ipea
Instituto de Planejamento Econômico e Social
IPLAN
Instituto de Planejamento
CNRH
Centro Nacional de Recursos Humanos

AUTOMATION & COMPETITIVENESS IN BRAZIL

Robert U. Ayres
Projeto PNUD/OIT/CNRH

Virginia Guanaes
SEI

Brasília, DF
April, 1985

AUTOMATION & COMPETITIVENESS IN BRAZIL

Robert U. Ayres
Projeto PNUD/OIT/CNRH

Virginia Guanaes
SEI

Brasília, DF
April, 1985

Introduction

The introduction of programmable automation in Brazil must be evaluated against a wide background. The economic driving forces operating worldwide are only superficially related to the high cost of labor, although this factor has received much public attention, especially in the context of wage-bargaining and concern about jobs. But the driving forces are really more fundamental in nature: they arise, ultimately, from the complexity and diversity of modern industry.

Around 1820 when factory mechanization was just beginning to be important, the chief products of metal-working shops were guns (e.g. muskets, pistols), cutlery, agricultural implements and tools, specialized carriage parts, locks, clocks and watches. Only a few shops were capable of making simple machine tools and/or steam engines.

All products (like guns) involving a number of parts required laborious fitting, largely with files, and the ancient goal of 'interchangeable parts' was still a quartercentury from practical reality. The most complex product made in any numbers was the pocket watch, consisting of fewer than 30 parts, mainly of soft brass. More complex devices were made virtually on a custon basis.

By contrast, the modern automobile is an assembly of around 2000 'end parts' many of which are themselves complex subassemblies, such as the engine (c. 200 parts), and the transaxle(150-200 parts). All told, an auto probably contains around 20.000 individual parts when all the nuts, bolts, washers, bushings,, bearings, wires and clips are included. An elevator has over 17,000 individual parts. A medium size twin engine commercial aircraft is much more complex than a car: there are as many as 28,000 'parts' many of which are actually subassemblies. Really complex products such as mainframe computers telephone networks, and military aircraft, are as much more complex again.

It is not very difficult to see that, increasingly, the problem of production is reduced to a problem of optimizing materials handling and inventory management.[1/] In fact the difficulty of the coordination problem is probably a non-linear function of the complexity (i.e. the number of parts) on the product. From another perspective, the problem is inherently information-intensive, involving many tens of thousands of binary go/no go (yes/no) decisions based on sensory data gathered at many points in space and time about the state of each tool, each component, each subsystem and the production environment.

Historically, only human workers have had the sensory capability to aquire and interpret the data needed to make these binary go/no go decisions. It is this ability--inborn as regards the senses themselves and sometimes trained as regards interpretation of sensory signals--that distinguish human workers from all machines (including robots) available until the beginning of the 1980's. Only in the present decade will the manufacturing firm begin to have an alternative available: the industrial robot driven by a "smart sensor".

While most human workers have excellent senses and far more intelligence than any computer is likely to be given for decades to come, humans share certain characteristics that make them undersirable in the role of 'machine baby-sitter'. In brief, humans cannot maintain a constant state of undivided attention for very long. There are both physiological and psychological limits. Even the most highly motivated and disciplined workers make occasional mistakes. To compensate for this, inspectors are needed--but they, too, are human and can and do make mistakes; so inspections are multiplied and proliferated. To minimize the incidence and consequences of human error, manufacturers of complex products have finally been forced to adopt a burocratic organizational structure and a production technology designed to <u>minimize the number of needed decisions.</u> It is an obvious corrolary that this

1/ The problem is exacerbated by lack of vertical integration. Manufacturers of very complex systems seldom manufacture more than a small proportion of the components 'in house'.

implies minimizing the number of available options (i.e. standardizing the product to the maximum feasible degree) and, by a further corollary, minimizing the rate of technological change in the product. (The auto industry has developed an elaborate technique for introducing purely cosmetic changes on a controlled basis to distinguish one model from another, while retaining most of the internal structures and mechanisms intact.)

