A Preliminary Study on Manufacturing Servitization in Machine Tool Industry

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Abstract--**Manufacturing servitization will be a turning point for machine builders to build competitive advantage to fight against cost-down oriented competition from emerging countries. We conduct a preliminary study on manufacturing servitization with the model of Product Life Cycle Service to identify the progress of manufacturing servitization in machine tool industry. Five cases of global machine tool manufacturers not only show the difference between each other but also point out how they approach manufacturing servitization.**

I. INTRODUCTION

Service industry has been playing an important role either in developed countries or developing ones. According to statistics of World Bank 2012, service sector accounts for more than 70% of Gross Domestic Product (GDP) in the developed countries such as United States, France, and Germany. In developing country, such as China, service sector contributed 43% of GDP in 2011. It's no doubt that the world economics has been shifting from agriculture and manufacturing to service sector.

On the other hand, in the manufacturing sector, emerging countries have been posing the strong competition to advanced economics in terms of product price. The research suggests that products of U.S. manufacturers have to reduce their cost by 30% in order to compete with Chinese producers [28]. The competition from emerging countries is inevitable. Porter and Ketels [20] suggest that manufacturers in developed economies have to move up the value chain to compete on the basis of value delivered rather than on the basis of cost.

Economists regard 3D printing technology, which implies network manufacturing, as one of industry revolution to a new paradigm of manufacturing. In relation to network manufacturing, industry 4.0, which was promoted by Germany government as one of high-tech strategies 2020 [11], implies paradigm shift from centralized production to decentralized production. Industry 4.0 integrate internet of things and service. It points out that manufacturing servitization might be a turning point for machine builders to build competitive advantage to avoid cost-down oriented competitors from emerging countries.

It is widely assumed that manufacturing firms can rarely remain as pure manufacturing firms in developed economics. Instead, they have to move beyond manufacturing and offer services and solutions, which are delivered through their products [16].

Manufacturing servitization has been adopted by machine tool manufacturers in developed countries to strengthen their product competitiveness. In addition to enhance product's precision and reliability, machine tool manufacturers in Taiwan are also providing more services to add values on their products. Purpose of this study is to identify and find out the gap in manufacturing sevitization between Taiwan's machine tool manufacturers and their global competitors in developed countries.

In order to sustain growth and strengthen competitive advantages, Taiwan's machine tool manufacturers not only have to enhance product's precision and reliability but also have to create new values and differentiations. As mentioned, machine tool companies of developed countries have been transforming their product oriented business model into service oriented. If Taiwan's machine tool manufacturers want to catch up their paces with their rivals in manufacturing servitization, they have to realize their deficiency and competitors' capabilities.

We observed five machine tool manufacturers including global companies like Okuma Corporation, DMG/ Mori Seiki Co. Ltd, Makino Inc and Taiwan leading companies: Tongtai and Hartford in this study. We conduct Product Life Cycle Service Modes with combined construct of Product Service System (PSS) and Life Cycle Cost (LCC) to make comparison of each machine tool manufacturers' servitization progress and service offering. It's found that Taiwan machine tool manufacturers currently do not provide all of the services to fulfill all of product oriented life cycle services. They rely on their distributor worldwide for product promotion and sales. The result also implies three different solutions which manufacturers could adopt for developing manufacturing servitization. They are internal resources integration, alliance, and external resources integration.

We make contribution to preliminarily study on identifying the progress of machine tool manufacturer in manufacturing servitization. We propose Product Life Cycle Service Modes comprising Product Service System (PSS) and Life Cycle Cost (LCC) to make comparison of each machine tool manufacturers' servitization progress and service offering.

This article begins with the theories related to manufacturing servitization. Following is methodologies and Product Life Cycle Service modes. Third part is the empirical case studies and results. Following we discuss the implication and finally make conclusion and suggestion for future research.

II. LITERATURE REVIEW

Life Cycle Cost (LCC) has become one of the decisive factors while industrial product purchasers making

purchasing decisions. Servitization involves the innovation of an organization's capabilities and processes in order to create value from selling product to selling Product Service System [1][2]. In this section, we have literatures review on the Life Cycle Cost along with the trend of servitization and Product Service System.

A. Life Cycle Cost, LCC

Life Cycle Cost (LCC) is an economic method for evaluating asset that considers all costs arising from owning, operating, maintaining, and disposing of the asset [6]. The LCC concept was initially applied by the U.S. Department of Defense (DoD). Importance of LCC was stimulated by findings that operation and further support costs for typical weapon systems accounted for 75% of the total cost [9].

Numerous costs appear in the product life cycle and these costs can be grouped into following three categories from purchaser's point of view: acquisition costs, ownership costs and disposal costs [3][4]. Acquisition costs are the combination of product price, installation cost, training cost, and shipping cost. They can be estimated and visible. Ownership costs occur during the whole period of product life. Operation cost and maintenance cost are treated as ownership cost normally.

From customer point of view, a product or system with guaranteed life cycle performance and competitive life cycle cost is preferred. From observation of evolution of industry, a trend is found that manufacturer adds services onto their products to ensure customer satisfied performance and cost, and take responsibility for risk and maintenance.

