The Dynamics of Robots' Introduction in the Electric Appliances Industry.

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ABSTRACT

The paper discusses some dynamic effects of robots' introduction on a company in the electric appliances industry. Two key aspects are analysed. The effects on cash flow are explored first, the conclusion is reached that under certain conditions it could represent a controlling element that would slow down the rate of robots' introduction with respect to the ideal rate suggested on the sole basis of economic convenience. The availability of skilled technical personnel is considered next. This availability increases through on the job training as more robots are installed. Under most circumstances, however, the availability of skilled technicians represents a controlling element that definitely slows down the introduction of robots. The effectiveness of training technicians therefore represents a variable of strategic importance.

INTRODUCTION.

The electric appliances industry in Italy is fairly important, it supplies close to one third of European production, about 60% of output is exported.

The data used for simulation is based on figures published for a company that represents an average situation in the industry, this data was supplemented with estimates by industry experts.

The introduction of robots in the electric appliances industry implies a major innovation in several respects.

The use of robots for assembly operations where about 65% of all workers in the industry are currently employed will require that products and production lines be redesigned bearing in mind the possibilities and limitations of the new technology. The new skills required for this redesign are of such complexity that their acquisition will take time. The new technology is likely to change radically the culture in the product design and in the process design departments.

The introduction of robots is also likely to alter fundamentally the process of matching products to market segments since robots' flexibility will enable production of small lots of products tailored to specific market segments at acceptable costs.

In the end the introduction of robots is likely to modify the structure of the industry, the strategies of the individual companies and the power map inside the companies in the industry.

This paper is concerned with some of the key cause-effect relationships that appear to have a major influence in the initial phases of robots' introduction. It does not pretend to explore all the issues involved but concentrates on the economics of substituting workers with robots and on the problems that arise from the need for new skills by the technical staffs in order to use robots effectively.

In the first part of this paper the economics of substituting workers with robots are examined. The decrease in cost of robots as compared to the substituted human labor is clearly the driving force. The ideal effects of reduction in robots' costs relatively to human workers' costs are explored assuming, for the moment, that no limitations would be posed by companies' structures. The number of shifts worked has a decisive importance. The more shifts are worked, the earlier the economics require the adoption of robots.

The second part explores how the insufficient number of skilled technicians able to solve the many problems arising from adoption of robots may cause a major delay in their introduction.

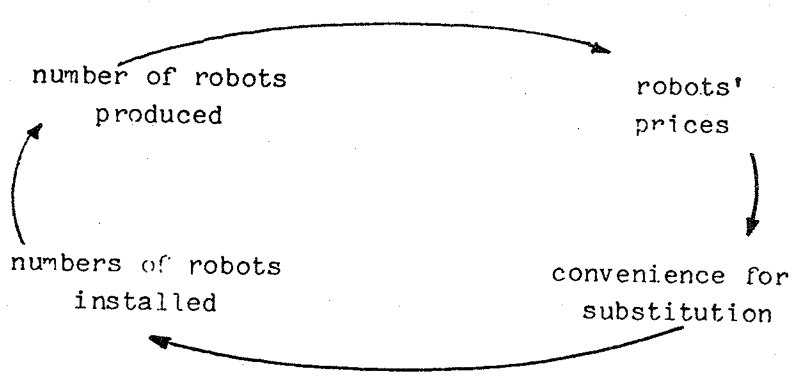
Resistance to robots' introduction both at the union level and on the management level have not been examined here although work on these issues is in progress.

ROBOTS INTRODUCTION RATE DETERMINED SOLELY BY ECONOMIC CRITERIA.

Robots still represent a new technology, it is probably rather early to determine the rate of their diffusion and the final saturation level. Robots' prices are decreasing considerably slower than the frequently encountered 20% on doubling of production. This and direct observation of the expansion of robots' capabilities suggest that the technology is still evolving rapidly and that a settled design is probably several years away.