But the accumulation of technological changes in the electronics industry since the mid 20th century has finally reached the point where microprocessors linked to sensory devices will foreseeably soon begin to offer a more accurate and reliable means of coordinating the complex processes required in modern manufacturing. "Smart sensors" are critical building blocks of the coming computer-integrated (unmanned) manufacturing plant of the future. The driving force behind this change is not really to avoid high labor costs per se, but the need to escape from the inflexibility of structure and system that was the price of relying an error-prone human workers for all of the information processing functions in the "Factory of the Past" (and, still, the present). Ultimately, it is increased flexibility that is the objective.

The point of these introductory remarks is simple: a new industrial revolution, based on the use of flexible (program mable) automation, is now in its early stages. Its scope will ultimately be world-wide. On the other hand, the rate of penetration of this new manufacturing technology will not necessarily be the same in all countries. The remainder of this paper explicitly considers the case of Brazil.

Automation in Brazil--Current Status

Interviews carried out with senior managers of 14 companies covering 18 product lines ranging from manufactures of automation equipment to major users (or potential users) clearly indicated that Brazilian manufactures in general use significantly less-and less sophisticate--automation than their counterparts in Europe, North America and Japan (ENAJ). The automation gap is most clearly evident in production lines. In general, Brazilian firms use less 'hard' automation (more stand-alone machines--fewer transfer lines) and much less programmable automation. NC and CNC machines are scarce and used almost exclusively for the manufacture of tools and fixtures, both by machine tool-builders themselves and other metal-products manufaturers, rather than for general production applications. For tool-making, the NC machines offer reliable high precision with low set-up time and thus permit much more efficient utilization of expensive capital equipment than manual methods. In high volume applications Brazilian manufacturers appear to utilize automatic machinery as readily as foreign firms, again because of the more efficient use of capital.

However Brazilian firms are much less inclined than ENAJ firms to link automatic machines together via transfer lines or other forms of 'hard' automation (replacing labor). To take one example, all automobile engine plants in the U.S. and Japan and most in Europe have been 'hard' automated for many years. On the other hand, most Brazilian plants still use large numbers of stand-alone machines. Transfer lines are used mainly for the most complex machining operations (the crankshaft, camshaft and

---

NC = Numerical Control: instructions are entered in machine language via paper tape or magnetic tape.

CNC = Computer Numerical Control: instructions are entered into the minicomputer (by keyboard), usually in a higher level language.

blocks).[1/] This, ironically, ensures that Brazilian engine plants can be converted relatively easily to handle new designs, although production is quite labor intensive.

Given this situation, it is no surprise that flexible integration of machine tools (DNC or FMS) is even less common than mechanical integration. Apparently, two FMS systems have been installed (by Grob) at Bosch, and four to six others are on order, for Cummins Engine and Varga. A few other manufacturers (e.g. Romi) are studying potential applications but most interviewees see little need for investing in this kind of automation in the near future.

Much the same can be said of applications of robots in Brazil. A few spot-welding robots are already used on the assembly line at Ford and VW, and up to a few dozen more will be introduced in the next year or two, "Semi-automatic" (non-robot) on-line welding systems have also been installed by Ford and GM and others. The apparent justification is not labor saving but superior quality: machines are more reliable than human welders and the incidence of bad welds is almost eliminated. Robots or semi-automatic machines may also be used for spray painting applications, again for reasons of quality improvement (and employee health). Uses such as these appear to be growing slowly in number. At least half a dozen Brazilian firms are said to be negotiating licensing agreements with foreign robot manufacturers, including Hitachi GM-Fanuc, and ASEA, but no robots have yet been built in Brazil as far as we know.

1/ The Ford 1.3-1.6 liter engine plant at São Bernardo follows the U.S. pattern, however.

DNC = Direct Numerical Control, refers to the case where a number of programmable machine tools are controlled and coordinated simultaneously by a single supervisory computer.

FMS = Flexible Manufacturing System, refers to a group of programmable machine tools linked by a material handling system and designed to produce a <u>family</u> of geometrically similar parts.