A typical example is Rolls-Royce's "power-by-the-hour" solution package. Customers of the package pay a fixed warranty and operational fee for the effective run time of the jet engines [12]. Rolls-Royce's entire solution package including jet engine, installation, after-sales maintenance, repair, and overhaul services is provided through a complex business network, which consists of specialized components suppliers such as Volvo Aero and maintenance specialists such as Lufthansa Technik. This business network replaces the traditional vertically integrated supplier-customer relationship between Rolls-Royce and its direct customers such as Boeing and Airbus [7]. According to Rolls-Royce's 2012 annual report services revenue accounts for 54% of total revenue of Civil Aerospace business unit [23].

In addition to Rolls-Royce, organizations such as IBM, General Electric, Xeros, and Canon have had a significant share of revenues and profits from services sector since the middle of 1990s; the result is attributed to a shift from product to service perspective [21].

LCC has been adopted by machine tool customers and users have to evaluate total life cycle cost rather than initial investments costs. For example, the developer of TCO (Total Cost of Ownership) standard, Daimler-Chrysler, buys machine tools and production lines according to a TCO contract where the total life-cycle-costs are assured by contract for 10 years [18].

B. Manufacturing Servitization

Manufacturing servitization, was firstly coined by Vandermerwe and Rada [27]. They defined servitization as the increased offering of fuller market packages or bundles of customer focused combinations of goods, services, support, self-service and knowledge in order to add value to core product offerings. In addition, their paper highlights the potential of services that are sweeping the whole industry.

"Servitization is happening in almost all industries on a global scale. Swept up by the force of deregulation, technology, globalization and fierce competitive pressure, both service and manufactures are moving more dramatically in to service" [27].

Servitization is now widely recognized as the process of creating value by adding intangible services to tangible products. Since the first introduction of servitization, more and more related studies were produced, such Product Service System.

Mathieu [14] distinguishes three generic benefits from implementing a service strategy in manufacturing companies: financial benefits, strategic benefits and marketing benefits. Neely [17] points out shifting to services will be a complicated process and engineering including solution, outcomes, relationship, network partners and ecosystem.

Manufacturers should consider five categories of challenges: embedded product -service culture, delivery of integrated offering, internal processes and capability, strategic alignment and supplier relationships while moving from a product oriented organization to a product-service oriented [15]. A manufacture's journey towards becoming a servitized organization is not only hinderer by internal, but also by external factors. Moreover, relationship with the external network plays a critical role [29].

C. Product Service System, PSS

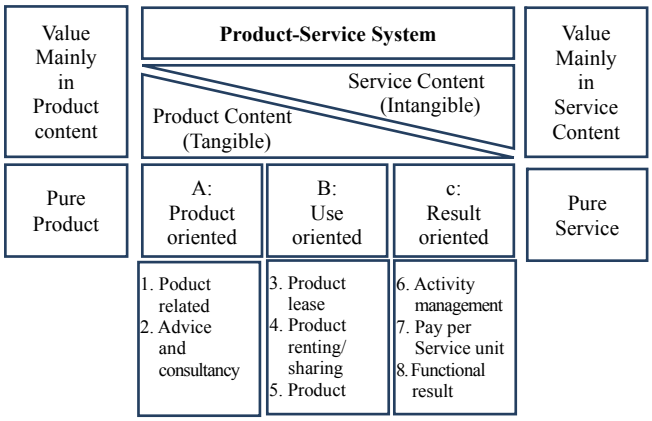

Figure 1. Product Service System (Tukker, 2004)

Product Service System, PSS is an integrated product and service offering that delivers value-in-use [1]. In PSS studies, a categorization scheme was compiled by Tukker [25]. In the scheme shown in Figure1, pure product manufacturers

transforms into pure service providers by decreasing tangible product content to increasing intangible service content. In such kind of approach, three categories are generated in terms of degree of service content.

The first main category is product-oriented services. This business model is still mainly geared towards sales of products along with some product related services.

The second main category is use-oriented services. The traditional product still plays a central role, but the business model is different. The product's ownership stays with its provider, and product utilization is available to it user in a different form, and sometimes shared by multiple users.

The last main category is result-oriented services. The provider and customer in principle agree on a result, and there is no pre-determined product involved.

III. RESEARCH METHODOLOGY

Machine tool manufacturers have been providing more service along with their products. Manufacturers have to look at the value chain through the customer's eyes, examining all the activities the customer performs in using and maintaining a product throughout its life cycle [30]. Downstream opportunities are usually much broader. In this section, a breakdown of life cycle cost for machine tool is combined with three categories of PSS and come out a mode to identify the manufacturer's progress of servitization.

1. Empirical Context: Machine tool industry in Taiwan

Global production volume of machine tools comes to US$ 932 billion in 2012 [24]. Leading Producing Countries in the production of machine tools are China, Japan, Germany, Korea, Italy and Taiwan. Taiwan is the sixth leading producing country. Taiwan's export value of machine tools reached USD 4,236 million in 2012. In terms of export revenue, Taiwan has become the fourth biggest machine tool export country in the world followed by the Japan and Germany, and Italy.

After decades of development of machine tool industry, Taiwan's machine tool products are able to compete against Japanese and German counterparts in the mainstream product segment in terms of quality and price. Currently, about 75% of Taiwan's machine tool products are exported to the worldwide markets, including China, the European Union, Association of Southeast Asian Nations (ASEAN) and the United States. However, due to lack of core technologies and capability to produce key components, Taiwan's machine tool industry is struggling to gain more market share in the profitable high-end segment which is occupied by the manufacturers from advanced countries. In the meantime, Taiwan's machine tool manufacturers also have to face emerging cost competition from China in the lower end of the market segment.

