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Manufacturing Engineering in Europe and Japan: A Preliminary Comparative Case Study of Two Automotive Component Suppliers

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Abstract: In recent years, increased attention is being paid to the tasks and functions of manufacturing engineering (ME), and how these tasks and functions may be transferred overseas. However, compared to Japan and the United States, we could find few academic works in English or Japanese that address the tasks and functions of ME in Europe. This paper compares the tasks and functions of ME in a European automotive component supplier with that of a Japanese supplier of a similar automotive component. Our preliminary comparative case study suggests that, at least prescriptively, the tasks and functions of ME in Europe, while containing important differences, are largely similar to what is found in Japan.

Keywords: new product development, production engineering, concurrent engineering, simultaneous engineering, manufacturing, automotive component supplier, comparative case study

1. Introduction

There is renewed practical and theoretical interest in how companies can improve the productivity of their existing production lines and introduce new production lines more efficiently (Jonsson et al., 2004; Nakaoka et al., 2005; Shibata, 2009), both of which are primary responsibility of manufacturing engineers (Shibata, 2009; Whitney et al., 2007; Koike, 2008). This interest is particularly high in Japan, where companies are increasingly focusing on the transfer of manufacturing engineering processes to overseas facilities, now that the transfer of production processes to overseas plants has become more routine (Shibata, 2009).

Previous research findings substantiate this renewed attention on manufacturing engineering. After conducting an analysis of new product development, manufacturing engineering and production processes in manufacturing companies, Eisenhardt and Tabrizi (1995) and Leonard and Sensiper (1998) argue that the use of cross-functional teams and concurrent engineering may improve technology transfer, innovation and time to market.

The importance of integration across functions has been pointed out in research on new product development (Clark and Fujimoto 1991, Wheelwright and Clark 1992, Adler 1995), and it has also been stressed that the successful integration of groups with different functions can be difficult. Moreover, Wheelwright and Clark (1992) argue that new product development is an activity that should involve all the different functions that exist in a company, and go on to assert that the choice of communication medium, direction, frequency and timing that is used to integrate the contributions of the diverse participants can largely determine whether this integration is successful or not.

New product development in the Japanese auto industry has been one of the principal objects of research on inter-functional integration. Fujimoto (1999, 2003, 2007) and Aoshima (2001a, 2001b) point out that there is much overlapping of tasks and personnel in the new product development of Japanese automakers, as well as a constantly high level of cross-functional integration. Also, product managers in Japanese companies tend to exert a particularly high level of influence over other participants in product development projects (Clark and Fujimoto, 1991; Higashi and Heller, 2012). Regarding integration in downstream processes like manufacturing, Koike (1994), Pil and MacDuffie (1999), Shibata (1999, 2001) among others, assert that production workers in Japanese companies integrate production skills with troubleshooting skills.

Compared with the volume of literature on the tasks and functions of new product development projects and manufacturing plants, there is little research that addresses the tasks and functions of manufacturing engineering. The importance of the tasks and functions of manufacturing engineering has been pointed out by Nakaoka et. al. (2005), however, it is difficult to find detailed research on the tasks and functions of manufacturing engineering, with a few notable exceptions (described below) that tend to focus on Japan in general, and Toyota in particular.

Shibata (2009) presents a comparative study on the tasks and functions of manufacturing engineers in Japan and the United States (based on nine Japanese and three American companies in different industries). Koike (2008) examined the tasks and functions of manufacturing engineers in a single Japanese automobile manufacturer (presumably Toyota). Whitney et al. (2007) studied the role of manufacturing engineering in door engineering and door assembly at Toyota. Murase (2007) also examined manufacturing engineering in Toyota and its role in knowledge creation. Murase (2011) conducted a comparative study of manufacturing engineering in Toyota and Honda.

Shibata (2009) points out that one of the unresolved questions for future research is the study of manufacturing engineering in countries other than Japan and the United States. Since we could find little research in English or Japanese on the tasks and functions of manufacturing engineers in another important and historically strong manufacturing region, namely Europe, the present paper uses a field-based comparative research approach to conduct a preliminary investigation of how manufacturing engineering is done on this continent.

This paper provides, firstly, a comprehensive review of the literature on the tasks and functions of manufacturing engineers. Secondly, the paper focuses on revealing the tasks, functions and organization of manufacturing engineers in a European supplier of automotive components, and comparing them with what is found in a Japanese supplier of similar automotive components. At this stage of the research we can pose a rather simplistic but basic research question: *What are the tasks and functions of manufacturing engineering in a European supplier of auto parts?* A Japanese supplier of similar auto parts provides a good basis for comparison because there is a decent amount of research on the tasks and functions of manufacturing engineering in Japanese automotive companies. We analyze the similarities and differences in the manufacturing engineers' tasks and functions, including the location of the workplace of manufacturing engineers (i.e., within plants, R&D centers, or headquarters).

The findings from our preliminary comparative case study suggests that, at least prescriptively, the tasks and functions of manufacturing engineering in Europe are largely similar to what is found in Japan. Differences were found in the allocation of responsibility among manufacturing engineers and the timing of the participation of production workers in new product development projects.

