*MMRC*
*DISCUSSION PAPER SERIES*

**No. 334**

# Fanuc's Competitive Advantage and the Revolt of Machine Tool Builders: A Look at Fanuc's User and Its User's Customer Relationships From a Historical Perspective (1950s–1980s)

Masato ITOHISA
Doctoral Candidate, Graduate School of the University of Tokyo

December 2010

東京大学ものづくり経営研究センター
Manufacturing Management Research Center (MMRC)



**http://merc.e.u-tokyo.ac.jp/mmrc/dp/index.html**

# Fanuc's Competitive Advantage and the Revolt of Machine Tool Builders:

## A look at Fanuc's user and its user's customer relationships from a historical perspective (1950s-1980s[1])

Masato ITOHISA
Doctoral Candidate, Graduate school of the University of Tokyo

## Abstract

This paper presents a new interpretation regarding the source of Fanuc's competitive advantage through conducting a historical analysis of Fanuc's relationships with machine tool builders, i.e., Fanuc's users, and machining factories, i.e., Fanuc's users' customers. From the dawn of the NC (Numerical Control) in the 1950s–1960s until the establishment of the de facto standard in the 1970s, Fanuc's ability to create collaborative relationships with its users and its user's customers functioned as the source of Fanuc's competitive advantage. However, with Fanuc continuing its lead into the 1980s, leading machine tool builders such as Mori Seiki and Yamazaki revolted against Fanuc's dominance. In response, Fanuc released a part of their CNC (Computerized Numerical Control) software, Fanuc allowed machine tool builders to conduct their own customization. Moreover, strong collaborative relationships with the user's customers created throughout the 1970s, however, functioned as a deterrent to the revolt of machine tool builders permitting Fanuc to regain its market share that was taken by Mitsubishi Electric and Yaskawa Electric in the 1980s.

Key words: Japanese machine tool industry, Fanuc, NC (Numerical Control), Customer's relationship, Autonomous strategy

## Introduction

This paper attempts to reinterpret the competitive advantage of Japan's leading numerical control (NC) manufacturer, Fanuc. It focuses on the relationships between Fanuc's users, namely machine tool builders, and the relationship between the user's customers, which are the machining firms.

In the early 1950s, the managing director of Fijitsu, Hanozo Omi, established a development team under the leadership of Seiuemon Inaba, an engineer at Fujitsu(and the future president of Fanuc), to develop NC system. Utilizing a MIT report that describes the development of the first NC, Fujitsu was able to manufacture Japan's first NC turret punch press in 1956. After which, Inaba developed an independent open-loop system with an electro-hydraulic stepping motor and an algebraic/arithmetic interpolation method through past collaborative development with Makino Milling Machine and Hitachi Seiki. In 1972, Fanuc was made an independent entity, and has maintained their competitive advantage holding 50~80% of market share in the Japanese market and 40-50% of the world market share with an operating profit of 30-40% of operating profit from time it made the shift to the closed-loop system in 1974 until now.

Although research on Fanuc as a standalone case is still limited (Friedman, 1988; Kawamura, 2000), past research has only discussed Fanuc's competitive advantage in an indirect manner. The reason for this is that the introduction of the NC machine tools played a key role in the history of the manufacturing system, with Fanuc being the central player in the growth of the Japanese machine tool industry. However, Fanuc's competitive advantage as explained in past literature has been explained as being a rather "obvious" interpretation. For example, the report of the MIT Commission on Industrial Productivity (1989) states that Fanuc was assigned to be Japan's only NC supplier in the policies adopted by Japan's Ministry of International Trade and Industry (MITI). In other words, Fanuc's competitive advantage was attained as a result of the deliberate actions by this government agency[2]. Additionally, the growth of Japan's machine tool industry has also been attributed to the modular design of the NC and the machine tools. This has not only led to a reduction in realignment costs, but by standardizing it with Fanuc's NC system, such costs relating to the education of operators and maintenance could also be reduced. The advantages of the modular design have been recognized by researchers including Finegold *et al.* (1997) and Chuma (2002), with Chuma (2002) emphasizing that the breakthrough in the Japanese machine tool industry is through its ability to savor the "power of modularity (Baldwin and Clark, 2000) ". However, both of these researchers fail to sufficiently consider the competitive advantages of Fanuc.

Changes in Fanuc's domestic market share, which can be used as an indicator to measure competitive advantage, however, shows that after Fanuc's market share peaked at 80.7% in 1972, rival manufacturers continued to increase their share, resulting in a decrease to around 60% by the late 1970s. Despite market share being further reduced to 50-60% in the 1980s, Fanuc was able to restore its position with 65.7% of the market in 1989. It should be emphasized here that the decline of Fanuc's share occurred during periods when MITI's implemented regulations on the mechatronics industry through the Temporary Measures Law for the Advancement of Designated Electrical and Machinery Industries of 1971-1978 and the Temporary Measures for the Promotion Information Machinery Law from 1978-85. This does not match the assumptions that policies by MITI supported Fanuc's competitive advantage. Moreover, it does not indicate why after the lapse of MITI industry policies in 1985, we can identify Fanuc regaining its market share in 1989. Therefore, the source of Fanuc's competitive advantage requires an analysis not only at the macro policy level, but also requires one to focus on the Fanuc as a specific firm.

Table 1: Market Share of NC Manufacturers in Japan, 1972-1989

(Units)

| Year | Fanuc | Fanuc's share | Mitsubishi | Yaskawa | NEC | Oki | Hitachi | in-house |
|---|---|---|---|---|---|---|---|---|
| 72 | 1,013 | 80.7% | 43 | − | 20 | 19 | 17 | 143 |
| 73 | 1,738 | 75.0% | 64 | − | 62 | 82 | 25 | 347 |
| 74 | 1,739 | 77.4% | 97 | − | 78 | 91 | 1 | 241 |
| 75 | 1,226 | 67.6% | 112 | − | 41 | 83 | 5 | 346 |
| 76 | 1,791 | 59.1% | 213 | − | 52 | 119 | 0 | 853 |
| 77 | 2,803 | 58.9% | 709 | 15 | 90 | 95 | 0 | 1,043 |
| 78 | 4,589 | 63.6% | 809 | 73 | 86 | 107 | 0 | 1,548 |
| 79 | 7,333 | 59.7% | 1,557 | 411 | 117 | 209 | 0 | 2,646 |
| 80 | 11,236 | 59.4% | 2,436 | 1,143 | 148 | 89 | 0 | 3,848 |
| 83 | 28,134 | na | na | na | na | − | na | na |
| 86 | 33,237 | 50.0% * | na | 5,000 ** | na | − | na | na |
| 89 | 46,500 | 65.7% | 13,700 | 3,950 | na | − | 500 | 6,100 *** |

Source: Data from 1972-80 provided by JMTBA, "Suchi-seigyo kosaku-kikai sangyo jittai chosa" (Survey of aspects of the current NCMT industries); Fanuc's 1983 and 1986 data from Inaba(1991); Data for 1989 is from an independent report by Fuji Economics.