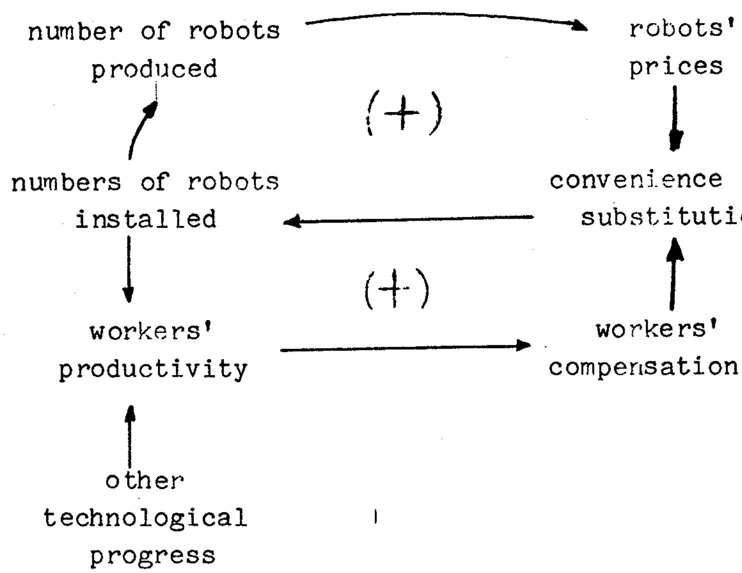
The above remarks imply the uncertainty of any quantitative forecasts of robots' final diffusion and of the rate at which it will be accomplished. It is logical, however to assume that qualitatively the increase in robots' production rate determines the decrease in their costs and leads to their diffusion.

Fig. 1.- As more robots will be produced their prices will fall leading to more robots being installed.



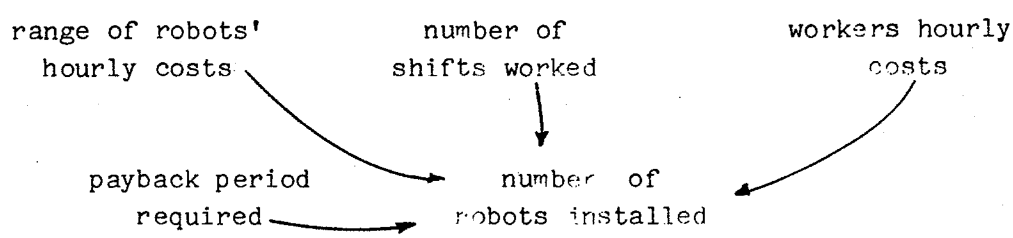
The increase in labor costs as the standard of living increases combined with the decrease in robots' costs implies that when robots are introduced in positions manned for about two shifts, it is already economical at this time to begin substituting men with robots.

Fig. 2.- Technological progress increases workers compensation and increases the advantages of substituting men with robots.



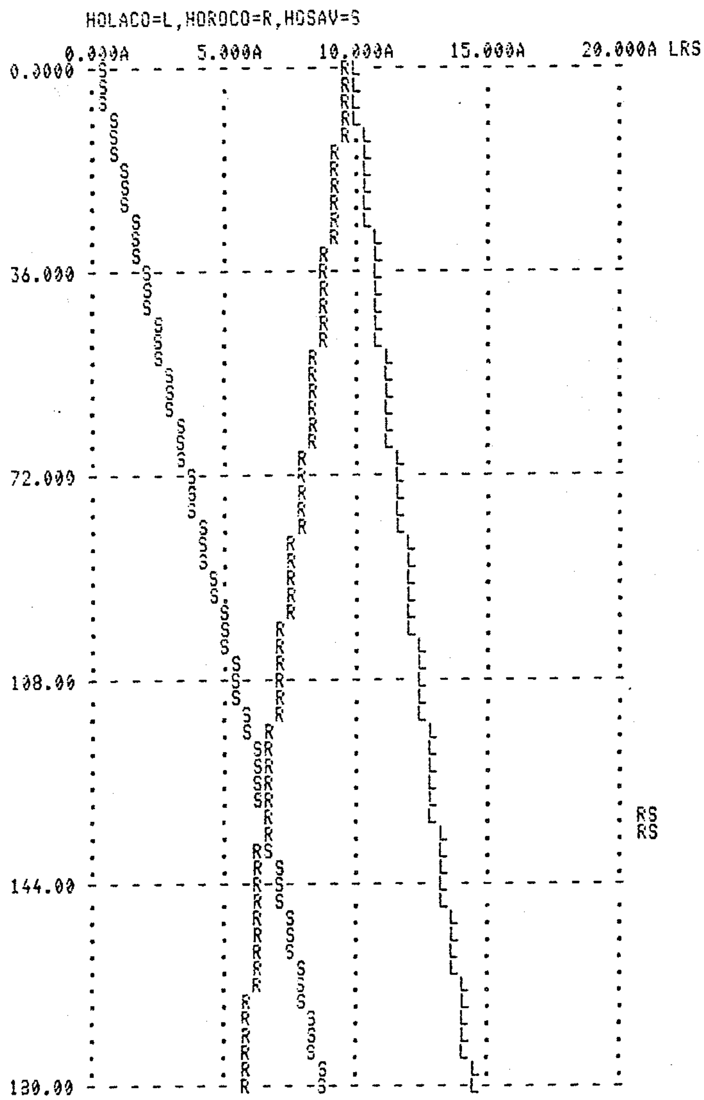
The elements that determine the economics of substituting robots for workers are presented in Fig. 3.- . The variables involved are: robots' costs reduced to hourly robot costs, workers' hourly costs, number of shifts worked - this last value inflences both the robots hourly costs and average workers' hourly costs -, payback period normally used in the industry to evaluate whether the investment in automation is a convenient one.