2. Literature review

2.1 What is manufacturing engineering? (Tasks and Functions)

Shibata (2009) researched nine Japanese and three American companies and concludes that the manufacturing engineers in these companies perform the following four main tasks:

(1) Line design - designing production lines or production processes;

(2) Method development - developing production methods, machinery, and/or equipment;

(3) Production preparation - preparing the manufacturing of new products, such as setting up new production machinery or equipment, making jigs, tools and dies, managing trial production, writing operations manuals, instructing workers on production operations, and stabilizing mass production;

(4) Production improvement - improving existing production lines, processes, machinery, equipment, jigs, tools, and/or dies, with the aim of getting productivity increases.

According to Shibata (2009), these four tasks require the fulfillment of two functions that are important for the success of the work of manufacturing engineers:

(1) Smooth and efficient mediation between product design (engineering) processes on one side, and production processes on the other side.

(2) Significant improvement in productivity that cannot be achieved simply by continuous improvements (kaizen) performed by production workers.

Koike (2008) indicates that in the single Japanese company that he studied, manufacturing engineers are broadly divided into two types - *seisan-gijutsu-sha*, who are mainly responsible for work related with the design of assembly lines, as well as the development of production facilities (upstream processes), and *seizo-gijutsu-sha*, who are mainly responsible for work related with manufacturing trials and production ramp-up (downstream processes). In his study on manufacturing engineering in Toyota's press shop, Murase (2007) confirms these findings and asserts that the tasks and functions of *seizo-gijutsu-sha* can be described as focused on operation, while the tasks and functions of *seisan- gijutsu-sha* can be described as focused on knowledge.

In Shibata (2009) the above-mentioned Japanese phrases are translated as follows - *seisan-gijutsu-sha* as manufacturing design engineers, who correspond to manufacturing engineers in American companies, and *seizo-gijutsu-sha* as production process engineers, who roughly correspond to manufacturing technicians in American companies. For the sake of clarity, this paper uses the English wording adopted by Shibata (2009) (for Europe, the American equivalents are used).

2.2 Why focus on manufacturing engineering?

In the academic literature, the involvement of production workers in improving the efficiency and effectiveness of Japanese production facilities has been highlighted as one of the factors in the success of Japanese production systems (MacDuffie and Pil, 1997). For example Liker (2004) argues that Toyota fosters production employee involvement at upper levels. Shibata (2009), while not denying the important role played by production workers, clarifies that in addition to production workers, manufacturing engineers play important roles in production processes in Japanese companies. Specifically, Shibata (2009) argues that production process engineers who are highly involved in manufacturing engineering work contribute to the overall efficiency and effectiveness of the production systems in Japanese companies. In addition, Shibata (2009) asserts that production systems in Japan are supported by the participation in upstream processes by engineers who work primarily in downstream processes. Extending this argument, one might argue that the tasks and functions of manufacturing engineering, notably production process engineers, and the involvement of downstream employees in upstream processes, rather than difficult to understand work concepts such as teamwork and kaizen, is what actually forms the critical supporting structure for Japanese production systems and contributes to their high efficiency and effectiveness.

2.3 Types of work organization in manufacturing engineering

According to Shibata (2009), in the nine Japanese firms of his study, the tasks and functions of manufacturing engineers is organized in the following three types:

First type (mainly assembly and part-processing shops - automobiles, car components, electronics): divisions of manufacturing design engineers (located in their headquarters) were in charge of (1) line design, (2) method development, and some parts of (3) production preparation; divisions of production process engineers (located in each plant or business unit) were in charge of other types of tasks related to (3) production preparation and (4) production improvement.

Second type (mainly material-processing shops - semiconductor-related, steel): divisions of manufacturing design engineers for (1) line design and some parts of (3) production preparation; divisions of production process engineers are in charge of other types of tasks related to (3) production preparation and (4) production improvement, and divisions of equipment engineers for (2) method development.

Third type (semiconductor, ceramics, chemistry): divisions of manufacturing engineers (including both manufacturing design engineers and production process engineers) are in charge of (1) line design, (3) production preparation, and (4) production improvement. Former divisions, now outside equipment makers, conduct (2) method development. In this type, the main task of the manufacturing engineering divisions was production improvement by the production process engineers.

In the three American companies, the tasks and functions of manufacturing engineers are organized in the following two types:

First type (mainly assembly and parts-processing shops - car/machine components): divisions of manufacturing engineers are in charge of the four tasks, i.e. (1) line design, (2) method development, (3) production preparation, and (4) production improvement.

Second type (mainly material-processing shops - ceramics): divisions of manufacturing engineers are in charge of (1) line design, (3) production preparation, and (4) production improvement; a division of equipment engineers is in charge of (2) method development.

In the three American companies, the manufacturing engineers and the manufacturing technicians are members of the manufacturing engineering divisions. The manufacturing engineers conducted decision-making in their offices, which were far from the plants. The manufacturing engineering work is actually done by the manufacturing technicians, who work close to the plant shops and get instructions from the manufacturing engineers.