* : The market share for 1986 is estimated using the description on page 137 of Friedman(1988) .

** : Yaskawa Electric 1986 sales figures provided through interview, Yaskawa Electric, June 10, 2010.

*** : The figures for the in-house group from 1972 to 1989 include 11 companies; Okuma, OM, Enshu, Japax, Toshiba Machine etc. However, 1989s data is for Okuma alone.

Section 2 of this paper reviews past literature that has directly targeted Fanuc, by which the significance of this paper will be clarified. Sections 3-5 will paint a picture of the relationships between Fanuc and its users, and its users' customers over three time periods; namely, the 1950-60s, 1970s and 1980s. Followingly, after conclusions are drawn, this paper will discuss the limitations and possible future research in section 6.

## The Limitations in the Past Interpretations of Fanuc's Competitive Advantages

Through a review of past literature regarding the source of Fanuc's competitive advantage, this section seeks to identify the limitations of those perspectives.

Fanuc is known as a technological leader with much research also pointing to the source of Fanuc's competitive advantage being related to technological factors. Firstly, Kodama (1991) suggests that the source of Fanuc's competitive advantage lies in the technological advantage of its simple electro-hydraulic stepping motor, which is characterized by a feedback control system not being needed. In response, Mazzoleni (1997) citing the analysis of Budzilovich (1970) refutes Kodama's (1991) explanation, claiming that the source of Fanuc's competitive advantage cannot lie in its technology alone as the capabilities of Fanuc's products are almost similar to the stepping motor of Superior Electric (USA), Pratt and S.A.M.M. Mazzoleni (1997) suggests that it is not the stepping motor nor the design of the open-loop system that is important, but rather the difference in the popularity of the open-loop system in Japan and America that influenced the trajectory of technological evolution. In other words, he explains that by adopting the MPU at an early stage, Fanuc development of a flexible CNC targeted at small and medium firms became the source of its competitive advantage. However, this paper does not provide any explanation with regards to why the open-loop system was so popular in Japan during the infancy of this technology.

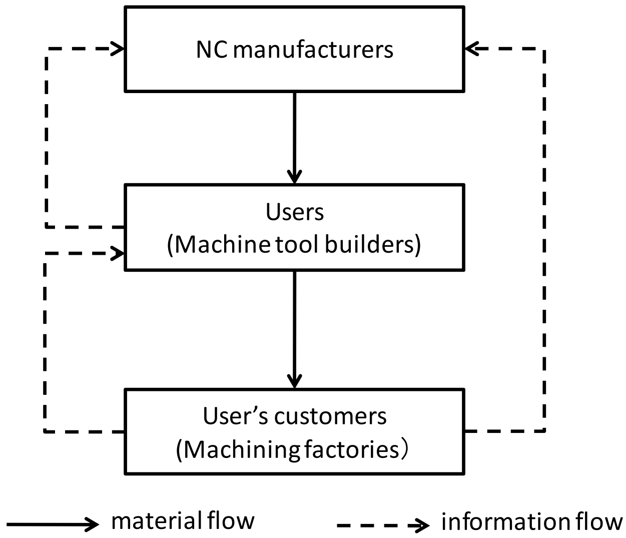
Also, Kawamura (2000) [3] like Mazzoleni (1997) shows that Fanuc's competitive advantage was in the early adoption of the MPU that led to a reduction in the price of the NC. However, although all of the Japanese NC suppliers having adopted the MPU ahead of American suppliers by 1976 may have gained a competitive advantage over its American competitors, this explanation alone does not sufficiently explain Fanuc's competitive advantage.

Shibata, Yano & Kodama (2005) and Shibata (2008) provide a detailed historical analysis of Fanuc's NC technological evolution from the product architecture perspective (Ulrich, 1995). As this research places its main focus on the theoretical contribution to clarifying the pattern of architecture evolution, it does not directly consider the implications on Fanuc's competitive advantage. As the source of Fanuc's competitive advantage, it does suggest however that through modulating the internal structure of the NC software, Machine tool builders were able to customize their Fanuc NC. In other words, Fanuc intended to create this situation "by not asking but making it for the users". However, although these policies may have a positive effect for the machine tool industry as a whole, looking at Fanuc as an individual company essentially means that they could lose their competitive advantage if they make a serious mistake. That is that if only Fanuc could understand the needs of machine tool builders, their reliance on Fanuc would grow, but if machine tool builders could experience all the know-how by themselves, their reliance on Fanuc would decrease.

As explained above, most of the past literature has explained Fanuc's competitive advantage has been mainly attained through technological aspects[4]. However, if you consider the technological factors in the case of the machine tool industry, it is crucial to consider the relationship with the machine tool builders as the user and the relationship with the machining factories as the user's customers. This paper seeks to clarify the source of Fanuc's competitive advantage through focusing on the strategic actions at a firm level and by also conducting a historical analysis on the two types of inter-firm relationships; namely, the relationships of NC manufacturers and users and that of Fanuc and its user's customers. (Ref. Figure 1) The reason for focusing on these two types of inter-firm relationships can be summarized into two key points. Firstly, the know-how of machining is held by machine tool builders with machining factories possessing the knowledge of machine operations. Fanuc must effectively adopt this knowledge in the development of new NC systems. However, machine tool builders and machining factories alike do not appreciate the risk that is involved in their in-house knowledge being leaked to other competitors. It can therefore be said that the ability to effectively manage the relationship with users and users' customers while effectively dealing with the above dilemma is the key to creating a sustainable competitive advantage. Secondly, the trajectory of technological evolution is frequently defined by the interaction with users (Clark, 1985). As such, focusing on the relationship with customers has the potential to reveal the factors that define the technological evolution of Fanuc.

This paper therefore emphasizes the actions of Fanuc as an individual firm and through a historic study of the inter-firm relationships[5] between the NC manufacturers and the users, and the NC manufacturers and the user's, customers will clarify the source of Fanuc's advantage. (Ref. Figure 1)

Figure 1: The triangular relationships of the NC machine tool industry




## The dawn of NC technologies in Japan：1950's-1960's

After the development of the world's first NC machine tool by Parsons and MIT Servo Lab in 1952, Fujitsu was the first privately-owned firm in Japan to develop a similar NC in 1956. Fujitsu's managing director, Hanzo Omi, foreseeing the arrival of the "3C generation (communication, computer, control)", made the decision to enter the computer and control business in addition to its communication tool business. At that time, Seiuemon Inaba, who was in his early 30s, was selected to lead the development teams of the control business. Inaba was successful in the development of NC machine tools through the use of the parametron for its calculation, Sanyo Electric's traditional DC motor as a servomotor and a Wiedemann made turret punch press for its machine tool. Participants from organizations such as the University of Tokyo, Tokyo Institute of Technology, Makino Milling Machine and Hitachi Seiki were invited to examine the completed NC machine tool in action. This resulted in the potential of NC technologies being recognized in Japan despite the needs not being completely met in terms of performance[6].

