SMALL AND MEDIUM-SIZED FIRMS
AND INNOVATION IN JAPAN (2)

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(III. and IV. are printed in this number of “Doshisha Shogaku”.)

III. Mechatronisation and SMEs

1. Outline of Mechatronisation

Mechatronisation takes many forms, but all are devoted to small-
quantity production. It is very different from the mass-production machineries that characterise automation systems, for example the transfer-machine. Mechatronisation is applied against a background of tendencies towards diversification in consumption, and small-quantity production runs, in a world situation of low economic growth (after the first oil shock of late 1973).

Table 3 shows the development of numerical-control machine tools (NC) in the 1980s. These NC are being introduced into general machinery, electric machinery, precision machinery, transport machinery and other industrial settings. Recently, SMEs have been introducing NC.

Figure 1 shows the rate at which mechatronics machines, for example NC, MC (machining centres) and robots, have been introduced into Japanese subcontractors. This Figure refers to the interrelation between firm size and the rate at which firms have completed the introduction of mechatronics machines. As the size of the subcontractor grows larger, the rate of introduction becomes higher.

The reason for this is that mechatronics machinery is very expensive and highly productive. Consequently, larger-size contractors with full orderbooks tend to introduce mechatronics first.

However, there is also strong motivation for even the quite small subcontractor to be willing to introduce mechatronics machines in the near future. So the current expectation is that the machines will increasingly be spreading from now on to small-sized subcontractors, and even outfits with barely a handful of employ-
Table 3  The changing ratio of NC in machine tools for metal processing in Japan

<table>
<thead>
<tr>
<th>year</th>
<th>Machine tools for metal processing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Old type</td>
</tr>
<tr>
<td>1975</td>
<td>93,407</td>
</tr>
<tr>
<td>76</td>
<td>119,637</td>
</tr>
<tr>
<td>77</td>
<td>125,499</td>
</tr>
<tr>
<td>78</td>
<td>133,586</td>
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<tr>
<td>79</td>
<td>149,711</td>
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<tr>
<td>80</td>
<td>155,899</td>
</tr>
<tr>
<td>81</td>
<td>139,534</td>
</tr>
<tr>
<td>82</td>
<td>119,846</td>
</tr>
<tr>
<td>83</td>
<td>117,181</td>
</tr>
</tbody>
</table>

\[ \text{Ratio} = \frac{\text{NC}}{\text{Old type} + \text{NC}} \times 100 \]

(Source: Small and Medium-Sized Enterprise White Paper)

Figure 1  The State of Mechatronics Introductions by Subcontractors in Japan  (Source: As Table 3)
ees. In these types of subcontracting firms there are internal factors pointing to the desirability of mechatronics: chiefly, we see that for small firms to attract skilled workers (who prefer the higher wages and better working conditions to be found in large enterprises) would be more expensive than to introduce the new machinery.

In the machine industries, where there is a high rate of investment in mechatronics, a subcontract system is developing. The transport and electric machinery industries in particular show a high rate of subcontract enterprises. The electric machinery and automobile industries, too, are developing subcontract systems, and we will now examine how they are mechatronising, and what kinds of problems they are facing.

2. Mechatronisation and the Household Electric Machinery Subcontractor

Published figures of the Japan Machine-Tool Industrial Corporation show that numerical-control machine tools like NC and MC as a proportion of all machine tools has gradually been increasing since the second half of the 1970s, and that during the 1980s the rate of increase has accelerated. In the electric machinery industry, the ratio of NC increased from 5.2% in the years 1974–1978 to 12.2% in 1979–1981. The electric machinery industry has also a relatively high ratio of automatic assembly machinery, which can be taken to include robots.

Furthermore, when we look at the sales volume of NC by size of enterprise to firms using the same materials, we can see that
the proportion purchased by SMEs has recently been increasing. Since 1978 SME purchases have accounted for upwards of 60% of the annual NC sales volume.

Taking the specific case of NC investment by household electrics subcontractors, according to research carried out by the Osaka Prefecture Governmental Economics Research Institute, one subcontractor processing printed circuits introduced, in 1976, NC for punching holes in printed circuits, at a cost of £166,000. According to research conducted by the Engineering Promotion Institute we see that some thirty enterprises (ranging from small to medium-size) have introduced NC and MC. Further details were given of these thirty enterprises: 10 worked on cutting and grinding, 5 on pressing, 3 on printed circuits, 2 on assembly and the remaining 10 on various other tasks.