In Brazil, most press-forming machines are operated manually. By contrast, in ENAJ high volume press lines for auto body parts, wheels and other stampings are generally linked by transfer machines, eliminating about 90% of the labor required by a manual line.[1/] An important recent development is the new Schuler CNC press, developed in Germany, which provides the flexibility of the old manual multi-machine lines in a single machine with even greater efficiency than hard automation. For the same level of output, investment costs are reduced by about 40%, space requirements by 65%-70%, and labor requirements by 95%. Setup time is down from 2 hours to 10 minutes, making the new system ideal for trucks and other lower volume applications. Ironically, Schuler (Brazil) is manufacturing the first two CNC presses for GM in the U.S., no Brazilian firm has yet ordered such a machine.

Assembly automation appears to be virtually non-existent in Brazil. None of the firms interviewed presently utilizes bowl-type parts feeders, on insertion devices for assemblying PC boards. Such devices are widely used in ENAJ to speedup manual assembly. The next logical steps are automatic (hard automated) assembly and programmable (robotic) assembly. None of the firms interviewed appears to be even considering the use of automated assembly.

The one type of programmable automation that evinced the greatest interest among Brazilian firms interviewed was inspection. For instance, Metal Leve, a manufacturer of pistons, bearings and bushings for the auto industry, has installed an automated inspection machine, (from Germany) capable of handling some 20 of its 1600 models of pistons. This greatly reduces the time required and--more important--increases the reliability of the inspection and therefore the product. Brazilian electronics manufacturers, who showed no interest in assembly automation, are already using sophisticated equipment to assist in the inspection of completed

---

1/ There are only two automated presslines in Brazil (VW, Taubaté and Ford, São Bernardo) but only the latter is fully operational.

circuit boards. Equipment to automate the inspection of purchased components before they are inserted in PC* boards, as well as work-in-progress, would undoubtedly find ready acceptance. Means of automating the final inspection process would also have great utility.

Factors Affecting the Rate of Adoption of Automation in Brazil

The Brazilian exporters of capital goods interviewed virtually all perceived quality/performance as being primary determinants of market demand. (Price was perceived to be a major factor in demand only where a Brazilian-made product of premium quality is currently more expensive than its chief competitors). Interestingly enough, no Brazilian exporter interviewed considered an aggressive cost-reduction policy to be a feasible tool for increasing market demand.

Among the survey respondents there was wide agreement that the primary motivation for installing programmable (or indeed, any other) automation in Brazil is to ensure meeting world standards of quality. The use of welding and painting robots on auto assembly lines provides one example already noted. The use of automatic or automated inspection systems constitutes another example that has already been mentioned.

It may be significant that Brazilian firms are seeking export markets primarily to replace sales lost in recent years due to 'soft' domestic demand. Pricing does not appear to be a major element of marketing policy. (In fact, most exporters are not the lowest-price source in their markets and some admit to prices significantly above competitive levels). New export markets for capital goods have generally been to U.S. auto manufacturers, (replacing U.S. OEM suppliers and/or machine tool manufacturers). Consonant with lack of emphasis on price as a marketing strategy, there is no apparent effort to cut production costs to the maximum degree possible. Brazilian machine tool and auto exporters largely rely on their low costs labor to compensate for disadvantages in other areas, but

---

* PC = Printed Circuit

not to gain a real competitive edge. In computers, electronic controls and related areas, however, the low cost of labor does not currently compensate for the high costs resulting from low production volumes and high import taxes. Prices of Brazilian-made computers, controllers and similar products appear to be 60% to 150% (or more) above competitive levels. Direct (assemly) labor for these products is tipically less than 10% and as low as 2% of total cost, compared to 40% or so for direct and indirect taxes.

A second positive (but potential rather than actual) motivation that was mentioned by a few respondents is to reduce the unproductive idle-time of expensive machine tools and other equipment. Currently, almost all respondents claim to be utilizing their production machines very efficiently--80% to 90% of the time during the standard 88 hour (5 day, 2 shift) work-week. However concern was expressed that shorter future work-weeks (perhaps combined with restrictions on required overtime) would adversley affect efficiency. The increased use of automation to compensate for this problem is being considered.