2.4 Manufacturing design engineers and production process engineers in a Japanese automobile manufacturer

Koike (2008) performed an in-depth study of a Japanese automobile manufacturer (a careful reading of the paper suggests that the manufacturer is Toyota as the paper is about a Japanese company and it mentions NUMMI, a joint venture between Toyota and GM that closed in 2010). According to Koike (2008), the manufacturing design engineers are responsible for (1) line design - designing new production lines and making changes to existing production lines, and (2) method development - developing machinery and equipment. The production process engineers are responsible for (3) production preparation and (4) machine troubleshooting and dealing with quality problems after volume production has begun. Manufacturing design engineers and production process engineers do the following at each stage the manufacturing process:

(1) Product engineering. Main role - product engineers. Manufacturing engineers (manufacturing design engineers and production process engineers) make suggestions regarding the design of new products. Plants are represented by teams of production process engineers and production workers who make written proposals concerning product design. These proposals can be accepted or rejected by the product engineers.

(2) Assembly line design. Main role - manufacturing design engineers. This stage starts almost at the same time as the product engineering stage. At this stage manufacturing design engineers:

a) determine the basic structure of the line; production process engineers and production workers participate too, especially in the detailed design of the assembly process;

b) select the manufacturers of the equipment;

c) determine the number of people necessary to operate the assembly line.

(3) Production facilities manufacturing and testing. Main role - manufacturing design engineers. Production process engineers participate too.

(4) Manufacturing trials. Main role - production process engineers. During this stage, meetings are held every day on the shop floor with a wide range of participants - production process engineers, manufacturing design engineers, product engineers and production workers. Koike (2008) explicitly states that the participation of production workers in this stage is an important characteristic of Japanese companies.

(5) Production ramp-up. Main role - production process engineers. Production workers actively participate in this stage too.

(6) Volume production. Production process engineers and production workers are responsible for troubleshooting.

2.5 Industry-specific characteristics of manufacturing engineering

Shibata (2009) points out that there are differences in the tasks and functions of manufacturing engineers in the nine Japanese and three American companies according to three industry types: assembly, parts-processing (parts, such as car or electronic components, are cut, pressed, and/or shaped in the shops), and material-processing shops (industrial materials, such as chemical or steel materials, are reacted, smelted, and/or rolled in the shops). The differences are as follows:

(1) Engineering of production lines or processes - manufacturing engineers in the assembly and parts-processing shops make blueprint drafts for new production lines, while manufacturing engineers in the material-processing shops, using existing production lines, decide the process sequences, the methods by which materials will react, and the condition under which the new products will be manufactured.

(2) Frequency of introduction of new production lines - manufacturing engineers in assembly shops more often introduce new production lines than manufacturing engineers in parts-processing and material-processing shops. In addition, manufacturing engineers, assistant, and first-line supervisors, and/or production workers in assembly shops more often improve existing production lines than in parts-processing and material-processing shops.

(3) Involvement in research & development or product design - the role of manufacturing engineers in research & development or product design performed in material-processing shops is bigger than the role of manufacturing engineers in research & development or product design performed in assembly and parts-processing shops.

2.6 Differences between manufacturing engineering in Japan and USA

Regarding differences between manufacturing engineering in Japanese and American companies, Shibata (2009) concludes that there are two characteristics in the nine Japanese companies of his research that "do not exist or are weak" (p. 1906) in the three American companies:

(1) inter-divisional tasks and functions of production process engineers; Shibata (2009) refers to the work of the production process engineers in the Japanese companies as "organized inter-division work" (p. 1906) and claims that organized inter-division work contributes to the performance of the Japanese production systems.

(2) the involvement of employees engaged in the downstream stages of the production process with work related to the upstream stages.

As for the division of labor in the work of manufacturing engineers, Shibata (2009) found that in the nine Japanese companies there is a horizontal division of labor between the manufacturing design engineers (*seisan-gijyutsu-sha*) and the production process engineers (*seizo-gijyutsu-sha*). Production process engineers in the nine Japanese companies are responsible for the organization and control of production preparation and consequently this stage of the production process, i.e. production preparation, receives a more clearly defined shape. In the three American companies, maintenance workers belonging to their respective unions play similar roles and have similar responsibilities as the production process engineers in the nine Japanese companies.

As for the division of labor in the manufacturing engineering work in the three American companies, the finding is that there is a vertical division of labor between the manufacturing engineers and the manufacturing technicians. There is a clear difference between the "directive work of the manufacturing engineers" and the "hands-on work of the manufacturing technicians" (p. 1906). The vertical division of labor between manufacturing engineers and manufacturing technicians found in the three American companies seems to derive from "a traditional dichotomy of vocational culture in the United States" (p. 1906) which can trace its history back to the Industrial Revolution in the 19th Century.

2.7 Interactions between downstream and upstream processes

Research and development is the first stage of the manufacturing processes, followed by product design, manufacturing engineering and finally production (Shibata, 2009). This flow of work is where the second characteristic of manufacturing engineering work in the nine Japanese companies, namely the interactions between upstream and downstream manufacturing processes, is to be found. In relation to this, Fujimoto (1999, 2003, 2007) points out that the transfer of information between upstream and downstream processes is important. Shibata

(2009) supports this conclusion of Fujimoto and claims that, regarding the different stages of the manufacturing processes, in Japanese companies downstream employees are heavily involved with work in upstream processes in the following two ways:

(1) from the manufacturing engineering processes to the research and development or product design processes;

(2) from the production processes to the manufacturing engineering processes.

This conclusion is supported by Koike (2008), who indicates that in the single Japanese company of his research, the tasks and functions of manufacturing design engineers (mainly responsible for upstream processes) considerably overlap with the tasks and functions of production process engineers (mainly responsible for downstream processes). Also, at the product engineering stage, manufacturing design engineers make suggestions regarding the design of new products.