Turning to the situation regarding sales of industrial robots into the machinery industry, research by the Japan Industrial Robot Institute shows that between 1978 and 1980 the electric machinery industry introduced the greatest number of robot sets, followed by the transport machinery (mainly car) industry. In the electric machinery industry in the same period, most robot introductions were in resins and assembly, followed (though at some distance) by pressing and cutting/grinding.


Among household electric machinery contractors, the Machinery Promotion Institute found that 7 enterprises had introduced industrial robots: 3 for pressing, 2 for assembly, 1 for cutting/ grinding, and one other. The Japan Small and Medium Enterprise Agency interviewed 5 subcontracting household electric firms: one had robots for removing and attaching, and two others (TV and audio electric equipment subcontractors) used them for painting, as did another electric equipment firm, while the last firm used them for pressing. These robots were relatively simple, low-level devices of the "fixed sequence" type, which are not even categorised as industrial robots in the USA.

However, the introduction of mechatronics machines is making more headway in the giant parent enterprises than in the subcontractors. Research by the Japan Small and Medium Enterprise Agency shows that parent enterprises had introduced mechatronics machinery as follows: 92.3% of the general machinery industry, 76.9% of the car industry, and 66.7% of the household electric machinery industry. At the other end of the system, among the subcontractors, mechatronics introductions had been made by 36.8% of firms in the car industry, 32.2% of those in general machinery, and 29.8% of those in household electric machinery.

The percentage of introductions of mechatronics in the household electric industry is a little lower than in other machinery

12 The Small and Medium Enterprise Agency, Ibid., 1982 ed., p. 171, Figure 2–2–2.
industries, but it was by the household electric industry that the insert machine, the automatic soldering machine, automatic screw-tighteners and other automatic machines were first developed and introduced. If these automatic machines do not qualify to be defined as mechatronics, they nevertheless carry beneficial effects of automation, labour-saving and rationalisation equal to, if not superior to, those of mechatronics proper. Therefore when we look at mechatronics, we need also to consider these other automatic and laboursaving machines in the same light.

A further piece of research showed that of 342 respondent enterprises, 12 (3.5%) had introduced industrial robots, and 33 (9.6 %) had introduced NC and MC. However, almost all had introduced automatic machines, and moreover most of the machines in question used microcomputers.

But it was the requirements of parent enterprises which fuelled the progress of mechatronics, including automatic machinery. They placed strong demands on their subcontractors for “short delivery terms, high quality and low cost”. So the parent companies directed the subcontractors, or at least suggested to them, to invest in NC, MC and industrial robots. If they directly ordered the mechatronics introduction they had, in return, to undertake to maintain and stabilise the quantity of orders. In many cases, mechatronics is introduced independently by subcontractors on the basis of “hinds” from their parent companies, except in

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the cases of special subcontractors where a unitisation effect is to be observed in middle assembly.

Following investments in NC, MC or robots, SMEs subsequently increased their operating hours, changing from an 8-hour operating system to shifts of between 16 and 24 hours, because they needed to complete their depreciation within a shorter period. As an inevitable result they registered steep increases over their previous production quantities. Subcontractors in household electric machinery had to cultivate many more parent enterprises and markets than previously.

These introductions of mechatronics, including automatic machines, into subcontractors have had the following significance. On the one hand, they brought effects of improvements in "quality and precision" to the primary subcontractors of the household electric machinery firms, and on the other hand allowed parent firms to benefit from the lower costs of their orders. In this situation, parent firms will in general accept order price estimates which take account of the reduced production costs caused by the use of mechatronics.

The progress of mechatronisation will bring about an improvement in technical standards and the reorganisation of primary subcontractor firms. Research by the Japan Small and Medium Enterprise Agency reveals the reasons why parent firms stopped orders to their subcontractors: in 60% of cases it was because "They can't meet our requirements for improvements in quality and precision"; in 31%, because "they can't meet our require-
ments for earlier delivery dates”; in 21%, because “they can’t adapt to innovations in the subcontract process”; and in 19%, because “as a result of our adoption of process innovations, the numbers of subcontract processes are reduced”.

Given the situation set out above, the progress of mechatronisation (including automatic machines) will accentuate the dislocation of levels of technological expertise among the primary subcontractors in the household electric machinery industry. A number of these firms were omitted from the list of primary subcontractors after their parent enterprises had pushed through their reorganisation.

So mechatronisation (which has been less progressive among subcontractors in the household electric machinery industry than in other machinery industries), will forget ahead more rapidly in the near future. Because an increasing comparative cost reduction can be expected where mechatronics has been installed, the assumption of mechatronisation as a normal precondition when estimating subcontract unit prices will extend, as parent enterprises’ requirements as to quality and precision grow more demanding.