Inaba had to somehow commercialize this new NC technology. However, there were an inumerable number of problems that needed to be solved in order for it to be sold. A request that came at that particular time from Makino Milling Machine to collaborately develop the NC milling machine. To be exact, in March of 1957, Makino Milling Machine's president, Tunezo Makino, approached Inaba asking him to assist in the production of a NC machine tool for the international machine tool exhibition held in Osaka the following year[7]. The background of that request is said to be that while visiting India as the chairman of the JMTBA, Makino received questions regarding Japan's NC technologies from other board directors and in response ended up making a promise that Japan would also exhibit a NC machine tool at the international machine tool exhibition the following year. With a development lead time of one year and a budget of 5 million yen, the technological issue was the contour control of the milling machine which was remarkably more difficult in comparison to the position control of the turret punch press. The engineers of both Fujitsu and Makino Milling Machine spend many days in collaboration to fix the various problems. These results of such laborious efforts led to a NC machine being exhibited at the third international machine tool exhibition held in Osaka in April 1958.

After the international machine tool exhibition, there was a request from Hitachi Seiki to join in a collaborative development project of the NC milling machine which was to be delivered to Mitsubishi Heavy Industries' Nagoya aerospace factory. This was the first useable machine tool to be created in Japan. The general manager of Mitsubishi Heavy Industries aerospace department, Takaharu Moriya, decided to implement the NC machine tool based on the logic that "in line with the Mitsubishi's name, the fighter jet F86 should be made with the very latest technology ". As such, focus should not be on a marginally higher cost[8]. With that desire, they made a request to Hitachi Seiki. The purpose for this project was to develop a NC milling machine that could deal with a series of complex metal components that were required for an airplane's wing to be connected to the body. Fujitsu pursued this development with Hitachi Seiki and Mitsubishi Heavy Industries as a three way partnership. However, the NC milling machine that was delivered in January of 1959 possessed a key weakness in terms of electrical noise. There were circumstances when even a motorbike riding outside the factory could cause the machine to stop completely. In addition, the servomotor circuit used an average of one hundred bulbs with one bulb breaking every month. In response to these potential problems, engineers were stationed at Mitsubishi Heavy Industries' factory for half a year following the implementation to address any problems that may arise.

Following this, an order was received from Fujitsu Heavy Industries for the delivery of a NC milling machine to manufacture aerospace components. Out of one year, two hundred days of the person-in-change at Fujitsu was dedicated to the NC milling machine project. Despite that, out of a total of 66 jet planes, only about 40 planes were able to be made using the NC milling machine with the rest being produce using a profile milling machine.

As explained above, NC development during its infancy was filled with numerous failures. However, we see that Fujitsu was able to obtain the know-how relating to the technological fusion of the electric mechanism through the collaborative problem-solving with its users and its user's customers. Inaba made the following remarks regarding this point.

> "The best result from this collaborative research was to be able to learn how to cooperate with specialist from both the mechanical and electrical engineering fields. With electrical engineers being covered in oil while grappling with the machine and mechanical engineers being engrossed in the oscilloscope, a new technological field was being created without a distinction between engineers. It is not an exaggeration to say that this was a great contribution to Fanuc's consequent improvement of NC technologies[9]"

Secondly, by being on the shop floor of the machining factories, Fanuc was able to regulate the direction of technological exploration to overcome the weakness of the close-loop system that was said to be caused by the DC motor and the position detection device. There were also problems with the calculation capabilities at that time which was not reliable due to the complexities of the circuit layout. To deal with this, research was continued in the attempt to simplify the control circuit and the servo system.

With the know-how attained from the fusion of mechanics and electronics as well as the research results that led to the simplification of the NC, the development of the pulse motor that employs a revolving switch construct and the electro-hydraulic stepping motor which could increase the total amount of output was achieved. Also, with the intention of simplifying the pulse distribution circuit, collaboration with the University of Tokyo led to the invention of the pulse distribution circuit using an algebraic/arithmetic interpolation method. Fanuc's independent open-loop system was created based on both of these technologies. Moreover, as the transistor started to prevail as the main calculation tool, the probability of machine breakdown reduced greatly, leading to the completion of the NC that was able to withstand the demands of the factory floor.

In 1960, Fujitsu's open-loop NC was sold as a Hitachi Seiki NC milling machine. After which, Fujitsu began to strengthen its NC sales team. However, in the first half of the 1960s, Fujitsu had to deal with two issues relating to the input interface of the NC program and the price of the NC. Firstly, the input interface required operators on the machining factory floor to make the necessary calculations for the pulse row, demanding a substantial amount of work[10]. For example, to process a die and mould that requires a high level of precision down to the micron, calculations for the pulse row needed to be frequently revised to match any differences with the tool. With regards to price, the 1962 Fanuc 220, which uses a diode instead of a transistor, commanded a total sales price of roughly 10 million yen, a price much greater than the machine tool alone. Therefore, even though this was an open-loop system, it was not a cheap NC for small and medium sized firms.

The source of a uniform solution for the NC program input interface and the price of the NC were provided by one lead user; namely, Makino Milling Machine. First, Makino Milling Machine presented an idea of the "cutter offset function" to deal with the required adjustments. This function adjusts the gap between the processed goods and the tool by using low resistance tools on the machining factory floor. Fujitsu in collaborative research with Makino Milling Machine was able to absorb this know-how and apply within the NC. At this time, Fujitsu was permitted to market this general purpose device to other firms[11]. In another words, through the use of Fanuc's multi-purpose NC, the know-how of machine tool builders such as Makino Milling Machine spilled over to other machine tool builders. New-entrant machine tool builders such as Yamazaki and Mori Seiki therefore succeeded through the mass production of machine tools and were able to better utilize the merits of this spillover.

To deal with the pricing issue, Makino Milling Machine requested that Fujitsu limit the functions of the device and downsize the product to reduce the overall cost. A proposal to overcome the problems of the input interface was to remove the curvilinear processing function and replace it with a straight line processing function. Also, the calculation device was also all-IC to achieve a reduction in the size. With the simplification and downsizing of the NC functions (Ref. Table 1), the price of the Fanuc 260 that was sold in 1966 was reduced by roughly 2 million yen.