Furthermore, Shibata (2009) maintains that such an interaction between upstream and downstream new product development processes leads to concurrent engineering and "shortens the lead-time of new product development, and reduces the times of trial production" (p. 1907).

Also, there are interesting indications from Whitney et al. (2007) that for example at Toyota, manufacturing engineering acts like a bridge between manufacturing (downstream) and product design (upstream), connecting them and making them communicate smoothly, seeking to reconcile their often conflicting interests and thus contributing to performance improvement. Whitney et al. (2007, p. 11), found that manufacturing engineering at Toyota "considers manufacturing variation and its effect on the (design performance) targets. Variation can arise in any (manufacturing) domain (e.g., press, paint, assembly)...", and manufacturing engineering "has taken on the role of negotiating among these domains before going back to engineering design with suggestions".

According to Whitney et al. (2007) the role of the manufacturing engineering department, at least in the body engineering part of Toyota's new product development process, is to be a pro-active interface between the product design department and the manufacturing department, thus playing the role of a systems integrator. Moreover, based on a research on Denso, a company that follows the Toyota Production System (Anderson, 2003), Whitney (1995) argues that Denso's strength is not strictly limited to manufacturing but rather Denso excels in the way it links manufacturing with new product development.

2.8 Why is manufacturing engineering in Japan different from manufacturing engineering in the United States?

Shibata (2009) explains the difference between the tasks and functions of manufacturing engineers in Japan and the United States with the following two orientations that tend to characterize Japanese companies:

(1) Integration (*suriawase*) orientation, and

(2) Production workplace orientation.

First, regarding the orientation towards integration, it is necessary to point out that according to Fujimoto (2003, 2007) product architecture can be broadly divided into two types: integral product architecture and modular product architecture. Compared with overseas companies, Japanese companies tend to possess higher capability to manufacture products with integral architecture. Automobiles are a typical example of products with integral architecture. Thus, Japanese companies in the automobile industry can benefit from their integral orientation.

Shibata (2009) confirms the findings of Fujimoto and asserts that in the nine Japanese and three American firms of his research, "not only assembly and parts-processing firms, such as automobile firms, but material processing firms in Japan have higher integral capabilities and are strongly oriented to integration" (p. 1907-1908). This description of the product architecture orientation of companies in Japan seems to be different from the description of American companies, which are characterized as "oriented towards segregation" (p. 1908). According to Shibata (2009), an important requirement for companies which are oriented towards integration is the employment of production workers who, in addition to production skills, also possess troubleshooting skills. The conclusion of Shibata (2009) is that the tasks and functions of manufacturing engineers are supported by the human resource management systems in Japanese companies.

Examples given in Shibata (2009) that show the orientation of Japanese companies towards integration include:

(1) Middle-up-down decision making performed by assistant and first-line supervisors.

(2) Mediating roles between product design (or research and development) and production processes performed by manufacturing engineers.

(3) Involvement of downstream employees with work and tasks associated with upstream processes.

Second, as for the production workplace orientation, Shibata (2009) states that in the nine Japanese companies, "everybody, from top executives to the lowest employees, is heavily oriented to production and production workplaces" (p. 1908). The usual practice in the nine Japanese companies is that managers and employees perform their tasks at the actual workplace where they can easily observe and participate in various activities. These activities include on-site problem solving and the concept known in Japanese as *genchi genbutsu* (actual place, actual thing). According to Liker (2004) Toyota has adopted the same concept too.

As a typical aspect of the *genchi genbutsu* concept, the actual production workplace is the training place where new employees, who have just graduated from universities and who are going to work as product engineers or manufacturing engineers, learn by watching what is actually being done at the *genba* (shop floor). In relation to this point, Shibata (2009) observes that assistant and first-line supervisors are often responsible for the education and the training of new engineers at the nine Japanese companies, which is a practice that cannot be observed at the three American companies in his research. Shibata (2009) concludes that the strong orientation towards the production workplace, which can be described as typical for Japanese companies, "organizes production process engineers near the production workplaces, and induces the production process engineers to conduct their production preparation and improvement work in the production workplaces thoroughly" (p. 1908).

2.9 Segregation of engineers and production workers in the United States

Bechky (2003a, 2003b) conducted research on the relationships between people and tangible objects at production workplaces, from which some conclusions regarding the segregation (as opposed to integration) of engineers and production workers can be drawn. The research was conducted at an American company, and it is based on the fact that machines can be touched and felt, which means that machines are “tangible objects”. According to Bechky (2003a), one of the important characteristics of tangible objects is that they create common ground that helps reconcile misunderstandings between people or groups of people. In this American company, these groups of people are engineers, technicians and assemblers (production workers), and each group represents "a different work context with distinct understandings of the product and the production process" (p. 317).

Bechky (2003a) found that the contrast in work context was greatest between engineers, "who rarely touched or even saw the machines while focusing on drawing their designs" (p. 317) and assemblers, who spent all of their time at the production workplace. However, Bechky (2003a) states that at least in the American company he studied, engineering drawings are not considered to be “tangible objects”. Thus, engineering drawings had the effect of separating the engineers, and to a lesser degree the technicians, from the assemblers. The technicians were separated to a lesser degree because their work context is placed between the engineers and the assemblers and it "overlapped that of the other two groups" (p. 317). The level of importance and high professional position of the engineers were strengthened by the complex language of the engineering drawings.