The improvement in process precision has been remarkable. The present limitations on precision (in precision shaping) are 5 microns (5/1000 mm) on common processes, 0.1 microns on precise processes, and 0.01 microns on super-precise processes, and (in flat surface work) 1 micron on common processes, 0.01 microns on precise processes and 0.001 microns (1 nanometre) on
super-precise processes.

The requirement of improvement in "quality and precision" from the subcontractor will henceforth be strengthened by the product and technical developments going on in the household electrical industry: meanwhile, augmentation and enrichment of the systems for financing and leasing NC, MC and industrial robots will lead to widespread mechatronisation among the household electrical subcontractors.

However, mechatronisation will give rise to the following two main problems.

In the first place, as mentioned above, there is the problem of the extension of operating hours, and the corresponding shift to increased production. To give concrete examples, labour management has to cope with the new adoption of two or three shifts and a new arrangement of employees, and production management has to effect an adjustment of production between the mechatronics machines in the process of being introduced, and the process as a whole. Marketing faces the problem of opening up a new market, while financial management has to cope with the depreciation of expensive mechatronics machines.

In the second place, there will be the problem of 'aftercare' of the mechatronics machinery that has been introduced. In the machine tools of the NC and MC type, personnel are needed

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to draw up and edit microcomputer tape (or floppy discs), and these employees need education and training. Also, with industrial robots, employees have themselves to develop jigs and attachments, and the maintenance and repair of the robots needs to be simple. As things stand at present, there is a high rate of robot failure, and the robot maker cannot in every case be relied upon to rectify a malfunction. Suppliers of hardware will generally undertake the initial training of employees in the operation of mechatronics machines; but after this training period the operators are on their own. It seems that when industrial robots have been introduced, a period of one year is a realistic time to get them operating properly; sufficient preparation time is therefore clearly needed.

In Japan, mechatronisation was developed mainly in larger firms. The introduction of industrial robots, initially a matter of concern to the Japanese trade unions, has now won the support of house unions, thanks partly to the existence of the lifetime employment system. This Japanese system is different from the pattern in Europe and America, where there are separate craft unions, and layoffs are common when new technology is introduced. In Japan, therefore, the larger enterprises have managed to adapt to the introduction of robots by reshuffling their labour force internally, thus avoiding extreme unemployment problems.

However, it goes without saying that mechatronisation will ul-

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timately have a tremendous labour-saving effect. For example, the FMS factory has reduced the number of its employees by 80%, its process costs by 50%, and the number of machine tools it uses by 90%. In the future, if the amount of money being invested in plant and equipment has the effect of making mechatronics devices cheaper, the progress of mechatronisation will advance still further, so that as a result the reduction in the number of employees needed at the production stage will become even more marked. But this progress will also bring about the development of tertiary (software) industry and the growth of a mechatronics-related service economy, which will hopefully compensate for the reduction in the numbers of employees in a factory. Mechatronisation, then, does not directly entail an increase in unemployment, although the structure of industries, and the relative concentration of labour within them, will certainly change.

With an ageing society, Japan will increasingly run up against the problem of middle-aged and elderly manpower. In SMEs a comparatively high proportion of employees in these age-groups have tended to stay in the same firms, who have until now made rich use of their labour. However, the progress of mechatronisation will lessen their chances of keeping such jobs, because older employees lack the flexibility needed to adapt to the new technology. A sure result of mechatronisation, then, is that older workers, feeling that they have no place in the new industry, will feel a sense of pointlessness and a growing alienation.

As we can see from the case of the household electric machin-
cry subcontractor, mechatronisation will create a two-layer system among SMEs, based on their technical standard, and will itself promote the distinction between the upper and lower strata.

3. Mechatronisation and the Automobile Subcontractor

In the automobile industry as at present organised, Japanese car-assembly firms employ mixed-running production lines, where several different kinds of car are assembled on a single line under computer control. In addition, these lines are adjusted to operate on a time-scale which fits in with the firms' subcontractors, a refinement which has been developed over a period of 20 or 30 years into the kanban (Just-In-Time) system, or APM (Action Plate Method), from the previous "Super Market System". So the character of the industry is one of mixed-running production lines operating in conjunction with the JIT system.