Machinery industry is expected to be the next "Trillion Dollar" industry followed by semiconductor and optronics in Taiwan. In addition to providing high-quality and high C/P value products, and in-time logistics, Taiwan's machine tool manufacturers have to build more competitiveness and differentiations to compete against their worldwide competitors.

As observation of machine tool manufacturers in developed countries, they have been providing intangible services along with selling tangible products to sustain their leading position in the market.

2. Methodology

In this research, a tool is developed to identify the position of a machine tool manufacturer. This tool, Product Life Cycle Services Modes, is a combination of PSS and a break down of machine tool's LCC (Life Cycle Cost). The product service related information, which are collected form machine tool manufacturer's website, are input into the Product Life Cycle Service Modes and being categorized. The result can show us the progress of this machine tool manufacturer. The whole model and procedure is show in Figure 2.

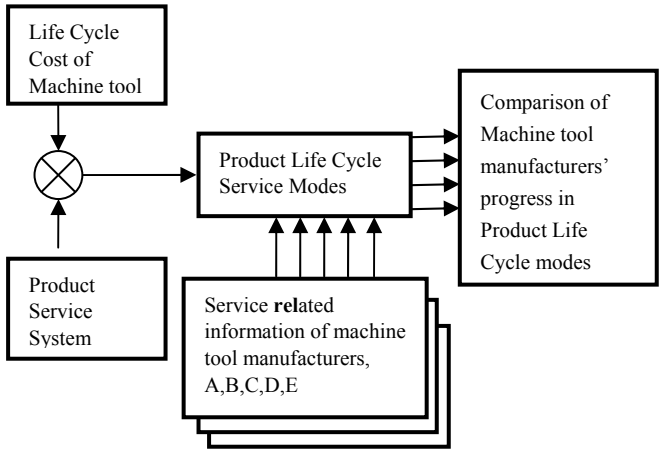

Figure 2. Research Methodology

A. LCC for machine tool

In general, life cycle cost can be divided into three categories including acquisition costs, ownership costs, and disposal costs. In this study, a detail break down structure of life cycle cost is needed to understand the specific cost items of machine tool. Rafael et al (2006) present a life cycle cost break down structure in their study as shown in Figure3 [22].

B. Service categories of Product Service System

There are three major service categories of PSS, product oriented, use oriented, and result oriented, as shown in Figure 1. Detail of these three services will be presented in the following section. In this section, thee major categories of PSS will be parts of the product life cycle service modes.

In this study, Product Life Cycle Service Modes are developed as showed in Figure 4, which is a combination of PSS and LCC of machine tool. Product oriented service, use oriented service, and result oriented service are provided to decrease the cost for each phase of machine tool life cycle.

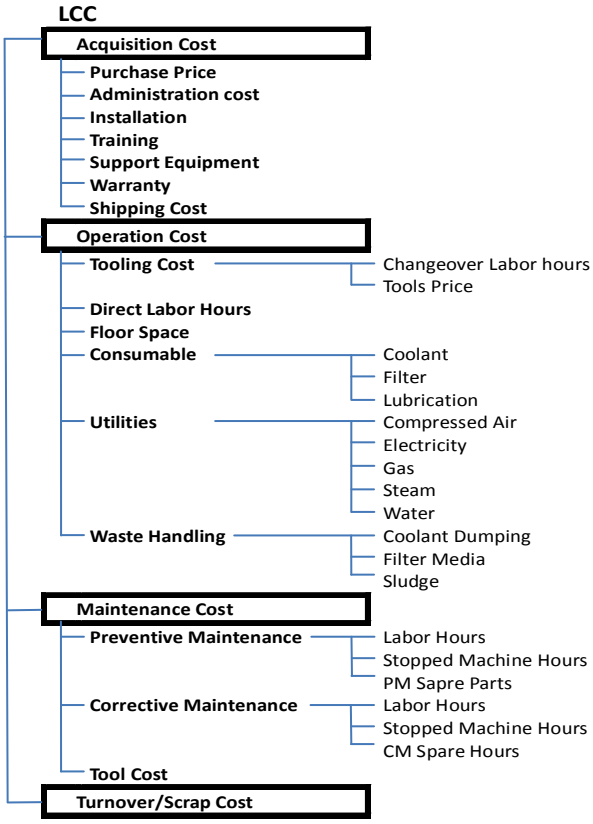

Figure 3. Life Cycle Cost Breakdown (Rafael et al, 2006)

A. Product oriented service mode

1) Acquisition Cost

Customer of the machine tool is also the user of the machine tool. Therefore, the ownership of machine tool is transfer from manufacturer to customer. Machine tool customer bears the cost for acquisition and administration. In the product oriented type, products related services are provided. For example, machine tool manufacturer provides sorts of training courses depending on the agreement between manufacturer and customer. In addition, for machine tool purchase, manufacturer may provide financial package to lessen the initial investment burden for the buyers.

2) Operation Cost

Machine tool installed and uses machine to manufacture their products in customer's factory site, therefore customer pays the cost related in the operation, such as labor cost, floor space, and electricity.