A third positive motivation that was repeatedly mentioned is the potential economic benefit of inventory reduction and the so-called "kan-ban"* system. At present however, purely administrative approaches to this problem are the only ones being actively pursued. In any event, programmable automation would not have any impact on inventories unless the entire factory were computer-controlled--a rather distant prospect.

On the other side of the coin, there are three factors operating in Brazil that will tend to discourage the use of programmable automation, as compared to ENAJ. These are:

---

* A Japanese phrase meaning "just-in-time", i.e. each part is delivered to its point of use "just in time", resulting in the elimination of inventories of parts.

1) Low cost labor ($2 to $3/hr. vs $10-$20/hr)

2) High-cost electronic equipment, whether made in Brazil or imported. As noted above, Brazilian made products typically cost from 60% to 100% more than, (untaxed) world prices, while comparable imported (and taxed) products are still more expensive.[1/]

3) High real (i.e. after inflation) interest rates, currently in the 25%-30% range in Brazil, (as compared to 7%-10% in the U.S. and less in Japan).

In addition, the problem of large-scale unemployment, especially in the northeastern part of Brazil, is likely to create institutional barriers and forces that will further tend to discourage extensive uses of automation in Brazilian industry, at least insofar as it is perceived to be primarily labor-saving in its effect. A final factor worth mentioning is that--because of the greater use of manual methods, inflexibility is seen to be less of a problem in Brazil than it is in ENAJ. This may inhibit the introduction of programmable automation in some cases.

Impacts on Competitiveness

The question now arises: given a slow rate of adoption of programmable automation, for the reasons noted in the last section, will this adversely affect the ability of Brazilian exporters of traditional manufactured products to compete in international markets?

In the near future (up to 1990, say) the tentative answer to the question posed above appears to be negative. This is primarily because the rate of introduction of programmable automation is still fairly low, even in Japan. For one thing, the new manufacturing technologies are still immature. Advanced

---

1) Consequently, there is a good deal of smuggling, with the usual corrupting effects.

system are not always as reliable as the ones they replace, and the advantages of small "islands' of automation embedded in a environment dominated by conventional methods are usually minimal. Also, the engineering costs associated with introducing new systems are commonly underestimated, resulting in many disappointments.

However, though the 'early adopters' of programmable automation are not yet obtaining major economic advantages, there is important organizational learning: how to design and operate a truly automated computer-integrated-manufacturing plant that will be virtually unmanned. Firms like GM, GE and IBM in the USA are especially interested in doing this because their labor costs are now so high. There is no question that, though they are multinational, they will build such plants first in the U.S., for the same reasons, in reverse, that they will not be built in Brazil, viz. labor costs are high, while automation equipment is rapidly becoming cheaper. Moreover, the preliminary organizational learning is now taking place in the U.S. Finally, given the growing hostility towards MNC's in much of the world, they will not be tempted to rely completely on plants located in "low cost" countries to supply Europe and North America. They will try to develop more efficient manufacturing technologies that can be located near their major markets. Thus, the long run effects on Brazil could be to reduce its potential for export. This competitive problem could be more serious if effective labor costs are allowed to rise rapidly in Brazil over the next several years without compensating productivity gains.

In the ideal case, the problem of excessively high costs for automation equipment in Brazil would eventually solve itself automatically. That is, the burgeoning Brazilian "informatics" industry would develop its capability and eliminate the need to utilize heavily taxed imported components and equipment not now made in Brazil. Unfortunately, current trends at the frontier of microelectronics technology may well be pointing in the opposite direction. The following are some of the major trends that can be identified clearly:

1. The maximum, "packing density" of circuit elements per cm of chip is rapidly increasing, with corresponding improvements in performance.
2. Specialized CAD* systems are being developed to design complex circuits for silicon chips more efficiently than manual methods.
3. Improvements in systems for inspecting chips for flaws during and after production are being sought eagerly and with some success.
4. Semiconductor manufacturers are competing to develop ways of increasing the "yield" of etching and diffusion operations.
5. Alternative semiconductor materials and processes are being explored as potential substitutes for MOS.**
6. 'Standard' software is being converted to 'firmware' and embodied in proprietary chips.
7. Semiconductors are replacing traditional components, and integrated circuits are replacing discrete components for higher and higher power levels.