Fig. 3.- The number of shifts worked and the minimum payback period acceptable for investments in automation are key to the decisions on robots introduction.



The expected evolution of hourly costs for robots (HOROCO=R) and workers (HOLACO=L) considering an average of 1.8 shifts, typical in the industry is presented in Fig. 4. The robots' acquisition costs are extrapolated from the history of Unimate's Mark II assuming a future evolution of costs for other robots along a similar learning curve. Overall installation costs are estimated in 125% of robots' acquisition costs. Depreciation over 5 years and maintenance costs represent other significant elements of robots' hourly costs. Labour costs are based on current values increased by 2.5% annually.

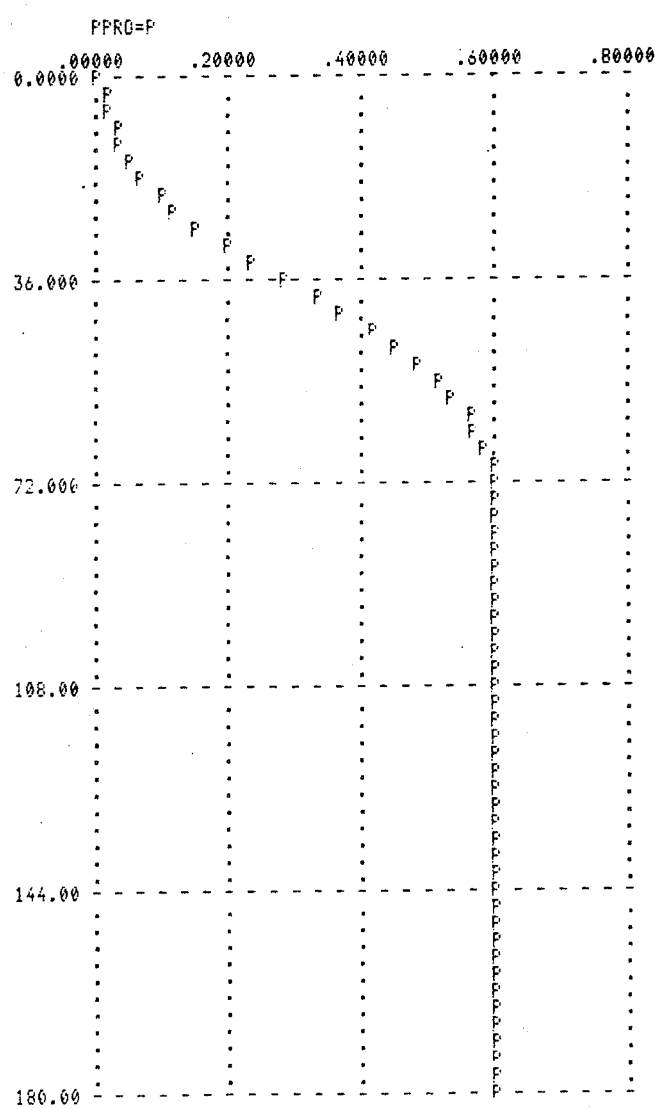
Fig. 4.- Over a period of 120 months the robot hour will cost about 50% of worker's hour if the robot will be operated 1.8 shifts on the average.



The various positions manned by human workers require different investment for the substitution of man by a robot. It will frequently be convenient to substitute some manual operations by robot operations while others will have to wait until robots will be less expensive.