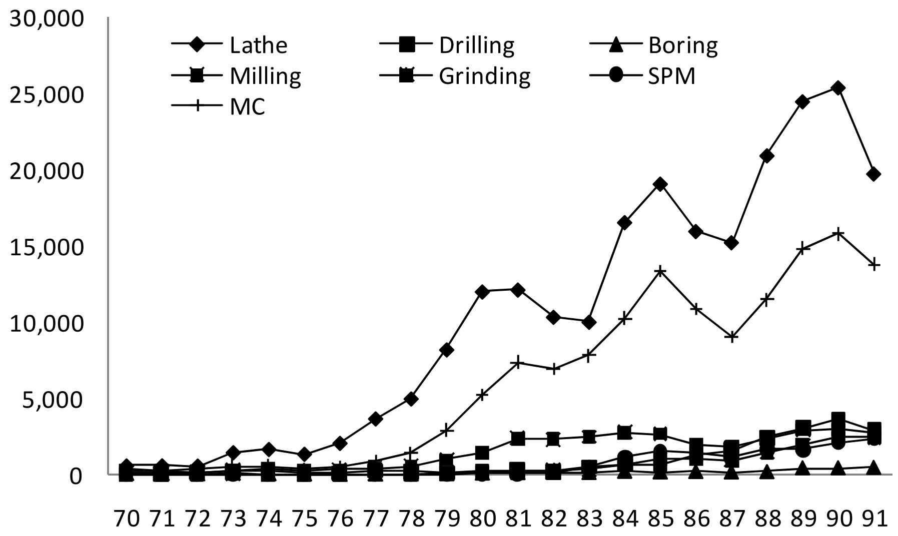
Table 1: A Comparison of FANUC 220 and 260

| Spec | FANUC 220 | FANUC 260 |
|---|---|---|
| Number of control axis | 3 axis (Only 2 simultaneously) | 3 axis (Only 2 simultaneously) |
| Maximum Dimensions | straight line：670000mm<br>circle radius：3350000mm | straight line：9999.99mm |
| Minimum Settings | 0.005mm | 0.01mm |
| Cutter Offset | 49.995mm | — |
| Weight | 700kg | 350kg |
| Price | about 10 million yen | about 2 million yen |

Source: Created by the author based on a Makino Machine Milling pamphlet.

With this change, small and medium sized firms were gradually able to obtain this product and sales in 1965 of 60 units increased to 388 units in 1968 and 1,683 units in 1969 (Mazzoleni, 1997) . At this time, the assumption of an NC was that a milling machine could be changed to accommodate the needs of the market, which was for a NC to be a lathe (Shibata & Kodama, 2009). The growth of the NC after this started with the NC lathe was targeted at small to medium sized firms[12].

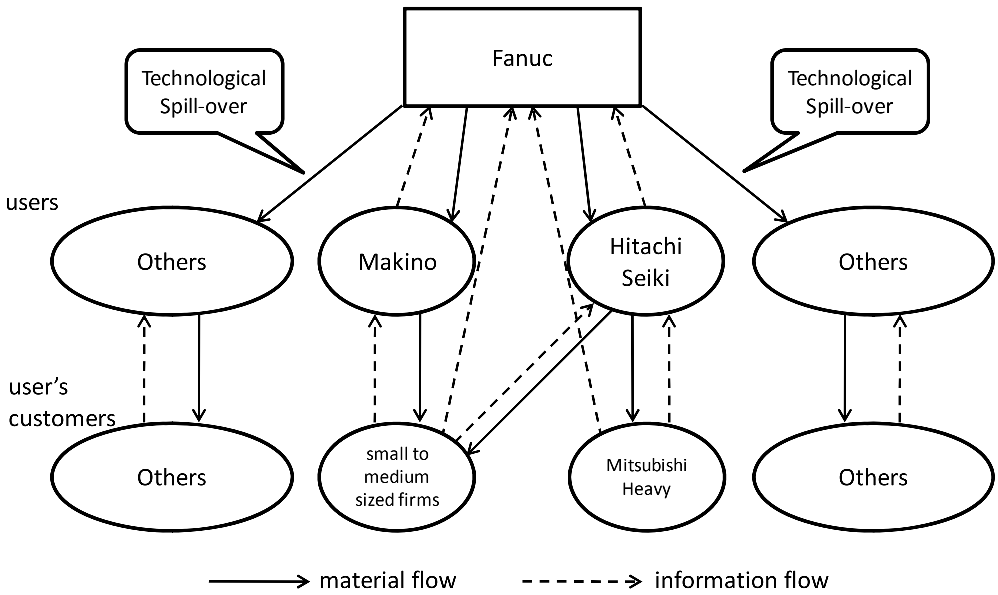
Figure 2: The change in units of NC across different models, 1970-1991




Source: Created by the author based on JMTBA, "Kosaku-kikai tokei yoran, 1981 and 1991" (Machine tool statistics handbook).

As described above, the role of Fujitsu's users and the user's customers in the dawn of the NC helped to collaboratively deal with the problems that this new innovation presented. At this time, they provided an important indication for the direction of further technological exploration. Inaba himself also emphasized the relationships with such users and the user's customers. Inaba's team that was charged with the task of developing the NC was upsized for a section to a formal division of the company and its sales was also separated. Inaba was assigned to a concurrent post both as the managing director of technology and sales. Through this, he was able to experience first hand the importance of maintaining a relationship with the user and correctly identifying their needs[13]. Moreover, the poor condition of the NC as a new electronic product were not left in the hands of machine tool builders, but were handle by Fujitsu alone[14]. This resulted in Fanuc's ability to develop a service network of end users nationally and globally while absorbing the needs of its clients contributed to the further development of NC. In addition, other machine tool builders were able to cope with technological changes by buying a multi-purpose NC from Fanuc. The relationships described here is conceptualized and displayed below in Figure 3.

Figure 3: A model of the source of Fanuc's competitive advantage: A perspective from the relationships with users and user's customers in the dawn of the NC.



## Technological Change and the Establishment of the De Facto Standard in the 1970s

Fujitsu's NC division under the leadership of Inaba was finally able to produce a profit in 1965. With the expansion of the market, it became a highly profitable division within Fujitsu. In 1972, Fujitsu's board of directors decided to create a separate entity leading to the birth of Fanuc[15].

Although Fanuc was able to maintain continued growth, several major issues arose within the firm. These issues led to a rapid change in Fanuc's reputation with regards to the electro-hydraulic stepping motor which is the core technology of Fanuc's NC. A cause of this was Fanuc's motor inability to respond to the needs of a faster NC machine tool[16]. As such, its users, Makino Machine Milling and Hitachi Seiki, strongly requested a shift to the DC servomotor. Additionally, Siemens, who had the sales rights to produce and sell the electro-hydraulic stepping motor in Europe, also recognized the change in their market and worked to cause a shift towards the DC servomotor. The NC machine tool operators of the small and medium sized firms also had complaints about the electro-hydraulic stepping motor as it required them to change the hydraulic fluid.

The feedback from its users and its user's customers became the trigger[17] for Fanuc's purchase of the right to produce and sell (1st July 1974 ~ 1st August 1984) the DC servomotor from Gettys Manufacturing on the 3rd of June 1974. This change also meant that the control method had to shift from an open-loop system to a closed-loop system[18]. At the end of September 1974, all of Fanuc's NC has changed to the DC servomotor.

Fanuc also changed its fundamental technology innovation strategy to one focused on open innovation. Fanuc was the leader of the open-loop NC system, but the closed-loop system which included such functions as the DC motor and sensor technology had other international firms that held a technological advantage. Fanuc, starting with a partnership with Gettys Manufacturing, continued to foster technological partnerships with several oversea manufacturers to increase the standard of technology required for the closed-loop system (Ref. Table 2).