Summarizing the implications of these trends, it is getting easier and easier to design and create special purpose, (i.e. proprietary) "chips" for a wider variety of purposes. Discrete components are being phased out. While 'PC boards' will probably always have some minor role, many of their present industrial applications, such as in microcomputers, logical controllers for machines, and power controllers and invertors for electric praction motors are already obsolescent and may be of minor significance in 5-10 years.

---

* CAD = Computer Aided Design

** MOS = Metal Oxide on Silicon (The predominant technology for integrated circuits at present).

It is important to ask: what will happen to the Brazilian microelectronics industry, which now almost entirely consists of the manufacture (and some design) of PC boards for these and similar purposes? Can it survive the coming transition from hybrid circuits consisting of discrete elements together with some mass-produced chips, to truly integrated circuitry? The PC board fabricator of today will have to become an integrated producer of solid state "microprocessors" for a variety of specialized applications. To do so, it will require a sophisticated State-of-the-art CAD capability, as well as silicon wafes fabrication (etching, diffusion) etc. available within Brazil, if not 'in house'.

Given the directions in which microelectronics technology is now developing, the real question is: will Brazilian electronics firms be less or more in need of protection five years from now? If the latter is the case, the excess cost burden imposed on Brazilian consumers of microelectronics products will also be higher, rather than lower.

Unfortunately if the trend towards integration is as fast as is suggested, there is probably no easy policy 'fix' for the problem. A large-scale state-of-the-art VLSI semiconductor fabrication facility in Brazil would be helpful, but virtually all of the critical equipment would have to be imported either from the U.S. or Japan and some of it would probably be subject to U.S. export restrictions. In the long run, these problems could be overcome by a well-financed and strongly focussed R&D effort in Brazil to develop processes and equipment for designing intergrated circuits, manufacturing ultrapure silicon, diffusion, inspection and the rest.

In the short-term any up to data VLSI semiconductor facility that could be built using purchased equipment would be at least 3-4 years behind the technology frontier simply because (1) the frontier is a year or two ahead of the equipment on the market and (2) the accumulation of many small delays in

plant design, construction, negotiation of "arms length" terms for licensing and burocratic red-tape in getting approvals (on both sides) would delay the installation of the equipment. A comparable plant based on copied or 'reverse engineered" equipment would be several years later coming on stream. In either case it would be expensive to build (because of taxes and duty or because of R&D outlays, yet would be forced to operate at a relatively low scale of production. Thus, even if such a project were initiated now, the adverse cost situation for electronic automation equipment in Brazil, would not be significantly improved by 1990, although the Brazilian microelectronics equipment sector at least would have a better hope for eventual viability.

However long-term competitiveness in microelectronics depends, also, on a scientific research base much greater than that which currently exists in Brazil. The extreme difficulty of putting all the necessary pieces of the puzzle together is underlined by the fact that, despite billions of dollars of investments and a great deal of protection for domestic industry, no European country yet has either a significant indigenous semi-conductor industry or an internationally competitive computer industry.* Only Japan has succeeded in closing the technological gap, but it has done so by a set of policies rather different than those in Brazil. Japan has actively encouraged the import of foreign (i.e. U.S.) technology, while finding other means to discriminate effectively against foreign-based firms in the Japanese market. Only after 1980 did the Japanese undertake a major effort to develop "Japanese" technology, with the launching of the well-known "5th generation computer" project. Brazil does not yet have the capability to undertake such an ambitious project.

---

* Defined as one that could survive without a protected domestic market.

Competitiveness of Brazilian firms in export markets also has another dimension. So far we have considered the possible impact of differential rates of automation--and its link to technological change in microelectronics. It is also important to note that electronic system are being grafted onto many traditionally electromechanical or even puraly mechanical products.