It has been assumed that the convenience for installing robots in the industry moves along an S shaped curve similar to the logistic curve. If about 60% of positions currently staffed by workers were potentially to be assigned to robots the assumed substitution would occur following a curve like the one illustrated in Fig. 5.-

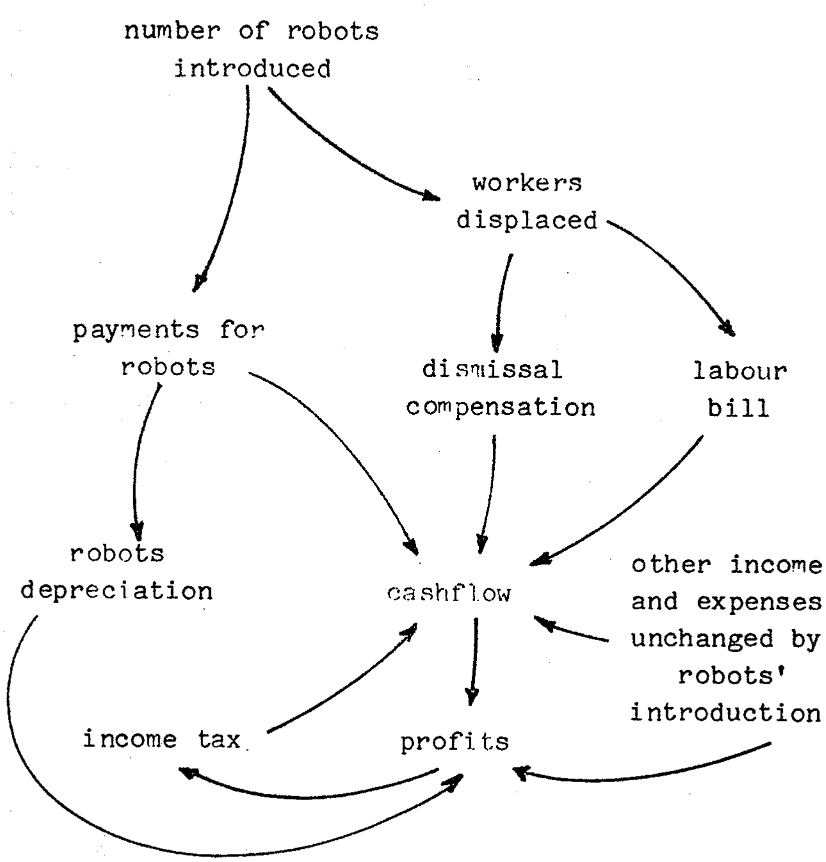
Fig. 5.- Robots could substitute a substantial percentage of men in the electric appliances industry over the next few years. The percentage of positions that can be manned by robots over the next few years is illustrated by PPRO=P.



In order to test the validity of the conclusions several alternatives were explored, a slower increase in labour costs - 1.5% annually - suggests only a minor delay in the massive adoption of robots. A 30% increase in robots' costs does not push too far into the future the massive adoption of robots either. Great sensitivity, however, was found with respect to the number of shifts worked. For one shift operations the convenience of massive substitution of men with robots is still several years away, while for a three shift operation the robots should be introduced immediately to substitute workers in almost all position where this is feasible.