Table 2: Fanuc's major NC technology licensing (1970s)

| company | country | licenced technology | contract term |
|---|---|---|---|
| Gettys | USA | DC servomotor | 1974-1984 |
| Gettys | USA | DC spindle motor | 1975-1986 |
| Farrand Industries Inductosyn | USA | position transducer | 1976-1986 |
| Heidenhain | West Germany | error compensation device | 1979-1988 |

Source: Created by the author based on financial report of Fanuc, 1981.

This orientation towards open innovation allowed Fanuc to become the forerunner in choosing to shift from the hard-wired NC to the soft-wired NC system. Fanuc having identified the actions of Intel, which was established in 1968, adopted Intel's MPU (8bit) in its FANUC 2000c. With the sale of the world's first one chip MPU Intel 8086 (16bit) in 1978, Fanuc made the decision to adopt this technology before any firm within the computer industry[19]. From that the FANUC SYSTEM6 was developed and first sold in 1979. This FANUC SYSTEM6 would be recognized at the de facto standard for CNCs within the Japanese machine tool industry[20]. Through this, machine tool builders and end users were able to use the custom macro to define the formula for the tool path. Other NC competitors also based their programs on the FANUC SYSTEM6 custom macro.

To cope with technological change, Fanuc continued to expand its overseas presence in addition to increasing the number of service centers within Japan in 1970 (Ref. Table 3). At that time, machine tool builders that began to gradually export overseas had obvious limitations in terms of the after-service they could provide by themselves. Fanuc on their behalf expanded its service network with many leading machine tool builders and other users thankful about this move[21]. From Fanuc's perspective, being able to directly connect with the user's customer held the merit of attaining information about future desires and requests for the future development of the NC machine tool. Based on this information, Fanuc continued to develop new products one after the other[22]. Inaba described the significance of constructing a service network in the following way.

> "The trust of the end user is earned through providing perfect service. To do this, any NC that has the Fanuc brand, irrespective of who sold the device, must be maintained by Fanuc. That is the rule[23]."

Table 3: Fanuc's Local Subsidiaries

| company | foundation | Location |
|---|---|---|
| General Numeric Corporation | 1976 | Chicago, USA |
| Fanuc Oceania Pty Ltd | 1976 | Sydney, Australia |
| Fanuc USA Corporation | 1977 | Chicago, USA |
| Korea Numeric Corporation | 1978 | Changwon, Korea |
| Fanuc France S.A. | 1978 | Pris, France |
| Fanuc Singapore Pte Ltd | 1979 | Singapore |
| Fanuc Germany GmbH | 1980 | Hilden, Germany |
| Fanuc UK Limited | 1980 | London, UK |
| Fanuc−Machinex Ltd | 1981 | Sofija, Bulgar |
| Fanuc Sweden A.B. | 1981 | Stockholm, Sweden |
| Fanuc Mechatronics S.A. | 1982 | Echternach, Luxembourg |
| GMFanuc Robotics Corporation | 1982 | Michigan, USA |

Source: Inaba(1982), pp107, 113.

The 1970s experienced a wave of technological change that could not always be easily acknowledged such as the technological shift away from the electro-hydraulic stepping motor. At each of those times, the trigger for a change in technology was from the feedback of its users and the user's customers. After the shift to the DC motor, Fanuc adopted an open innovation orientation whereby external technology was aggressively implemented. The result was the FANUC SYSTEM6 which is said to be the CNC de facto of Japan's machine tool industry. On the other hand, Fanuc continued to establish a service network globally to cope with the continually increasing demand of NC machine tools. The establishment of local subsidiaries provided a base on which machine tool builders could export its products to areas that their own network could not provide the required after service. From Fanuc's perspective, being connected to the user's customers allowed it to absorb the various needs that they had.

## The Revolt of Leading Machine Tool Builders: 1980s

During the technological changes of the 1970s, emergent machine tool builders such as Yamazaki and Mori Seiki expanded their market share through the sale of the NC machine tools (Friedman, 1988). They purchased Fanuc's multi-purpose NC and actively sold NC machine tools with an attached Fanuc device in oversea markets and to small and medium sized firms. In the early 1980s, Mori Seiki, Yamazaki and Okuma held the top three positions in NC lathes (Ref. Table 4).

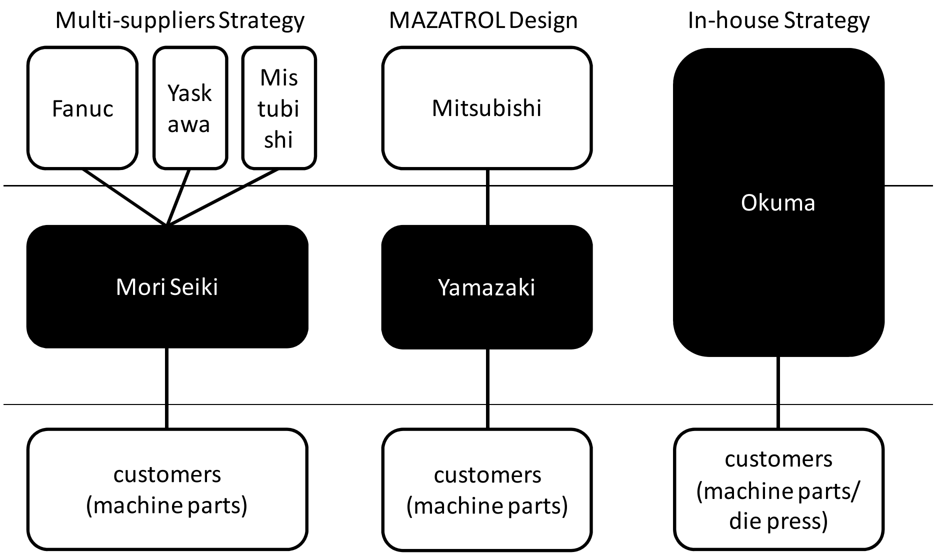
Table 4: The Market Share of NC Turret Lathes from 1983 to 1985

| year | 1983 | | | 1984 | | | 1985 | | |
|---|---|---|---|---|---|---|---|---|---|
| rank | company | units | share | company | units | share | copany | units | share |
| 1 | Mori Seiki | 1,703 | 17.0% | Mori Seiki | 2,648 | 16.0% | Okuma | 3,256 | 17.0% |
| 2 | Yamazaki | 1,603 | 16.0% | Okuma | 2,648 | 16.0% | Mori Seiki | 3,064 | 16.0% |
| 3 | Okuma | 1,403 | 14.0% | Yamazaki | 2,483 | 15.0% | Yamazaki | 2,873 | 15.0% |
| 4 | Miyano | 801 | 8.0% | Miyano | 1,324 | 8.0% | Miyano | 1,532 | 8.0% |
| 5 | Hitachi Seiki | 501 | 5.0% | Hitachi Seiki | 1,324 | 8.0% | Hitachi Seiki | 1,341 | 7.0% |
| total | top5 | 6,011 | 60.0% | top5 | 10,427 | 63.0% | top5 | 12,066 | 63.0% |
| | total | 10,018 | 100.0% | total | 16,550 | 100.0% | total | 19,084 | 100.0% |

Source: Nikkei sangyo shinbun(Nikkei industrial paper)

In a generation where the need for the NC continued to increase, the top three machine tool builders faced a strategic dilemma with Fanuc having set the de facto standard and continued to hold a run away lead over its competitors. The NC is an important core module that determines the machine tools capability. Therefore, machine tool builders wanted the ability to customize their NC to differentiate themselves from other competitors. However, as Fanuc manufactures a multi-purpose NC, they were not able to completely respond to those requests. Even if they did respond to those requests, there was still a possibility that a user's know-how could be leaked to other competitors[24]. In light of this reality, Mori Seiki, Yamazaki, Okuma employed the policies below to reduce their reliance on Fanuc[25].