The JIT system, which produces or assembles just the right quantity, no more and no less, in the early stages of a process to meet the requirements of the finished product, has shown itself capable of achieving good results in reducing stock inventories and enabling adjustments in timing to be made. However, when we come to the present stage of innovation, many problems in operating the JIT system come to the surface, for example a drop in the utilised efficiency of plant and machinery, a slump in the drive to make improvements in plant and machinery, a failure to coordinate operations with the most up-to-date innovations, and so on. So, now that the JIT system has matured and out-

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17 On the Just-in-Time System Which is Entering a New Stage, The Toyota.
lived its full usefulness, we pass on to the next new stage, chiefly characterised by the progress of mechatronics and robots.

Since the beginning of the 1980s, many robots have been quickly introduced into car assembly lines to carry out welding and painting functions. In the welding process, for instance, the Multi-Spot Welder, which was specific to each type of car, was incorporated into the assembly process in the second half of the 1960s and the first half of the 1970s. Since then it has been the welding robot, able to adapt flexibly, which has been introduced. Furthermore, mechatronisation has developed among primary (and also secondary and tertiary) subcontractors.

(i) The progress of mechatronisation among primary subcontractors

The assembly firms, the parent enterprises, have required from their subcontractors adjustments in timing to fit in with their assembly lines, improvements in precision, and reductions in cost. In order to fulfil these requirements, primary subcontractors have introduced NC, MC and, more recently, robots.

To meet the parent enterprises' requirement of an annual cost reduction of between 2–3% and 5–6%, primary subcontractors have been operating ordering, production and sales management with the aid of personal computers or office computers, or have introduced NC. Special primary subcontractors have brought in NC, MC and robots which they themselves have developed.

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Robots especially have been the subject of recent introductions. When subcontractors install robots, they have to make preparations by developing jigs and original applications to accord with their particular situations. Thus their own 'personal' products and processes form part of their business, though they have to be ready to change the designs of their products in order to adapt to their parent enterprises' robot production. Although it is often emphasised that robotics carries the disadvantages of employee-shuffling and alienation-building, there are many cases where morale actually improves as workers are able to secure for themselves a measure of independence. Moreover, when mechatronisation has been developed to a higher degree, firms will develop along the lines of FMS, which is tied up with software and related machines.

*Nihonデンソ*, a member of the *Toyota* group, provides electronic parts, and is in fact the only firm making IC independently. This company introduced FMS into its speedometer assembly line in 1977; a development clearly arising not from any extension of the *kanban* system, but from a completely different kind of thinking. First they reduced the overall number of parts from 48 to 17, by standardising the six kinds of component unit going to make up the product, which meant that a unit was limited to a maximum

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of four parts. However, using the FMS in conjunction with robots for inspection, the system can now assemble 288 kinds of instrument by a secondary re-combination of parts.

In developments like this, we can see among primary subcontractors a new raising of the level of technical expertise, which owes nothing to the *kanban* approach. Furthermore, when FMS and mechatronics machines are geared to the total management system throughout the entire enterprise, they will inevitably form part of the information revolution and networks like LAN and VAN.

(ii) Introduction of NC in secondary and tertiary subcontractors

Many kinds of mechatronics are being introduced, and subcontractors in the car industry show the highest numbers of introductions of every kind of machine. The percentages of car subcontractors which have introduced mechatronics machines are 48.0% for NC, 20.9% for MC, 32.4% for industrial robots and 23.2% for other machines incorporating microcomputers. So NC has the highest rate of take-up among mechatronics-type equipment.

From the end of the 1970s and through the 1980s, there have been increasing numbers of cases where secondary subcontractors with fewer than 10 employees have introduced NC lathes. This

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clearly reflects parent enterprises’ stringent requirements on quality improvement and shortened delivery time.

When NC machines are brought in, many new skills are needed — the ability to write programmes, to select and make jigs and tools, and to set up and maintain the machines for operating an NC lathe. For programming, especially, it is obviously necessary to have some knowledge of computer science and the structure of electronic devices and control systems, in addition to existing knowledge of the lathe. The acquisition of programming skills has actually been done in many cases by owners or their sons, because it is not enough simply for a machine-tool maker to undergo short-term study and training. Therefore the owners have mastered the technical books and also the on-the-job training on their own initiative.

There seems to be a widespread fear that when these NC lathes are introduced, existing skilled labour will be entirely driven out. But the actual situation is quite different. Even when NC are introduced, there still remains a dependence on skilled labour in the process field. Judgement based on comprehensive knowledge of the actual work is indispensable for the rationalisation of production processes and for handling high-efficiency machines. For example, cutting of jigs for a NC lathe requires the process skill of a skilled lathe operator. Where only a few lots of an article have to be processed, it is more efficient to use the old general lathe-work process than the new NC lathe. This too needs a lathe operator skilled in the actual task. Also, when processing
on the NC lathe, it is important to arrange how the cutting tools are set, and the most efficient jig for the job. So here, too, the skilled operator with rich experience in handling is needed.