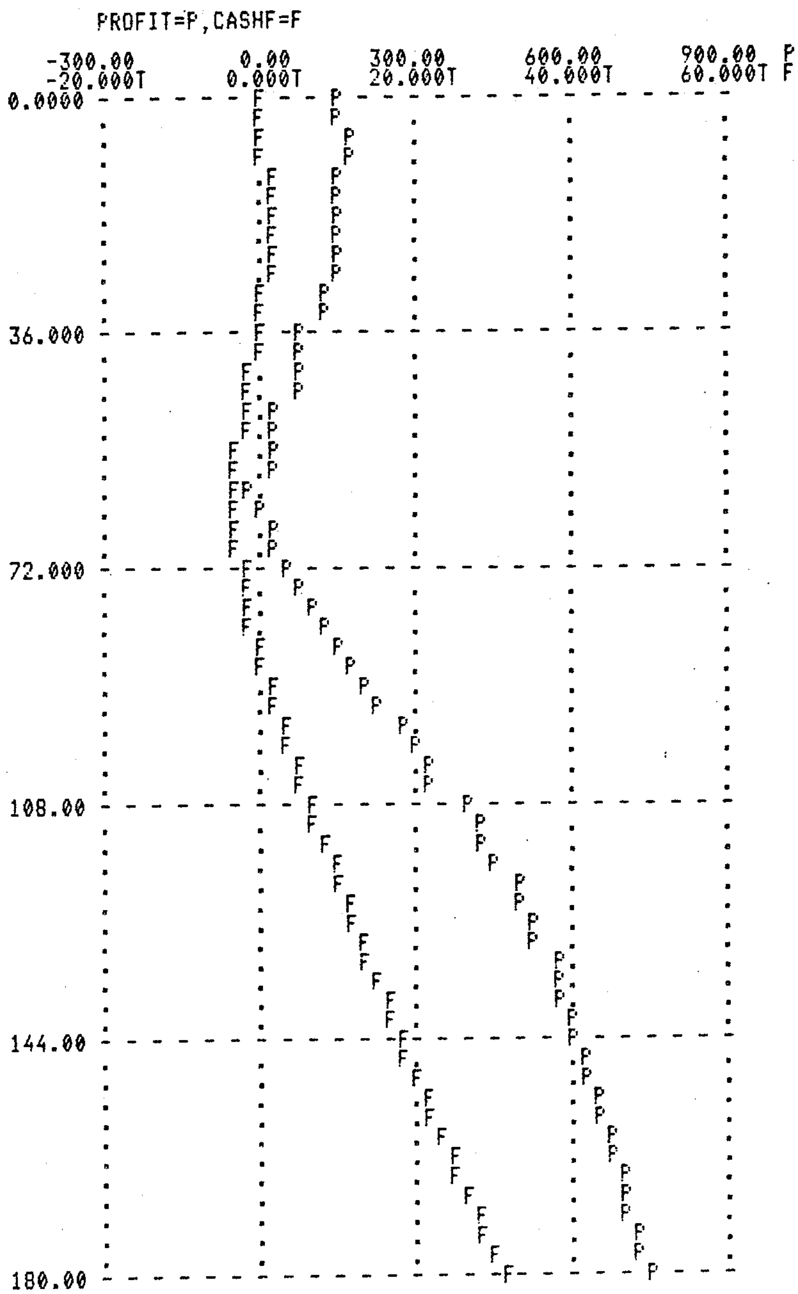
The effects on cash flow and profitability of robots' introduction occur through the chain of causes and effects illustrated in Fig. 6.- . As robots are introduced they need to be paid for. As they arrive and become operational workers are first displaced and then dismissed. Dismissal compensation needs to be paid but the remaining labour bill is consequently reduced. The above elements influence the cashflow directly. Taxes on additional profits due to robots' installation need to be paid but since additional profits are diminished by depreciation of robots the outflow for income taxes is also influenced.

Fig. 6.- The cashflow and profitability are directly influenced by adoption of robots.



It can be seen that if robots could be introduced at the rate which appears economically convenient for 1.8 shift operation, the cashflow could represent an obstacle to their rapid adoption. This limitation by availability of cashflow could get even worse when three shift operations are considered.

Fig. 7.- For operations at 1.8 shifts the cashflow (CASHF=F) goes negative only slightly and in the long run becomes much more atractive while profitability (PROFIT=P) doubles after the substitution of robots for men is completed.

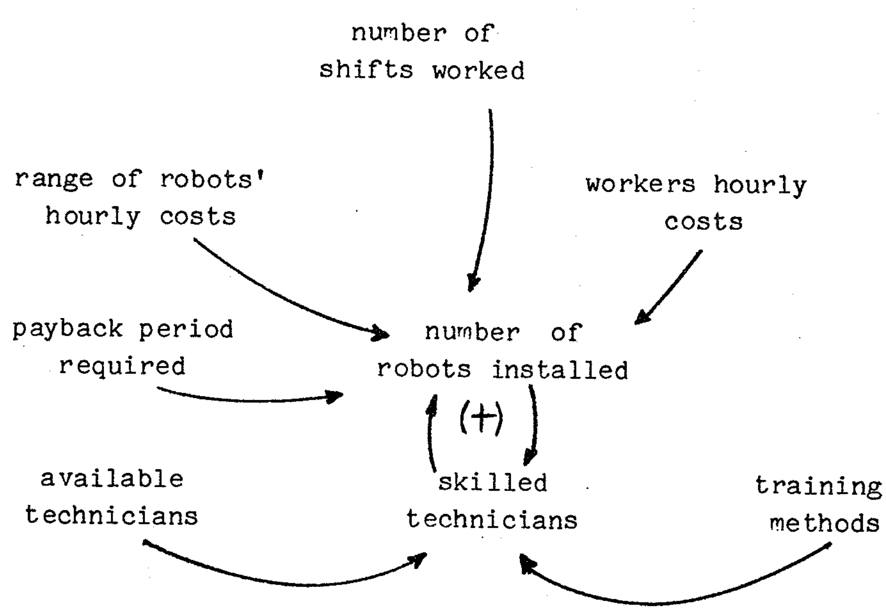


THE INSUFFICIENT AVAILABILITY OF SKILLED TECHNICIANS SLOWS DOWN THE RATE OF ROBOTS' INTRODUCTION.