Figure 4: Autonomous strategies employed by leading machine tool builders




<u>Mori Seiki's multi-suppliers strategy</u>

In opposition to Fanuc's dominance, Mori Seiki strategically employed Yaskawa

Electric's YASNAC and Mitsubishi Electric's MELDAS. By purchasing from two other suppliers, a supplier's power is weaken (Porter, 1980) and as such Mori Seiki could comparatively increase its bargaining power. With regards to NC customization, YASNAC allowed for more functions to be customizable[26]. However, from Mori Seiki's perspective, although they were able to determine the path of NC using YASNAC, they were aware of the high risk of placing their dependence on it. Fanuc therefore continued to hold the position as the main supplier. Incidentally, the cost of a customized YASNAC led to a cost increase in comparison to Fanuc's NC[27].

Yamazaki's "MAZATROL design"

In 1981, Yamazaki collaboratively developed the NC MAZATROL with Mitsubishi Electric and decided to make a clean break from Fanuc. MAZATROL is an interactive NC with a dialogue function, not the G-code that has been used until now. Therefore, this input interface is recognized as being user friendly allowing new operators to utilize this system with ease. By developing a close relationship with Mitsubishi Electric, the CNC software permitted Yamazaki to improve the key functions required for their machine tool device. However, this interactive NC was still limited in terms of the number of complex processes that it could conduct. Therefore experienced operators tended to favor the G-code as it allowed for more freedom in terms of path settings. However, Yamazaki's shift to Mitsubishi Electric as their main supplier resulted in Fanuc's share being reduced.

.

Okuma's In-house Strategy:

From the dawn of the NC in the 1960s, Okuma has chosen to keep the manufacturing of their NC systems in-house. Okuma favored the closed-loop system over Fanuc's open-loop system because of the additional absolute positioning function. Okuma developed their original NC (OSP) as part of their differentiation strategy. It also responded well to the wave of technological changes such as the adoption of the MPU a year after Fanuc in 1976 and the development of a multi-processor CNC device in 1980. From an early stage, Okuma emphasized the "total responsiveness" of the machine tool to include the NC, sensor, actuator and other processing technologies. Although Okuma tried to sell this NC outside the organization, competitors were not open to the idea as Okuma was recognized as being a machine tool manufacturer[28]. As such, the use of Okuma's NC was restricted to Okuma and its subsidiaries.

The revolt of the leading machine tool builders became a trend that Fanuc could not ignore. Mitsubishi Electric, who sold the MAZATROL, sold it as the MELDAS to other machine tool builders and continued to increase their market share along with Yaskawa Electric[29]. To respond to the requests for flexibility and more extensive customization, Fanuc released a part of its NC software that had been kept black-box so far. In other words, by releasing the API (Application Interface), machine tool builders were able to independently customize their NC. In addition, the C-language library tool kit was also released allowing easier customization[30].

By making public a part of their NC software, Makino Milling Machining for example could place an independent Makino controller called the GI control and a screen on the NC to allow faster processing. Makino created an independent function through an interchange with the Fanuc NC using an external I/O or API, while the software for the GI control was created in-house[31]. Although other machine tool builders may not have been able to customize their NC to that of Makino, they were now able to add various functions specific to the user. This led to success in linking Fanuc to the machine tool builders.

On the other hand, automobile manufacturers shifted from a profile to NC machine tools in the early 1980s. For example, along with Honda's implementation of CATIA, a 3DCAD in 1984, they continued to pursue further NC in the form of specialized machine that could profess the "clay to die" [32]. Also, other automobile manufacturers following the lead of Toyota emphasized the compatibility of a customized macro and therefore made requests to machine tool builders to use only Fanuc products[33]. As a result, NC manufacturers that have minimal share within those factories were excluded from the automobile factory floor. In addition, it can be said that the success of Fanuc products is dependent on Fanuc's ability to create trust-based relationships between the machining factories which are its user's customers while maintaining a service network as well[34].

The late 1980s saw a period where the amount of Japanese machine tool exports continued to rise, with exports worth 1.12 billion dollars in 1980, to 1.66 billion dollars in 1985 and 3.1 billion dollars in 1989. During this time, Fanuc was able to utilize its network of subsidiaries that it had setup in the late 1970s ahead of other competing firms. Small and medium machine tool builders especially chose to continue using Fanuc's NC because of its reliable after service that could be provided to their end users[35].

In summary, the 1980s was a decade where leading machine tool builders were concerned about Fanuc's de facto standard. To reduce their reliance on Fanuc, several firms rallied against the use of Fanuc's devices. In response, Fanuc released some details of its CNC software which allowed for the customization of the NC to the independent specifications of the machine tool builders. Moreover, the user's customers especially within the automobile industry and oversea factories played a key role in deterring the revolt of the leading machine tool builders. Through this, Fanuc was able to recover its market share in Japan holding 65.7% in 1989, up from a sharp decrease to roughly 50% in the early 1980s.

## Conclusions and Discussions

Past literature has explained that the source of Fanuc's competitive advantage was obtained through the MITI industrial policy and Fanuc's technological advantages. However, this paper uses a historical approach to reinterpret the source of Fanuc's competitive advantage by focusing on the relationship of Fanuc's users, namely the machine tool builders and the user's customers, the machining factories.

Firstly, from the dawn of the NC to the establishment of Fanuc's de facto standard, the source of Fanuc's competitive advantage lay in its ability to maintain cooperative relationships between its users and the user's customers. In collaboration with key lead users, Makino Milling Machining and Hitachi Seiki, who held the know-how regarding processing technologies, Fanuc was able to commence production of the NC at an early stage of the technology's evolution process. Collaborative problem solving played a major role in the creation of a long-term collaborate relationship, with these two firms helping to direct the innovation of NC technologies based on their user's needs. As Fanuc chose to bear the cost of development, they were permitted to market any technological developments as a multi-purpose device to other firms. Also, with the decline of the electro-hydraulic stepping motor, these users' request functioned as the trigger for the following changes in technology. Fanuc also continued to strengthen their collaborative relationships with the user's customers by constructing a network of service centers both in Japan and globally as well. Machine tool builders welcomed this as it was a period where exports overseas began to gradually increase.