Shibata (2009) supports Bechky’s conclusion and asserts that at least in the three American companies in his research, manufacturing engineers "believe that they grasp production and production workplaces more thoroughly than production supervisors and workers" (p. 1908). Also, it seems that the engineers do not visit the production workplaces very often. The result is that in the production workplaces of the three American companies machines cease to function as Bechky's (2003a) "tangible objects".

In contrast to the American cases, in the nine Japanese companies studied by Shibata (2009), the production workplace is where production process engineers usually do their job and spend much of their working time. In addition, according to Shibata (2009), a considerable number of supervisors and workers are given support to learn how to do machine troubleshooting and how to understand engineering technology, such as engineering drawings. As a consequence, it can be argued that in the nine Japanese companies physical objects such as machines, products and components, and even conceptual objects, such as engineering drawings, function as Bechky's (2003a) "tangible objects" and serve as common ground that can reconcile differences among groups. Shibata (2009) concludes that the integral capabilities of the Japanese production workplaces are supported and reinforced by the above-mentioned tangible objects and by the fact that engineers and production workers learn from each other.

3. Methodology

Building on Shibata (2009), we employ a comparative case study methodology, utilizing qualitative data obtained through in-depth interviews in a European supplier of automotive components and a Japanese supplier that makes similar automotive components. All of the components we studied at both suppliers are largely mechanical, used in the same major sub-system of an automobile (i.e., powertrain, chassis, body, and interior) and have an impact on safety and perceived quality. The components can be described as "black-box parts" (Clark and Fujimoto, 1991) that require co-development and integration (*suriawase*) between a supplier and an automaker.

We interviewed personnel who fit our working definition of manufacturing engineering: engineers who are primarily responsible for tasks that can be described as "in-between" product design and manufacturing (e.g., modifying or suggesting modifications to a product engineering drawings to better fit with existing equipment in a plant or plants). This working definition is similar to that used in Whitney et al. (2007) too, although in this particular paper the term, production engineering, is used.

As our object of analysis, we have selected two suppliers that occupy similar positions in the value chain of the auto industry. This research design allows us to identify and illuminate similarities and differences, not only in the observed characteristics of manufacturing engineering in each of the two companies, but also in the search for possible explanations of these similarities and differences. Since we control for industry-specific characteristics, we are able to obtain a greater understanding of the processes that are standard and those that are country-specific and/or firm-specific, which has important implications for the transferability of the overall conclusions of the research. At the present preliminary stage of this research, our comparison focuses on describing the work characteristics (tasks and functions) of manufacturing engineering in a European supplier of automotive components and a Japanese supplier that makes similar automotive components.

The next step is to try to understand why these two suppliers have formed different or similar work characteristics of manufacturing engineering and to seek to identify and explain both the differences and the similarities. This approach allows the research to go beyond description and towards the more fundamental goal of explanation. The overall aim of this research is to add to the existing body of knowledge on manufacturing engineering, with particular attention paid to the under-researched subject of the tasks and functions of manufacturing engineering in Europe.

The qualitative data used in this present paper to compare the manufacturing engineering in a European supplier of automotive components (Supplier E) and a Japanese supplier who makes similar automotive components (Supplier J) comes from the following first-hand sources. One or both of the authors visited a European plant and the adjacent R&D center of Supplier E twice, in June 2011 and January 2012, and closely observed the production process of automotive component on two assembly lines, during which time we also conducted interviews with manufacturing engineers. We also visited another R&D facility of Supplier E in September 2011, during which time we held numerous discussions with a director of manufacturing and participated in a phone discussion with a manufacturing engineer of this company. During the third visit (January 2012), the first author and another accompanying researcher conducted an interview with the head of the manufacturing engineering section of the R&D center. Follow-up email correspondence was also conducted with the same employee in September and October 2012.

We visited a Japanese plant of Supplier J in June 2012, where we observed the production process of the automotive component and interviewed some of the local managing staff, one of whom had an extensive background in manufacturing engineering at Supplier J. We visited another plant of Supplier J in Japan and its headquarters in August 2012, where we observed the production process of the automotive component again and interviewed the head of the manufacturing engineering department and four other manufacturing engineers. We made a follow-up visit to the headquarters of Suppler J in September 2012 and talked with the head of the manufacturing engineering department and three other manufacturing engineers.

4. Preliminary findings from the comparative case study

The preliminary findings of our study on the tasks and functions of manufacturing engineers in Suppliers E and J generally confirm the conclusions of Shibata (2009) regarding the main tasks that are carried out by manufacturing engineers, namely line design, production method development, production preparation and production improvement. The manufacturing engineers in Suppliers E and J also perform these main tasks and functions.

Regarding the organizational structure of manufacturing engineering in Supplier E, manufacturing engineers and manufacturing technicians work in a R&D center which is located next to a plant where the automotive components are made. Product engineers who design standard components work in the same R&D center, as well as product engineers who are responsible for the customization of standard components. The aim of the customization is to make changes in the design of standard components in order to provide the best fit with each customer's requirements. Product engineering for standard and customized components is done in separate departments, and manufacturing engineering for standard and customized components is separate too, however all of them are directly subordinated to the manager of the R&D center, a product engineer. So, we can say that for the automotive components we studied in Supplier E, manufacturing engineering is part of research and development.