For instance, one might mention calculators, typewriters, sewing machines washing machines and automobiles--as well as machine tools and industrial equipment. In automobiles, electronic systems are gradually taking over the engine (fuel) control and emissions control as well as the electrical system itself and the instrumentation. Electronic locks, safety interlocks, and diagnostic systems are also being introduced rapidly. Evidently any competitive disadvantage in manufacturing the electronic control and other systems associated with such products will have an impact on the ability of Brazilian-based exporters there of.

Moreover it is conceivable (but not certain) that the electronic 'share' in the value of representative manufactured products such as automobiles will rise fast enough to negate the Brazilian cost advantage in manufacturing the mechanical components. (Perhaps an appropriate strategic goal for SEI should be to ensure that the made-in-Brazil fraction will rise equally fast or faster).

Generalized policies often have unanticipated adverse consequences, however several examples were pointed out in the course of our interviews. For example, there is a clear trend toward the use of electronic fuel injection in place of carburetors. The world leader in this field is Robert Bosch, of Germany. Bosch is not allowed to produce this product in Brazil, but it refuses to license. 'Reverse engineering' might be technically feasible, but Bosch has formidable worldwide patent coverage and established relationships with the automobile manufacturers. It is inconceivable that VW or Mercedes-Benz would jeopardize these relationships by buying pirated fuel injection systems from a new supplier. In short, there is

no 'Brazilian' solution in view. The net effect is, Brazilian cars must make-do with old-fashioned Carburetors or bear the substantially higher cost of fuel injection units made in Germany, and transported to Brazil (and object to duty). This extra cost could have a negative effect on Brazilian auto exports, even if the duty per se is waived on export models. It also deprives Brazil of the Bosch manufacturing technology and employment.

A final example is the use of CAD. Since CAD systems are part of the "reserve" import licences must be individually approved by SEI, on the basis of a specific 'project' proposal. As a consequence of the red tape barrier, at least in part, use of CAD in Brazil is lagging considerably. Some firms are just starting to experiment with CAD, while others have yet to begin. In large scale manufacturing operations where product change is slow and engineering/design component of costs is small, the cost of this delay is probably tolerable. However in sectors where the product is customized and design component is very large CAD is an essential competitive tool. This is true both in the 'custom' machinery sector (Schuler, Grob, EPP) and in the electronics sector (Elebra, Itau-tec, Maxitec, Metal leve controles Electrônicos, Electro controles Villares, etc). To date, no state-of-the-art CAD system is made in Brazil. Ironically, the effort to reserve a segment of the electronics industry for Brazilian firms may be severely inhibiting these same firms in a critical area.

Summary of Major Conclusions

There is a worldwide trend toward increasing both quality control and flexibility in manufacturing without sacrificing the economies of scale. This is driving manufacturing technology gradually away from both the anarchy of manually controlled stand-alone machines and the rigidity of mechanical integration (e.g. transfer lines) towards the use of computer controls at the machine level subject to overall coordination and integration, also by computers. In the Brazilian context, only the first imperative (quality) is currently perceived by industry, and then only because of the need to export in competitive markets. This is resulting in selective use of automation only where improved quality or reliability is the objective. Programmable automation is not, in general, being introduced to reduce labor costs. Automation may be justified in some instances on the basis of increased efficiency of utilization of existing machines. There is virtually no assembly automation in Brazil now or in prospect. However certain kinds of inspection may be automated quite rapidly (as appropriate technology becomes available) to improve quality control.

The major reason for the peculiar pattern of automation observed in the survey appears to be the fact that labor costs are so much lower in Brazil than in more industrialized countries (ENAJ). A lesser, but not negligible, contributing factor is that the costs of electronic equipment used in automation equipment are simultaneously higher in Brazil than in ENAJ.

The implications of these findings for future international competitiveness of Brazilian-based exporters are not altogether clear. Much depends on whether the "informatics" policy is successful in its objectives. There are some adverse technological trends, including the increasing integration of circuitry into solid-state "chips" and the correspondingly increased role of microprocessor design and manufacturing (vis-à-vis" PC boards) in the electronics sector. This problem should be studied in greater depth.