In 1979, Fanuc established the de facto standard with the SYSTEM6 leading to an increase in Fanuc's brand as a NC supplier. A proportion of leading machine tool builders began to adopt autonomous strategies to diminish the reliance on Fanuc as a supplier. Mori Seiki's multi-suppliers strategy and Yamazaki MAZATROL design are examples of this. In responses to this, Fanuc demonstrated their cooperation with machine tool builders through releasing a part of their CNC software which it had kept black-box until then. Also, as user's customers mainly consisting of automobile manufacturers requested a Fanuc device to be used, Fanuc was able to regain the share that it had lost to rival manufacturers such as Mitsubishi Electric and Yaskawa Electric in the late 1980s. This relationship with the user's customers became the source of Fanuc's competitive advantage as it restricted the revolt of the users.

The paragraphs above describe the conclusion of this paper, but the reality of the Japanese NC industry is that it is made up of few NC suppliers, 1,332 machine tool builders[36] of different sized and a few thousand machining factories. In other words, NC suppliers have links with an extremely broad range of industries. With that understanding, this paper focused on Fanuc as a firm within all of these inter-firm networks. This paper therefore only explores a proportion of the relationships between leading machine tool builders and the end user. As such, there maybe other important details included within Fanuc's relationships with small and medium sized manufacturers that could explain the source of Fanuc's competitive advantage.

Also, in order to discuss Fanuc's competitive advantage in detail, a similar analysis and comparison with other NC suppliers such as Mitsubishi Electric, Yaskawa Electric and the in-house manufacturer Okuma. This is a point to consider in future research. From preliminary interviews, however, we identify that although Mitsubishi Electric took an offensive approach to Fanuc in the early and middle 1980s, they were not able to build a service network like Fanuc because of a lack of manpower in their relationships with Yamazaki. Yaskawa Electric positioned as a supplier of semi-customized NC did not allow itself to cope with the wide range of requests and as such their client were restricted to Mori Seiki, Matsuura Machining and a small number of other firms. On the other hand, Okuma sought to gain a competitive advantage through positioning itself as a machine tool that allows the pursuit of technology from the perspective of total responsibility. For example, Okuma being a lead user of the double column machine center was able to create a collaborative relationship with Fuji Technica, a pressed die and mold manufacturer. Fuji Technica sharing their technological needs with Okuma and through working with them in the problem solving phase as well allowed them to market the research results to other firms. This resulted in Okuma holding most of the market share in terms of double column machine center sales.

This paper also contributes to the theoretical discussion of Pfeffer and Salancik (1978) in regards to the importance of the resource dependent perspective of inter-firm relationships research. Firstly, it explores the mechanism regarding how a component supplier like Fanuc gains power over time. Past research about inter-firm relationships often takes a comparatively static approach by using tools such as network analysis. The example of Fanuc as described in this paper adopts a dynamic perspective to exploring one mechanism needed to tackle the problem of how component suppliers gain power. Namely, by creating cooperative relationships with the user and the user's customers, the component supplier is able to absorb their know-how and is therefore able to utilize it in the manufacturing of their products. Also, another mechanism exists which allows suppliers to gain power through the achievement of economies of scale by selling a multi-purpose component to other users. Secondly, the bargaining power that this component supplier holds from the existence of this mechanism may face a latent problem at a time when it gets too big. This is because firms want to break its reliance on one firm and will adopt autonomous strategies. From the perspective of the component supplier, however, the autonomy of the user should be avoided and if possible through the creation of a condition whereby clients are reliant on the supplier will allow it to maintain it's the power. In that situation, there is a possibility that firms can use the power of the user's customer as a counter power to the autonomous strategies adopted by the users.

---

[1] In the 1980s, production of Japanese Machine tool industry overwhelmed US and Germany and many researchers, for example Johnson (1982) and Porter (1990), gave interpretations to such "Japanese miracle". This paper focuses on this period and provides new perspectives to the competitive advantages of Fanuc, which has been a leading NC manufacturer in the Japanese machine tool industry. The main issue will stand on the relationship of Fanuc's user (machine tool builders) and its user's customers (machining factories).

[2] Carlsson (1989), Vogel (1984), Porter (1980), Kotha and Nair(1995) and many other researchers suggest that Fanuc's competitive advantage is by MITI industrial policies.

[3] Kawamura's (2000) research clarifies why Japanese NC suppliers adopted the MPU ahead of its American competitors. The reason is that in America, the 5 axis and 7 axis NC milling machine was main stream, there was a need for a mini-computer that could do the complicated calculations. However, as the 2 axis lathe was popular it could perform the calculations even on a cheap MPU. This resulted in a fall of the price of NC.

[4] Other research include Yonekura (1991), who discussed the merits of focusing its resources when Fanuc was granted independence from Fujitsu and Shibata and Kodama (2004) that indicated the importance of organizational flexibility to accommodate technological change.

[5] This paper's research perspective is closes to that of Matsuzaki (2000). That paper indicates that Fanuc's competitive advantage lies in its ability to absorb the know-how of machine tool builders and to sell the multi-purpose NC to the end user. However, this research only explains the establishment of Fanuc's competitive advantage at one point, it does not mention anything about how Fanuc was able to maintain its competitive advantages.

[6] Inaba (1982), pp21-22.

[7] Inaba (1982), pp23

[8] Kano (1983), pp47.

[9] Inaba (1982), pp29-30.

[10] In the first half of the 1960s, there were several defects with regards to operation. At that time, there were more automatic lathes using a pin ball panel.

[11] Interview, Makino Milling Machine, June 14, 2010.

[12] The lack of laborers in the period of high economic growth from the middle of the 1960 was a serious problem. It was a generation where while the salaries of skilled workers, there were a lack of junior high school and high school graduates known as the "golden egg". This was especially a serious problem for small and medium sized firms. The purpose of implementing the NC lathe was not only to

help skilled workers achieve the level of precision, but also the relatively user-friendly NC lathes could deal with a lack in the number of available workers. It should be noted that at this time small firms that employs less than 20 people are not included. The use of NC machine tools in small sized firms became more popular from the late 1980s. (Interview, retired person of Kuaki, June 23, 2010.)

[13] All Fanuc's executives have worked in sales as determined by the company's policy.

[14] Kano (1983), pp177.

[15] The official company name from 1972 to 1982 was Fujitsu-Fanuc.

[16] Interview, Makino Milling Machine, June 14, 2010.

[17] Before changing to the DC servomotor, Inaba last challenge was to start developing a high-power electric motor that would not use any hydraulics. The dateline was the end of May. The prototype that was created vibrated too much and still needed a lot more work for its completion. In light of this, Inaba decided make the shift to the DC servomotor.

[18] Although other competitors such as Okuma, Mitsubishi Electric and Oki Electric also adopted the closed-loop system, the market share of Fanuc's NC continued to rise.