Manufacturing design engineers (*seisan-gijyutsu-sha*) in Supplier J work in the headquarters of that company, however, the headquarters is located next to a plant where automotive components are made. In addition to the manufacturing design engineers in the headquarters, there are two groups of manufacturing design engineers in two large-scale plants in Japan. In the organization of Supplier J manufacturing design engineers are part of the research and development division, together with technology planning, cost planning, and product engineering.

Manufacturing technicians in Supplier E are in the same R&D center, together with the manufacturing engineers. Also, there are manufacturing technicians in every plant of Supplier E who are integrated into a section belonging to the plant management and/or integrated into a workshop team on the plantfloor, depending on the size of the plant.

Production process engineers (*seizo-gijyutsu-sha*) at Supplier J are in the department of the manufacturing design engineers at the headquarters, as well as in production control sections, which are found in every plant of Supplier J. In larger plants, production process engineers form their own subsection in the production control section, while in smaller plants they are simply part of the production control section without forming a subsection of their own. However, regardless of the number of production process engineers and their formal organizational subordination, they always work closely with the manufacturing design engineers who are located at the headquarters of Supplier J and the two large-scale plants.

Regarding interactions between upstream and downstream new component development processes, in Supplier E before the start of a new component development project, manufacturing engineers usually hold meetings and discuss different aspects of the new project with product engineers. Interactions between upstream and downstream processes are facilitated by the fact that the desks of product engineers and manufacturing engineers are in the same office room. In one case the desks actually face each other. This change to co-locate was made in the late 2000s. According to one of the manufacturing engineers, sharing the same boss (i.e., the manager of the R&D center) made "working together harder in the beginning, but better."

As already mentioned, product engineers, manufacturing engineers and manufacturing technicians in Supplier E are located in the same R&D center. For each new project related to the development of a new standard component, a design leader in charge of product engineering is nominated and paired with a manufacturing engineering leader in charge of line design and production method development. These two people are a product engineer and a manufacturing engineer respectively, and both of them receive support from other employees who are members of the same team and whose work is associated with downstream processes, like manufacturing technicians. All of these participants work together closely and hold meetings on a regular basis.

Manufacturing engineering leaders in Supplier E are responsible for product quality improvement, cost reduction and achievement of higher manufacturability of new standard components. To facilitate the above-mentioned improvements, a workshop is held after the new product drawings have been made. During this stage, the new product drawings are not frozen and not approved for manufacturing yet. The workshop is held in two phases and its duration is 3 or 4 days in theory. The manufacturing engineering leader is in charge of this team, and its members encompass a wide range of employees including, for example, manufacturing engineering, purchasing, quality control, maintenance, and when possible, line operators. The participation of line operators in the workshops depends on their availability. So, the involvement of the most downstream employees is prescribed as a preference. In addition, manufacturing technicians participate in FMEA (failure modes and effects analysis).

In Supplier J, manufacturing design engineers (*seisan-gijyutsu-sha*) as well as production process engineers (*seizo-gijyutsu-sha*) participate together with product engineers in FMEA and product and process reviews that are conducted within new component development projects to help identify potential design problems based on past experience with similar products or processes, or based on common failure mechanism logic, enabling the development team to design those failures out of the component with the minimum of effort and resource expenditure, thereby reducing development time and costs. The participation of production process engineers in FMEA is based on their experience and knowledge of potential problems that may occur during manufacturing. Production process engineers take part in line design and production method development, which is an area of responsibility of manufacturing design engineers, and in product design reviews, which are done before but sometimes concurrently with or after FMEA. Manufacturing design engineers and production workers (line operators) also participate in FMEA and design reviews.

Any other requests from the plant (i.e., production process engineers) regarding manufacturability, quality, cost, easy maintenance of equipment, etc. for new products, first go through the manufacturing design engineers who act like a filter, and then reach product engineers who take these requests into account when making the engineering drawings of new products. Dies are an exception; only manufacturing design engineers make proposals related to manufacturability, cost and quality. Production process engineers do not participate in the development of dies.

During the line design phase and the production method development phase, the manufacturing engineers in Supplier E perform the *lead role*, that is to say coordinate and strongly influence decision making in these phases, which among others includes decisions related to cost, cycle time, machine efficiency, number of operators, layout of the line, specific performance indicators like mean time before failure (MTBF), etc. This lead role played by manufacturing engineers also extends to execution of the majority of the tasks in the line design phase and the production method development phase, which among others include mechanical, electrical and software development for production equipment, equipment validation and acceptance, etc.

In Supplier E, during the line design phase and the production method development phase of a new component development project, the focus of participation of the manufacturing technicians who are co-located in the R&D center is on providing *technical support* to manufacturing engineers. This *technical support* encompasses analytical tasks such as methods-time measurement, R&R (repeatability and reproducibility) studies, calculation of run-at-rate for the equipment acceptance phases, etc. Subsequently, manufacturing technicians in plants play the *lead role* in the production preparation phase, that is to say coordinate and strongly influence decision making and execute the majority of the tasks in this phase which among others include equipment setting-up, validation and acceptance of the new manufacturing process in the plant, writing operation manuals and standardized work sheets for operators, training workers, etc..