3) Maintenance Cost

Two kinds of maintenance services, preventive and corrective, are provided by machine tool manufacturer. Preventive maintenance is carried out periodically to prevent unexpected machine downtime. Machine tool manufacturer proposes the list of preventive maintenance and execution frequency based on user's production plan. Corrective maintenance services are required when machine goes down. Improper usage, component failure, or lack of preventive maintenance would cause unexpected breakdown of machine.

To minimize machine downtime cost for customer, some machine tool manufacturers provide 7/24 service program to provide in time service for customer.

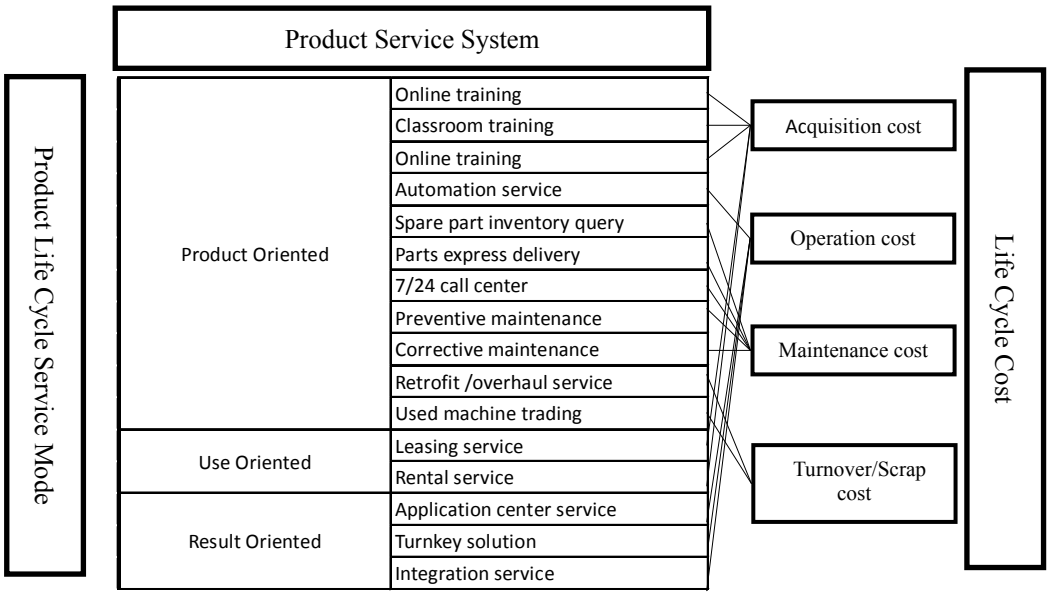

Figure 4. Life Cycle Product Service System Modes

4) Turnover/Scrap Cost

Existing machine tool is not able to produce the new products market requests probably due to its functions, precision or speed. Machine tool can be disassembled, retrofitted, refurbished, and relocated to new user's factory site. The retrofits or refurbishment services might be provided by this machine tool's original manufacturer or a 3rd party company who is running used machine trading business. In addition to retrofits, dissembling, relocation, and reassembling services are also needed during the ownership transaction of used machine tool.

B. Use Oriented mode

1) Acquisition Cost

In user oriented type, machine tool is still owned by its provider. A machine tool provider can be its manufacturer or a 3rd party, such as financial service company. Machine tool user rents the machine from the provider on a monthly basis or annual basis. This machine tool can be used by another user after end of existing leasing contract. Besides, different training courses are offered by manufacturer according to the agreement between manufacturer and user. In user oriented type, machine user's initial investment is less than product oriented one.

2) Acquisition Cost

Machine tool customer installs and uses the machine in his own factory site. Therefore, user is responsible for the cost related in the operation, such as labor cost, floor space, and electricity.

3) Maintenance Cost

Machine tool user pays for maintenance cost for operation. Two kinds of maintenance services, preventive and corrective, are provided by machine tool manufacturer. Different package maintenance service provided based on mutual agreement.

4) Turnover/Scrap Cost

Since machine tool user doesn't own the machine, therefore he doesn't need to concern about overhaul and scrap cost. Machine tool manufacturer or 3rd party service is responsible for machine tool's overhaul and scrap.

The major difference between product oriented and user oriented is machine tool user in not owner of machine. Ownership of machine tool is either stay in it manufacturer or transferred to 3rd party company. User uses the functions of machine tool but own the machine.

C. Result Oriented mode

1) Acquisition Cost

In result oriented mode, ownership of machine tool is not key, but function and result of total production process. Machine tool provider integrates kinds of the whole production system related hardware and software for a certain kind of customer product manufacturing. Machine tool provider provides an integrated production system solution rather than a discrete machine tool. Customer does not have to deal with different suppliers to build up its production system; therefore acquisition process can be more efficient and acquire right product and solution customer needs. In result oriented, machine tool customer may be charged by pay-per-use, pay-per- part, or pay-per-availability.

2) Operation Cost

In result oriented type, machine tool manufacturer provides total production system integration service which can help customer reduce total operation cost, such as floor space, energy efficiency, and labor cost. For the customers who is served by pay per service unit, their operation cost can be lower because they just have to pay when they need service.