[19] The recently released Intel 8086 still had problems with its reliability. The 8086 passed the stand alone test, but problems arose when it was placed inside the NC system which had a higher voltage and temperature. In response, Intel sent 4 engineers to Fanuc's Nino factory and was able to solve the problems through the progressive improvements over multiple tests. (Okuda, 2000)

[20] Interview, a president of CADCAM manufacturer, May 17, 2010. Interview, Makino Milling Machine, June 14, 2010. Interview, a president of machine tool trading company, January 25, 2010.

[21] Fanuc committed to its stance of carrying out the servicing of its machines in the European markets as well. This is in spite of Siemens being a sales proxy in these markets.

[22] Kano (1983), pp178

[23] Kano (1983), pp178

[24] If a firm had a request for a new function, they could gain the sole right to use the functions if they provide a detailed method of how to meet their requirements and if the bore the cost of the development. However, if the detailed method solving was developed collaboratively, Fanuc would hold the right to sell it on to other firms as part of their multi-purpose device.

[25] Other firms include Hitachi Seiki which adopted a form of the multi-suppliers strategy using both Fanuc's multi-purpose NC and its own in-house NC. On the other hand, Makino Milling Machine continued its collaboration with Fanuc. The reason is that Makino thought it was better to choose a path of collaboration rather than conflict. Moreover, the "Fanuc" brand was not displayed on the NC that was purchased by Makino. They instead had the Makino's original "Professional" brand displayed. Fanuc permitted this because of the weight of its relationship with Makino since the dawn of the NC. (Interview, Makino Milling Machine, June 14, 2010)

[26] Interview, Yaskawa Electric, June 10, 2010.

[27] Interview, Yaskawa Electric, June 10, 2010.

[28] Interview, Okuma, May 19, 2010.

[29] We have identified the MELDAS 300 series with a 32bit CPU that was sold in 1986 had a particularly high capabilities, leading to much of Fanuc's market share being stolen (Interview, a president of CADCAM manufacturer, May 17, 2010).

[30] Shibata and Kodama (2009), pp32.

[31] Interview, Makino Milling Machine, June 14, 2010.

[32] Interview, Honda, April 16, 2004.

[33] If the generation of the NC is different, the custom macro was not compatible. However, many end users wanted it to be Fanuc specific. (Interview, retired person of Kuaki, June 23, 2010)

[34] Japanese, German and American machine tool builders came together to show their resistance to Molins' lawsuit that dealt with the Flexible Manufacturing System in partnership with many of the major automobile manufacturers and industrial machine manufacturers. In response, Fanuc choose to quickly solve this problem by paying a settlement of roughly 2 million dollars (Hosokawa, 2007). These actions signaled to automobile manufacturers that they could feel safe in purchasing Fanuc's NC.

[35] Interview, a president of CADCAM manufacturer, April 12, 2010

[36] Japan's Ministry of Economic, Trade and Industry, Kogyo Tokei Chosa (Census of manufacturers), 1990.

# Reference

Baldwin, C.Y. and Clark, K.B., 2000. *Design Rules: The Power of Modularity*. MIT Press.

Budzilovich, P.N., 1970. Use Electrohydraulic stepping motors for all-digital drives, *Control Engineering*, January 1970, 82-88.

Carlsson, B., 1989. Small-scale industry at a crossroads: U.S. machine tools in global perspective. *Small Business Economics* 1, 245-261.

Chuma, H., 2002. Module sekkei-shiso no yakuwari ( A role of modular design percepective). In Aoki, M. & Ando, H. (Eds), *Module-ka (Modularity)*. Toyo Keizai Shinbun-sha.

Clark, K. B. 1985. The interaction of design hierarchies and market conceptions in technological evolution. *Research Policy* 14(5), 235-251.

Finegold, D., et al., 1994. *The Decline of the U.S. machine tool industry and prospects for its sustainable recovery*, vol. l, Critical Technologies Institute, Rand.

Friedman, D., 1988. *The Misunderstood Miracle: Industrial Development and Political Change in Japan*, Cornell Univ. Press, Ithaca, NY.

Hosokawa, M., 2007. Kosaku-kikai sangyo ni okeru kokusai-tokkyo-funso no rekishi( A history of international patent disputes in Machine tool industry). *Strategy Management Consulting*.

Inaba, S., 1982. *Robot-jidai wo kirihiraku: Kiroi-shiro karano chosen(Developing a robot age: Challenge from yellow castle)*. PHP Research Institute.

Inaba, S., 1991. *Kiroi robot (Yellow robot)*. Nihon Kogyo Shinbun-sha.

Johnson, C. 1982. *MITI and the Japanese Miracle: The growth of industrial policy, 1925-1975,* Stanford University Press.

Kano, A., 1983. *Fanuc: Joshiki hazure no keiei-hou(Fanuc: Incredible management style)*. Kodan-sha.

Kawamura, H., 2000. NC sochi maker no gijyutu-kakushin to kosaku-kikai no kakaku-kyoso (The Development of Microprocessor-Based CNC and Machine Tool Industry in Japan). *Shogaku-Ronshu* 41(4), 269-308.

Kodama, F., 1991. *Analyzing Japanese High Technologies: The Techno-Paradigm Shift*, Pinter Publishers, London.

Kotha, S., & Nair, A., 1995. Strategy and environment as determinants of performance: Evidence from the Japanese machine tool industry. *Strategic Management Journal* 16(7), 497-518.

Matsuzaki, K., 2000. Fanuc advantage. *Takachiho-Ronshu* 35(2), 1-35.

Mazzoleni, R., 1997. Learning and path-dependence in the diffusion of innovations: Comparative evidence on numerically controlled machine tools. *Research Policy* 26(4-5), 405-428.

MIT Commission on Industrial Productivity, 1989. *The US Machine Tool Industry and its Foreign Competitors*, Working Paper.

Okuda, K., 2000. *Intel ga mada chiisakatta koro(The story of the time Intel was a small company)*. B&T Books.

Pfeffer,J., & Salancik, G. R., 1978. *The external control of organization*. New York, Harper & Row.

Porter, M. E., 1980. *Competitive strategy*. New York, The Free Press.

Porter, M. E., 1990. *The competitive advantage of nations*. New York, The Free Press.

Shibata, T., 2008. *Module dynamics*. Hakuto-shobou.

Shibata, T., & Kodama, F., 2009. *Management architecture strategy*. Ohm-sha.

Shibata, T., Yano, M., & Kodama, F., 2005. Empirical analysis of evolution of product architecture Fanuc numerical controllers from 1962 to 1997. *Research Policy* 34(1): 13-31.

Ulrich, K., 1995. The role of product architecture in the manufacturing firm. *Research Policy* 24(3), 419-440.

Vogel, E. F., 1989. *Japan as number one: Lessons for America*. Harvard University Press.

Yonekura, S., 1991. Kigyo-kakushin to soshiki-gaibuka senryaku: Fuji Denki, Fujitsu, and Fanuc(Strategy of externalization). *Hitotsubashi-Ronshu* 106(5), 472-495.