Manufacturing engineers in Supplier E are responsible for line design and production method development, and they deliver to equipment suppliers specifications, such as performance targets, number of line operators, etc. The design and manufacturing of the equipment is outsourced but the manufacturing engineers of Supplier E are responsible and actively participate in equipment design, testing, and validation (see below), and their responsibility continues down to production preparation (management of manufacturing trials, line installation, operator training, etc.) and production ramp-up. In fact, although manufacturing technicians at the plant play the lead role in the production preparation phase, a manufacturing engineer at the plant has the overall responsibility for production preparation. The *main task* and responsibility of manufacturing technicians in plants is productivity improvement during volume production.

A similar distribution of *lead roles* along the different phases of the new component development project between manufacturing design engineers and production process engineers was observed in Supplier J, as well. Thus, in Supplier J manufacturing design engineers have the *lead role* during the line design phase and the production method development phase and their responsibility continues down to production ramp-up.

In Supplier J, the *main task* of production process engineers is equipment maintenance during volume production, but they also execute tasks related to continuous improvement (kaizen) and give full consideration to problems related to usability of equipment and potential manufacturing defects in the products. In executing these tasks, during the line design phase and the production method development phase, the focus of production process engineers' participation is on giving *informational support* to the manufacturing design engineers providing them with feedback from the point of view of the line operators. It is also necessary to mention that plant maintenance personnel are included within the organization that holds the production process engineers.

In Supplier J production process engineers actively participate in production preparation and production ramp-up. However, the weight (or level of responsibility) of manufacturing design engineers gradually starts to decrease from the manufacturing trials phase, at the same time the weight of production process engineers gradually starts to increase. This finding is largely in agreement with the first type of work organization of manufacturing engineering in Japanese companies described by Shibata (2009), where the tasks and functions of manufacturing engineering in production preparation are shared by manufacturing design engineers and production process engineers.

In Supplier E, manufacturing engineers are responsible for development of production methods (assembly sequence, etc.) but they usually do not develop or manufacture machines and equipment, although they are closely involved in this process. The manufacturing of machines and equipment is outsourced to equipment suppliers. Supplier E has a commitment from the suppliers to dedicate the necessary staff for the development and manufacturing of the equipment. Checking the allotment of resources and the outsourcing of tasks is another important role that manufacturing engineers in Supplier E perform. Visits to the supplier are made every 2 weeks during the development phase, every month in the beginning of the building phase, and every 2 weeks at the end of the building phase. During the setup phase Supplier E personnel work constantly at the supplier's plant. Personnel from the supplier work constantly at Supplier E during the installation and validation phase. Good relations between engineers on both sides is important. There is daily communication during the whole time.

In Supplier J, manufacturing design engineers develop production methods too, but in addition they also develop machinery and equipment together with the equipment suppliers. The manufacturing of large equipment is outsourced to equipment suppliers, however smaller equipment is manufactured in-house.

5. Conclusions, limitations, and future research directions

The aim of this research is to examine the tasks and functions of manufacturing engineering in a European supplier of auto parts, and to compare these tasks and functions to those in a Japanese supplier of similar auto parts in order to identify similarities and differences between the two companies with regard to manufacturing engineering. By doing so the research seeks to add to the existing literature on manufacturing engineering by advancing our understanding of how manufacturing engineering is done in Europe.

Due to the preliminary nature of the findings, at this stage it is not possible to give a definitive and detailed answer to the question about tasks and functions of manufacturing engineering in Supplier E and Supplier J. Nevertheless, our current preliminary findings are summarized in Figure 1.

The major difference between the tasks and functions of manufacturing engineering in Supplier E and Supplier J appears to be in the area of responsibility of manufacturing technicians and production process engineers respectively. In Supplier E, the focus of participation of manufacturing technicians in the line design phase and the production method development phase is on providing *technical support* to the manufacturing engineers by executing some of the analytical tasks associated with these two phases. While in Supplier J, the focus of participation of production process engineers in the line design phase and the production method development phase is on providing *informational support* to the manufacturing design engineers, a sort of liaison between the plants and R&D. Unlike what was found in Supplier E, in Supplier J equipment maintenance is an another important task executed by production process engineers. In Supplier J we also observed that in the production preparation phase overall responsibility is shared between manufacturing design engineers and production process engineers.

Figure 1. Distribution of manufacturing engineering tasks in Supplier E and Supplier J during a new component development project

