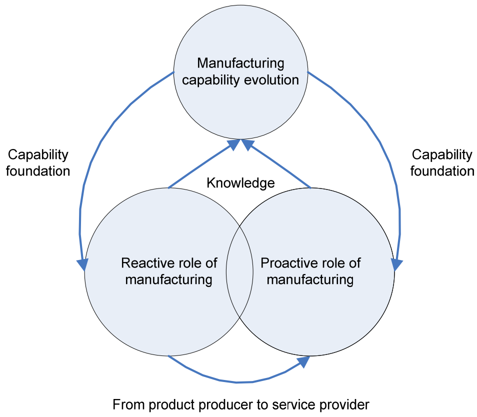

Figure 2: A holistic framework of self-evolution and reactive/proactive role

Self-evolution and reactive/proactive role. On one hand, self-evolution prepares capability foundations for future operations and provides supports to reactive/proactive role. On the other hand, reactive/proactive role provides opportunities to self-evolution on accumulating manufacturing experience and absorbing external manufacturing knowledge.

Reactive and proactive role. Most companies--product manufacturers and service providers alike--are largely service operations, according to which, producing products can be viewed as the basic service that manufacturing can provide [45]. Listed in table 2, besides producing products, there are various other services that manufacturing can provide not only to customers but also to suppliers and other functions, i.e. manufacturing has potential to transform from product producer to service provider. Actually, this also concurs with the servitisation of manufacturing firms, which has various manifestations (e.g. providing product-related services, providing product function services and providing total solution, etc.). Taking Case B an example, it is possible to see that manufacturing plays an important role and gives strong support in such transformation.

In a word, as illustrated by figure 2, self-evolution and reactive/proactive role complement each other and work together in a holistic way to constitute manufacturing capabilities, which further indicates that a hybrid of the Porterian external positioning and RBV is emerging as the two views are increasingly seen as complementary to each other [46] and a degree of blending or a combination of outside-in (an environmental and market-based) and inside-out (a RBV and associated dynamic capability) approaches would appear to be the most appropriate way to achieve and sustain competitiveness [47]. Accordingly, the manufacturing function can be viewed as one of the central "processors" or knowledge repositories of industrial companies and can progressively take the leadership of strategy formulation; create portfolios of operational capabilities for strategies of organisational agility; and implement world-class practices/best practices more effectively through evolutionary strategic frameworks [48].

6. Conclusions and implications

Instead of being limited as product producer, it is evident that manufacturing has the potential to be a service provider to other functions, suppliers and customers. Table 2 can be viewed as a checklist, which managers can use to inspire their decisions on how to design services that manufacturing can provide. Meanwhile, RBV also has impacts on current view of manufacturing, which is concluded as self-evolution in this paper. These challenges, no matter theoretical or practical, all indicate that a new paradigm on manufacturing is necessary. For the purpose of establishing such paradigm, OSS [49] and open innovation [50] are taken as analogies and further transposed to manufacturing. Treating manufacturing as an open system, the new manufacturing paradigm termed as Open Manufacturing can be illustrated in figure 3.

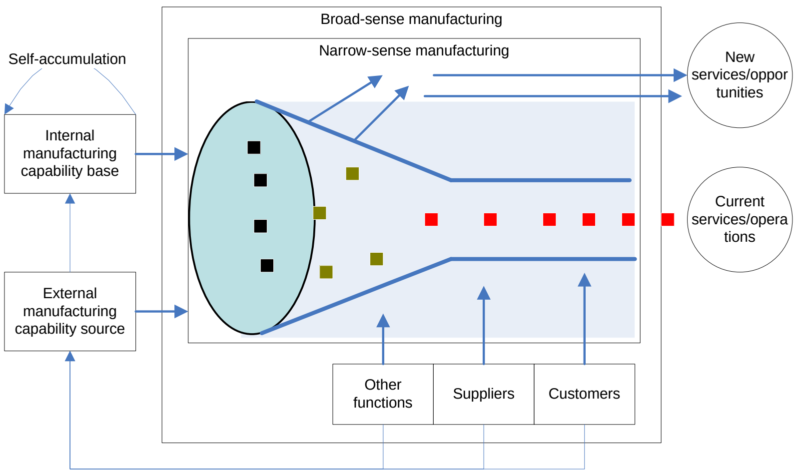

Figure 3: An open manufacturing paradigm

First, derived from RBV, manufacturing capabilities becomes extremely important for industrial companies to address rapidly changing environments. Similar to OSS and open innovation, internal accumulation based on many years' operations is only one of sources while external manufacturing capability sources, including suppliers, customers or even their external knowledge centres, play an equally important role. As depicted by cases, complementing the internal capability source, knowledge from external capability sources is normally absorbed and used for upgrading existing manufacturing capabilities. Therefore, it is reasonable to say that manufacturing capabilities are developed in a public, collaborative manner, relying on not only internal manufacturing capability source, but also external ones. Second, it is essential to explain reactive/proactive role of manufacturing as different usages/services developed and transformed from manufacturing capabilities. Just like OSS, manufacturing capabilities can not bring any benefit to companies. In order to create benefit, they need to be transformed into different services, no matter reactive or proactive, on the basis of co-operations/interactions between manufacturing and other functions, suppliers and customers.

In this case, it is significant for manufacturing managers to open their minds and have "open-source" thinking on manufacturing. On one hand, they need to control the evolution of manufacturing capabilities as well as being open to suppliers, customers and other functions to search for knowledge which can be used to complement internal manufacturing capability base and support the upgrade of that. On the other hand, they need to manage how to transform manufacturing capabilities into different services under the collaboration between manufacturing, other functions, suppliers and customers. Furthermore, they also need to change ways in which other functions, suppliers and customers think about manufacturing by propagandising how manufacturing could contribute more than only producing goods and encourage them to "customise" not only products but also manufacturing itself by exploring and creating new manufacturing usages depending on specific situations.

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