In addition, in the case of precision metal mould-making by NC, many fine undulations remain on the surface, and only skilled workers with ten to fifteen years' experience can do the final finishing.

In this way, in small subcontractors, even if NC is introduced, the existing complement of skilled workers will be kept on. These small workshops differ from larger ones in that so many different operations are carried out in them that harmony between previous skilled labour and new skills, and cooperation between younger workers with new knowledge and skilled middle-aged and elderly workers must both be maintained.

(iii) The independent introduction of robots in secondary and tertiary subcontractors

In secondary or tertiary subcontractors, there were many cases where robots were introduced on the firm's own initiative, without prior recommendation from the parent enterprise.

However, when the parent enterprises have introduced robots into their subcontractors, they have held up the JIT system, product design, and the unit price of orders (the so-called "unit price by robot") to the subcontractors as preconditions for introducing the robots. Therefore there is an increasing number of cases of subcontractors introducing robots. The advance of mechatronisation in parent enterprises acts indirectly as a factor promoting
mechatronisation in subcontractors.

However, the secondary and tertiary subcontractors which do introduce robots require a considerable standard of technological know-how. For example, when a press processing subcontractor introduces robots, it will make a big difference to the practical use of the robots whether the firm can make the precision metal moulds by themselves. If they do not have the skills needed for such tasks based on existing technology, they will have to spend a great deal of time acquiring the ‘old’ technological knowledge before the new.

When their technological standard is low, even if they introduce robots, the net work rate of their robots will be low, too, and will actually decline, because when the help provided by the robot installation men has gone, the subcontract workers are on their own. We may imagine that there are many cases where this happens, to the detriment of management performance, because of the repayment of interest.

As has been mentioned a propose of the progress of mechatronisation among primary subcontractors, the subcontractors need the ability to develop jigs to operate the robots smoothly. When introducing robots, they must keep existing high technical standards. For subcontractors who are uneasy about maintaining previous advanced skills, there are special firms which were set up to undertake production from the stage of jig-setting to the

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stage of robot operation, in accordance with the situation and requirements of each subcontractor.

(iv) The effects, influences and problems of robot introduction

Among the effects of introducing robots are: (1) improvements in quality, (2) labour-saving, and (3) cost reduction.

Robots are so suitable for the production of many kinds of products and small lots that they have made what was previously the territory of SMEs into their own production and process territory. Therefore the giant firms have advanced into the SMEs' field, and also changed from placing orders with outside suppliers to carrying out their own production themselves.

Consequently, the effects of introducing robots into an industrial organisation will include (1) the fear of raising the degree of oligopolistic concentration by giant firms, and (2) the reforming of the division of labour between larger enterprises and smaller ones.

A common characteristic of all robots, but which also applies to NC, MC and computers, is that they are strong in the production (management) of different-kind products and small lots. The effect of automation on multi-type and small-lot production is greatest in the reduction of personnel costs.

However, in small secondary and tertiary subcontractors there is a tendency for robots to compensate for actual shortages of skilled workers, by taking the place of skilled workers in daily activities. These effects are larger than the reduction of personnel costs.

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As to the change in labour arrangements, after the introduction of mechatronics machines, fixed working hours decreased in smaller firms with fewer than 30 employees.

Moreover, the progress of mechatronisation has brought about the reorganisation of subcontractors: that is to say it has led to the placing of concentrated orders with a specific subcontractor by parent enterprises in the upper echelon, an increase in the numbers of suncontractors, and excessive competition in the lower strata of industry.

IV. Summary

Section I discussed the innovation that has been proceeding so actively in the fields of ME, new materials and new diodes, and biotechnology — but mainly in ME. These fields have developed innovations which have been mutually influential.

In Section II, I studied the electric machinery and car industries, which are remarkable for their R & D. Comparing Europe and America, we can point to the minor role played by smaller Japanese firms in major innovation. The reasons for this are to be found in a complex of factors drawn from the developmental history of the Japanese economy, and the structural features of its industry, especially the existence of the subcontract system.

In Section III, I investigated the introduction of mechatronics into household electric machinery and automobile subcontractors. When this happens, it is necessary to maintain existing skilled
labour standards, and the ability to develop jigs and attachments, and the training of programmers.