3) Maintenance Cost

In result oriented mode, total production system integration help customer to reduce it maintenance cost tangibly or intangibly since maintenance is not so complex comparing with multi-supplier. On the other hand, if user is charged per use of machine. Machine tool manufacturer is responsible for timely and efficient maintenance service to ensure user's production quantity and quality. Maintenance cost can be included in the fee per use of time.

4) Turnover/Scrap Cost

For the machine tool manufacturer who provides result oriented service also provide service for overhaul and scrap. For the customer who is served by pay per service unit, he doesn't own the machine and doesn't have concern for overhaul and scrap cost.

In result oriented type, machine tool manufacturer help customer improve total production system's result and reduce life cycle cost. On the other hand, for customer who is served by result oriented can be charged either by pay- per- use, pay-per- part, or pay- per -availability.

For example, copy machine provider installed the machine in his customer's office and charges his user by the times of copying. Operation cost, such as paper, electricity, floor space belongs to machine user. Copy machine provider offers free maintenance service and ensures the minimum downtime of the machine. If current machine cannot meet customer's new requirements, copy machine provider will replace it with a new model.

In this section, the Product Life Cycle Service Modes for machine tool is developed. The service modes help us to understand when services are requested and provided, and who providers the service. In next section, we will present machine tool manufacturers' servitization progress and status by collecting service related information of machine tool manufacturers and categorized by product life cycle service modes.

VI. CASES STUDY

In the previous section, the product life cycle service modes are proposed by combining PSS and LCC. In this section we collect service related information of machine tool manufacturers. Service related information on machine manufacturer's website presents its capabilities to provide services bundling with its products and emphasis its differentiation comparing with its competitors. In addition, some information is from machine tool manufacturer's distributors as supplement. These services related information is collected, sorted, and categorized by machine tool product life cycle service modes.

There are five machine tool manufacturers selected as focal targets according to following rules:

1. The foreign companies are listed as top-15 machine tool manufacturers worldwide.
2. Services related information is enclosed relatively complete on company's websites.

Service related data is collected from public information, for example focal company's annual report, company's and its distributors' websites. In addition, supplement information is gained from local media. After their information are sorted and categorized, a comparison is presented to show their different progress in manufacturing servitization.

1. Case A : Okuma Corporation

Okuma Corporation was found in 1898, and its capital is ¥18,000M currently. Okuma manufactures and sells of Numerical Control (NC) machine tools (NC lathes, multitasking machines, machining centers, grinders), NC controllers, FA products, servo motors, etc. Its sales revenue is ¥133.8 billion in FY2012[19].

Okuma has three domestic and thirteen overseas subsidiaries and affiliates companies operate business in America, Europe, China and Taiwan. Okuma highlights its total solution offering by integration of key components built by Okuma itself, such as controller, motor, drive, and encoder. Detailed information for the services provided by Okuma is as below:

A. Product Oriented Service

Okuma doesn't provide financial (loan) service to its customer directly. The financial service is supported by 3rd party financial company. For example, one of Okuma's North America distributor C.H. Gosiger Machinery Company will refer customer's financial service request to a 3rd party company called Connext Financial [8].

In addition to training courses provided by Okuma, customer can also get training and education by Okuma's partners. For example, in the U.S., Okuma's partnership with York Technical College's Center for Advanced Manufacturing provides opportunities to train on the latest technology available. The college offers Okuma distributors and customers hands-on training in machining practices using Okuma machines and tools. The center educates a wide range of students from Fortune 500 companies to small job shops. Students have come from companies such as: Rolls-Royce, The Boeing Company, General Motors, John Deere, Honda, Siemens and Harley-Davidson.

Okuma cooperates with its distributors or 3rd party partner to provide automated manufacturing process. The THINC control solution created by Okuma provides an interface between Okuma's machine tool and 3rd parties system, such as robot. For example, FANUC Robotics has worked with Okuma for many years to automate machine tool systems. Okuma's THINC controls the machining process, and coordinates the activities of the robots, gauges, other machine tools, and reporting tasks.

Customer can get 24/7/365 access to replacement parts inventory look up and get technical support. Q24 is an exclusive service of Okuma, through a partnership with FedEx, Okuma offers global door-to-door emergency parts shipping.

Regarding maintenance service, to minimize machine downtime and reduce repair cost, THINC control system is developed by Okuma for remote troubleshooting and monitoring services. Okuma's Constant CARE products and services enhance remote troubleshooting and monitoring capabilities. Constant CARE focuses on minimizing machine downtime and repair costs, while maximizing effectiveness and resources.

Machine tool rebuild and retrofit services are provided by Okuma's partner. For example in the U.S., Infinity Rebuild Inc., formerly the Okuma Rebuild Division, provides the highest quality machine tool rebuilds for Okuma's customers. Infinity Rebuild, Inc. is also a member of Partners in THINC and offers complete machine tool retrofits with the THINC-OSP control. With the ability to rebuild the machine and offer a new THINC-OSP control retrofit integration, customers can continue to use their existing equipment while updating it with today's technology.

B. Use Oriented Service

Okuma does not provide machine tool leasing service. The service is provided by 3rd party or financial company.