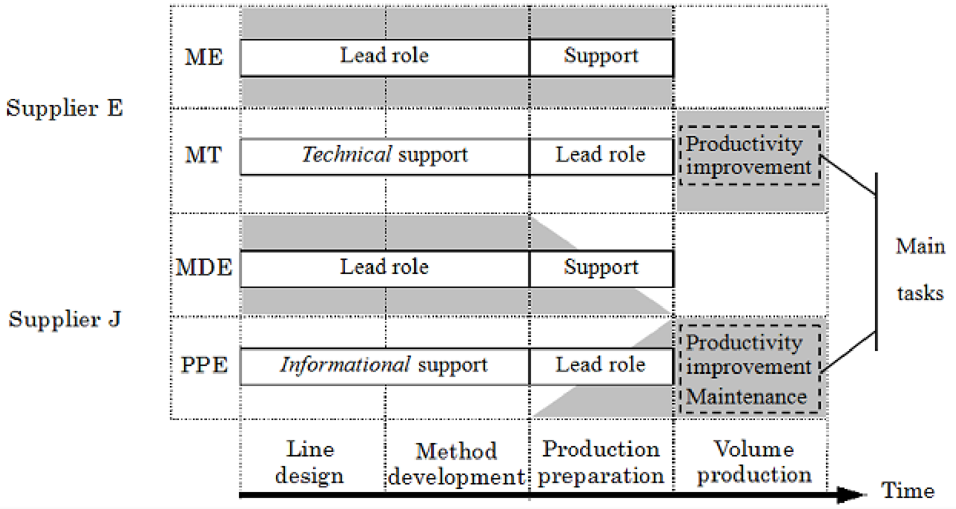

Figure Key:
ME - manufacturing engineers; *MT* - manufacturing technicians; *MDE* - manufacturing design engineers; *PPE* - production process engineers; *Grey color* - overall responsibility; *Lead role* - coordinate and strongly influence decision making and execute the majority of the tasks in the phase; *Technical support* - focus on analytical tasks in the phase; *Informational support* - focus on providing feedback from the point of view of the line operators; *Support* - provide various forms of technical and/or informational assistance.

Notes:
1. At Supplier J, in the production preparation phase overall responsibility is shared between MDE and PPE, with MDE's level of responsibility gradually *decreasing* as the phase progresses and PPE's level of responsibility gradually *increasing* as the phase progresses.
2. This figure omits the product engineering phase for simplicity reasons, which starts before the line design phase and during which product engineers have the overall responsibility and perform the lead role.
3. This figure amalgamates production ramp-up into production preparation for simplicity reasons.
4. This figure shows the different phases in sequential order for simplicity reasons, although in reality the phases are overlapped at both companies.

Even at this early stage of our research it seems that in Supplier E interactions between production workers and manufacturing engineers on one side, and product engineers and manufacturing engineers on the other, are prescribed in a way not noticeably different from how these interactions are prescribed in Supplier J, in that both companies prescribe involvement of production workers in upstream processes. However, the way production workers are prescribed to become involved appears to be different. At both Supplier E and Supplier J production workers are prescribed to become involved from the product engineering phase, when the new product drawings are being validated for manufacturing. However, at Supplier E production workers become involved through a single workshop event that covers both the product engineering phase and the line design phase. Whereas, at Supplier J, they are prescribed to become involved preferably from the beginning but certainly from the first FMEA and DR of the project. This involvement is not a single event but typically occurs multiple times.

In addition, we do not know the extent to which this prescribed preference is actually realized in Supplier E. Also, Supplier E and Supplier J are similar in the organization of manufacturing engineering because in both companies the manufacturing engineers are part of their respective new product development divisions. The status of manufacturing technicians in Supplier E remains an important ongoing line of inquiry in this research.

Another finding that shows similarities between Supplier E and J is the location of their manufacturing engineering divisions. The divisions of both companies are located near plants, which is in striking contrast to what Shibata (2009) observed in the United States, where the divisions of manufacturing engineers are located far from the plants. In the case of Supplier J, the plant that is near the headquarters is relatively old (for Supplier J), and so is the equipment. However, we know that in the case of Supplier E, the company recently relocated product and process engineering, including the manufacturing engineering division, near a plant, as part of a recent operational realignment.

Supplier J on the whole does not deviate considerably from what Shibata (2009) found about manufacturing engineering in Japanese companies. There is considerable interaction between downstream and upstream processes at Supplier J, and the involvement of production process engineers extends up to product engineering through the participation of production process engineers in the product design review and FMEA.

The deliberate choice of two suppliers of similar automotive component for analysis, while necessary for the particular purpose of this study, is of course a limitation of the research. In relation to the specific case studies, the lack of more detailed information with regard to the tasks and functions of manufacturing engineering, such as that which could be obtained through a questionnaire survey for example, rendered it difficult to measure the extent of manufacturing engineering's interaction with new product development and production.

Like all research, this study has unearthed other questions. The possibility exists to continue to deepen the findings of this paper and explore any other important attributes and characteristics that might underpin and determine manufacturing engineering in other companies both in Japan and overseas. Furthermore, recognizing the importance of historical, economic and socio-cultural circumstances as influencing factors in the development of manufacturing engineering, the opportunity exists to explore these areas further, and to broaden our understanding of their influence on manufacturing engineering.

Moreover, the performance implications of differences in the functioning of manufacturing engineering, such as time compression (shorter lead time) and manufacturing cost reduction, may provide researchers with another promising avenue of approach to understand the importance of manufacturing engineering and, for example, the degree to which manufacturing engineering of Japanese companies can and should be transferred to their overseas affiliates.

Finally, this research focuses on just one country in Europe, so there is need to establish the degree to which this case is representative of other auto suppliers in this country. A next step could then be to see how the functions of manufacturing engineering in this country compare with other countries in Europe. Additional studies of different companies and industries in Europe and Japan would be a valuable exercise and would help define the external validity of this research.

If further research finds that the functions of manufacturing engineering in Supplier E are typical in Europe then another question may arise: how such a European work context can be expected to impact efforts by Japanese manufacturers as they increasingly expand the functions of their European facilities to include an increased role of manufacturing engineering at their local site.

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