C. Result Oriented Service

Okuma cooperates with its distributor worldwide to establish Tech Center to make customer to have fully experience of the excellence and quality of Okuma CNC machine tools by participating in live, hands-on cutting demonstrations. For instance, Okuma America Corporation and its Mexico's exclusive sales agent HEMAQ opened an Okuma Tech Center in Monterrey, Mexico. The center enables customers to improve their productivity by testing different technologies and processes, and through numerous training opportunities. In addition to demonstrations showcasing Okuma CNC machines, the center provides turnkey services including runoffs with access to metrology equipment, ready inventory of cutting tools, process analysis

for CNC machine selection, simulation machine tools for training, and support from onsite application engineers.

2. Case B : DMG/ Mori Seiki Co. Ltd

GILDEMEISTER AG and Mori Seiki Co. Ltd. are two global machine tool manufacturers cooperating with each other worldwide by combining sales and service activities [5]. DMG/Mori Seiki offers its customers a broad product portfolio as well as unique market presence. The partnership comprises joint sales and technical services, such as customer service, training as well as technical support.

Life Cycle Service is promoted by DMG/Mori Seiki to maximize the productivity and extend machine tool life cycle. Life Cycle Services of DMG/Mori Seiki includes training, services, automation, pre-setting devices, software, retrofitting, overhauling, and used machine offering.

In the case of DMG / Mori Seiki, various services related to machine tool's life cycle are provided to fulfill customer's demand for product life cycle and extend its advantages to result oriented service. More detail information for the services provided by DMG/Mori Seiki is as below.

A. Product Oriented Service

Purchase finance service is either supported by 3rd part or subsidiary of DMG/ Mori Seiki. In Europe, MG Finance GmbH is a finance service company founded by joint venture of DMG, Mori Seiki and Mitsui & Co. Ltd. This joint venture offers DMG/ Mori Seiki's customers individual financing solutions.

DMG/Mori Seiki is the world's largest dealer of DMG and MORI SEIKI used machines, DMG/Mori Seiki offers customers certified used machines for all requirements under expected budget. A wide selection of used machines, short delivery times, and comprehensive customized service are offered along with trade- in and financing service.

In addition to work piece handling, pallet handling, and tool handling, DMG/Mori Seiki can modify the tried-and-tested ready-to-connect automated solutions, for example through the use of rotary tables instead of workpiece drawers, optical image processing and location detection, or loading of several machine tools with one robot etc.

Customers can get support from DMG/Mori Seki through the service hotline of each country. Service experts of MDG/ MORI SEIKI are available 24 hours per day, 7 days per week.

In order to ensure customers' machine productivity, DMG/ Mori Seki offers more than 10,000 different parts on stock and availability in excess of 95 percent. Whatever part customers need for operation, DMG/ Mori Seki's global spare parts service will deliver it in time.

MORI-MONITOR is DMG/Mori Seiki's application system for remotely controlling and browsing the MAPPS control system from an office computer over a network. Customer can check the status of machines and deal with problems, in the office instead of factory floor.

After years of operation, precision and productivity of machine tool decreases. By overhauling service of DMG/Mori Seiki, performance of machine can be restored to 100%. Additional software update and retrofitting can also improve performance.

B. Use Oriented Service

Leasing, renting, and rent-to-buy options are provided by DMG/Mori Seiki or 3rd party, finance service company for example.

C. Result Oriented Service

Aerospace Excellence Center of DMG/ Mori Seiki is to provide perfect result for aerospace components manufacturing. The service includes solution feasibility studies, project management, process development for cost effectiveness, knowledge transfer, and new technology innovation.

3. Case C: Makino Inc.

Makino Inc. is one of the leading company in metal-cutting and manufacturing technology, with industry-leading horizontal machining centers, vertical machining centers, wire EDM and Ram EDM, and graphite machining centers [13]. Makino emphasize its competitive advantage in term of software, engineering services, financing, turnkey engineering, integration services, automation systems, training and process technology. More detail information for the services provided by Makino is as below:

A. Product Oriented Service

With loan financing, customer owns the equipment and receives the tax benefits of depreciation and interest deduction. Makino may finance up to 100 percent of the purchase price of the equipment, including sales tax. Or, Makino works out a schedule that allow customer pay for equipment with the revenue it generates.

Makino offers customers a number of formal training opportunities on selected topics and products. Content is based on specific skill sets and objectives and is designed to transfer a working knowledge and understanding of the machine tool system and related processes. Makino training credits may be provided with the machine purchase based on machine type and machine purchase agreement. These credits must be used during the first year after purchase. Training for additional personnel or after the standard first year period is on a tuition basis. In addition, Makino provides online training courses. Customers can access the online training courses after registration.

Since the mid-1990s, Makino has developed automated solutions for manufacturers. Makino's automated systems deliver benefits including higher utilization rate of machining, higher throughput, reduction in labor content, process consistency associated with automated part load, flexibility to redeploy for future production needs

In decrease machine downtime, customers can get support from Makino through the service hotline for 24 hours a day,

seven days a week.

Makino Preventive Maintenance Program, a structured schedule of proactive maintenance activities, detailed maintenance procedures and recommended service parts designed to keep customer's machine operating efficiently. Worn components that need servicing or replacement can be identified. Service is performed quickly and thoroughly so that machines are placed back into productive use once standard predictive and preventive processes are identified.

The Makino Parts Express online store provides the ability to check availability, shipping status by direct connection to carrier delivery-tracking websites, s price and place order for the parts needed maintenance requirements. Ordering by online store not only reduces ordering costs, in addition customer can check order such as UPS.

Makino Retrofit Option services support machine upgrade requirements ranging from programming support to high-pressure coolant systems or probing additions. Makino Machine Relocation and Refurbishment services are beneficial during any sort of machine relocation. They include coordination of de-installation from the old site and reinstallation at the new site to ensure continued effective operation. Makino machine refurbishment provides a comprehensive list of repairs.

B. Use Oriented Service

Makino's rental agreement provides customer short-term utilization of Makino equipment, typically for a minimum term of 12 months. In addition, customer will have an opportunity to purchase the equipment or renew the rental agreement upon its scheduled expiration. Customer can choose from two great options: a Rent-to-Own Rental Agreement or a Month-to-Month Program.

C. Result Oriented Service

Makino Integration Services provides full automation engineering services including cell controller programming, robot reach services, robot end-of-arm tooling gripper design, robot programming, conveyor designs, third-party technical management and human management interface development.

Makino's turnkey solutions help demystify and simplify customer's operations by serving as a single project engineering resource for such things as application engineering, fixture design and building, process design, tooling design and building, project management, cost and time guarantees, installation, runoffs, and technology transfer. Turnkey solutions can guarantee cycle times, production and throughput rates that help grow customer's bottom line.

4. Case D: Taiwan machine tool manufacturer, Tongtai company

Tongtai company is a Taiwan based machine tool manufacturer providing vertical machining centers, horizontal machining centers, CNC lathes, wheel machine. Consolidated sales revenue is NT$7.2B in 2012 [26]. In order to enrich its product portfolio, Tongtai company built strategic alliance with another Taiwan local machine tool manufacturers. There are three oversea subsidiaries located in U.S., Netherland, and Japan.

Service related information is collected from Tongtai company's and it distributors' websites. In addition, supplement information is gained from Taiwan local media. More detail information for the services provided by Tongtai company is as below:

A. Product Oriented Service

Financial service to machine tool customers is provided by 3rd financial company.

Tongtai provides proprietary automatic loader solution for CNC lathes products to minimize labor costs.

Preventive maintenance software, such as tooling life time management, is provided to avoid unexpected machine downtime.

Overhaul and retrofit services are provided by Tongtai company's distributors.

B. Use Oriented Service

Leasing and rental program is provided by 3rd party company.

C. Result Oriented Service

In 2013, Tongtai company opened its first technical application center in Taiwan headquarters. The aim of the center is to provide customer's processing consultations and fulfill the requirement for higher degree of efficiency. As company's plan more technical application centers will be established to serve local customers in China, Europe, America, and Southeast Asia.

5. Case E: Taiwan machine tool manufacturer, Hartford company

Hartford company is another Taiwan based machine tool manufacturer providing vertical machining centers, horizontal machining centers, double column machining centers, and precision boring and milling machines [10]. Hartford company's products are sold via its distributors worldwide, and sales revenue is NT$3.7B. More detail information for the services provided by Hardford company are described as below:

A. Product Oriented Service

Financial service to machine tool customers is provided by 3rd financial company. Software package, "Hartnet", provided by Hartford company allows customers to monitor real time status of machine via internet. In addition, this software package can be also used to check machine parameter setting, upload/download programs from distance, and analyze machine operation efficiency.

Parts inventory can fulfill distributors' needs within 1~5 days shipped from Taiwan. Distributors of Hartford are requested to prepare full line of service and maintenance parts.

Customer's request via instant-call or e-mail can be response less than 1 day. Machine overhaul and retrofit service are provided by its distributors. Used machine trading service is provided by distributors.

B. Use Oriented Service

Leasing and rental program is provided by 3rd party company.

C. Result Oriented Service

Hartford started to run the project called " Total solution " since 2013. Content of the project includes, machine turnkey engineering, medical service engineering, customized replace normalized, and Hartnet for multiple brand.

6. Discussion

Service related information from cases study of five machine tool manufacturers are consolidated into the table 2, which shows us the differences of service offering and degree of manufacturing servitization.

TABLE 2. PRODUCT LIFE CYCLE SERVICE COMPARISON OF MACHINE TOOL MANUFACTURERS

PSS	Services	Tongtai	Hartford	Okuma	DMG/ Mori Seiki	Makino
Product Oriented	Purchase finance service	⭘	⭘	⭘	●	●
	Classroom training	●	●	●	●	●
	Online training				●	●
	Automation service	●	●	●	●	●
	Spare part inventory query	⭘	●	●	●	●
	Parts express delivery			⭘	⭘	⭘
	7/24 call center			●	●	●
	Preventive maintenance	●	●	●	●	●
	Corrective maintenance	●	●	●	●	●
	Retrofit / overhaul service	⭘	⭘	⭘	●	●
	Used machine trading	⭘	⭘	⭘	●	●
Use Oriented	Leasing service	⭘	⭘	⭘	●	●
	Rental service	⭘	⭘	⭘	●	●
Result Oriented	Application center service	●		●	●	●
	Turnkey solution	●	●	●	●	●
	Integration service		●	●	●	●

⭘ means provided by distributor or 3rd party
● means service provided by machine tool manufacturer

Most of product oriented services are connected with machine tool's life cycle, from purchase, operation, maintenance, to overhaul for used machines. Leasing and rental services are related to use oriented since product ownership still stays in manufacturer or provider. Services of result oriented tend to provide customer better or guaranteed result in terms of total solution or system integration.

According to the comparison there are three findings to illustrate Taiwan machine tool manufacturers' servitization progress and service offering comparing with their rivals.

1) Taiwan machine tool manufacturers currently do not provide all of the services to fulfill all of product life cycle needs for product oriented service such as finance, retrofitting, and overhaul.
2) However, Taiwan machine tool manufacturers have been providing result oriented services such as application center service, turnkey solution.
3) Taiwan machine tool manufacturers rely on their distributor worldwide for product promotion and sales.

The comparison table not only tells the difference between these five machine tool manufacturers but implies three different models they might use to develop capabilities for offering service. These three different models are internal resources integration, alliance, and external resources integration.

A. Internal resources integration

Makino develops and integrates internal resources to provide more services. In order to enhance its service, Makino established a subsidiary company called Makino technical service Co. Ltd since 1977. Makino technical service Co. Ltd provides services from machine installation, operation instruction, diagnostic and maintenance, machine relocation, retrofit for Makino's products.

As Neely's study, more service offering to a manufacture company bring in more risk to expose itself into finance problem [16]. According to Makino's 2013 fact book, 24% of company share is held by Japan financial institutions. Shareholder structure may help Makino to reduce the financial risk.

B. Alliance

Alliance is strategy enables two companies to share the resources and get synergy from each other's advantages. DMG/ Mori Seiki is a typical example. As Dr. Masahiko Mori, President of Mori Seiki said, "The combination of high-end technology and a strong sales and service network creates efficiency advantages for everyone." By combining sales and service activities, DMG/Mori Seiki offers its customers a broad product portfolio as well as unique market presence. The partnership comprises joint sales and technical services, such as customer service, training as well as technical support. After combination, 2,692 employees at 99 sales and service locations are available to customers worldwide.

In addition, from customer point of view, they have many advantages as following,

1) Technology solutions offered by DMG/Mori Seiki come from single source.
2) 3D software solutions and intelligent software products

enable machine efficiency.
3) Over 96% availability of spare parts keeps your DMG and Mori Seiki machines well maintained.
4) 24/7 hotline numbers for round-the-clock help and support with service issues.

3. External resources integration.

If services are not related to core business or internal resource is limited, machine tool manufacturer usually seeks for integration or leveraging with external resources to provide customers service more efficiently. For example, Okuma, Tongtai, and Hartford leverage external financial service company to provide finance service. Overhaul, retrofit, and used machine trading services are provided by distributors or 3rd parties also.

In addition to capabilities for core technology development and system integration, finance support is also a key factor for manufacturing servitization. From customer's point of view, capital expenditure on the machine tool will be eased by the finance service, such as loan, lease, and rental program. On the other hand, finance support to machine tool manufacturer help manufacturer to provide more and long-term life cycle services or integration solution. From the case of Makino, it's found 24% of Makino's company share is held by Japan financial institutions. Shareholder structure helps Makino to get strong financial support.

V. CONCLUSION

In this thesis, Product Life Cycle Service Modes are developed by combining PSS and LCC. 5 machine tool manufacturers' servitization progress and service offering can be clearly represented and compared with each other. It's found that Taiwan machine tool manufacturers currently do not provide all of the services to fulfill all of product oriented life cycle services. Taiwan machine tool manufacturers rely on their distributor worldwide for product promotion and sales. The result also implies three different models which manufacturers use for servitization. These three different models are internal resources integration, alliance, and external resources integration.

In addition, the result responds Neely's (2011) study on shifts to servitization [17] as follows:

1. From product to solution. Machine tool industry servitization is a shift from selling products to providing total solutions which integrates lots of intangible service contents.
2. From transaction to relationship. Machine tool industry servitization is a shift from a short term product ownership transaction to a long term relationship between machine tool manufacturer and customers. For example, life cycle service is provided from product acquisition to end of product.
3. From supplier to network partnership. Servitization sometimes is so complicated and maybe beyond machine tool manufacturer's capabilities. Machine tool manufacturer integrates resources with network partnership to fulfill more customer demands of service, such as finance, or overhaul services.
4. From output to outcome. Customer not only cares about output of a single machine tool but outcome of the total manufacturing solution. For example, in nowadays machine tool manufacturer's total solution can not only improve machine tool's availability, reduce labor hours, increase energy efficiency, but also reduce waste and consumables.

In this thesis Product Life Cycle Service Modes are developed to identify the progress of machine tool manufacturer in manufacturing servitization. The comparison table not only tells us the difference between two Taiwanese machine tool manufacturers and three foreign competitors but also point out how they approach manufacturing servitization.

In this thesis information for our case study is collected from websites of machine tool manufacturers. Taiwan machine tool manufacturers have been developing ICT and software to maximize product availability, and reduce maintenance and downtime cost. However, from the process of case study, Taiwan machine tool companies posted few service related information comparing with the foreign competitors. It becomes a limitation of this study.

Most of Taiwan machine tool manufacturer account on integration of external resources to provide customers better product service. Future study on the integration of external resources is recommended to understand how the integration works.

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