Robots' introduction requires that relatively complex skills be acquired by the technical staff. To begin with, a new version of time and motion analysis must be prepared for each set of operations. This is much harder to prepare than is the case with human workers because each robot has its own speeds and movement possibilities and each robot may have different capabilities. Next, components must be redesigned so as to be easily grasped by a robot in the correct position. A close match between assembly methods and robots' capabilities needs to be established.

The feeding of robots and the transportation of processed components to the next station require usually a major transformation in the transportation system. To make matters more difficult, in most cases the introduction of robots is made to coincide with product and process innovation. This if not carefully planned requires a massive application of the new skills simultaneously to solve problems in product design, production and in production flow. If the new skills were to be in too short supply delays and poor solutions could result. Therefore it is essential to program intelligently where and at what rate robots will be adopted.

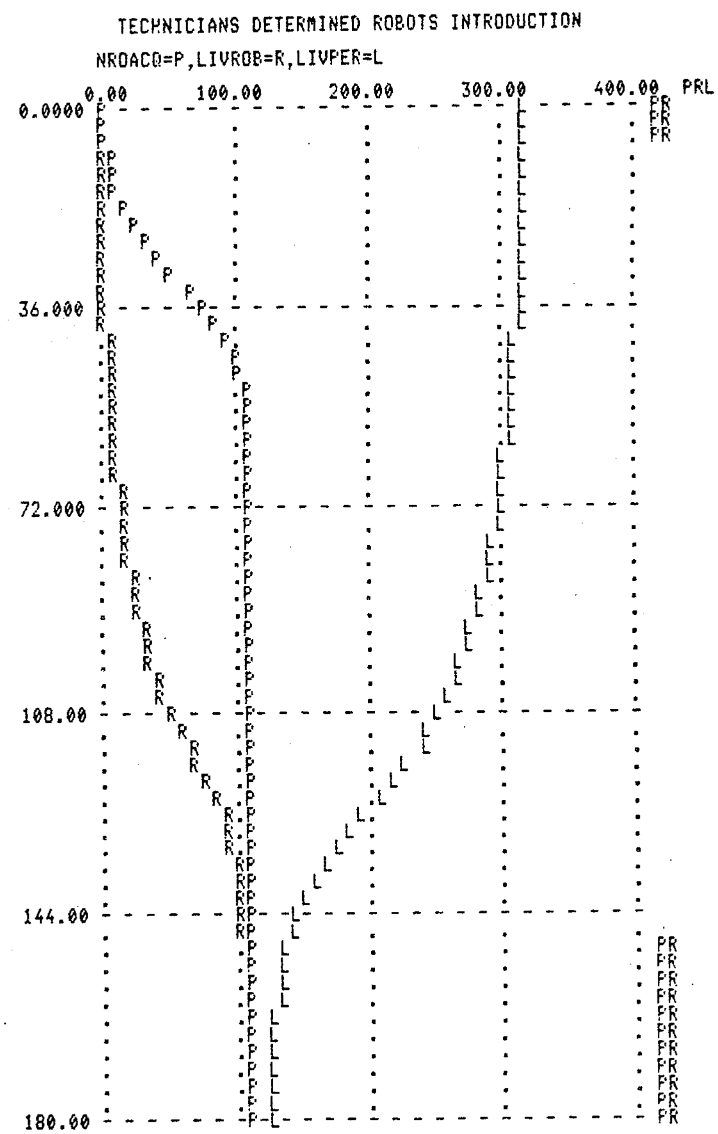
Fig. 8.- The scarcity of skilled technicians initially limits the rate of robots introduction. With time their availability may speed up the diffusion of robots through the effects of internal learning curve.



The acquisition of required skills represents a major milestone in the process of robots' adoption. The technical staff can certainly be equipped with some theoretical background but experience in solving the various problems is essential for the technicians to be considered trained for the job. The better trained and experienced technicians also tend to select less expensive solutions to the various problems thus making the substitution of men with robots convenient earlier than it would have been under the sole influence of the robots' cost reduction caused by the learning process external to the company.

The delay caused by the need to acquire the new technical culture are critical and imply that considerable attention must be paid to the methods of selection and training of technicians in the new skills.

Fig. 9.- The delay required for training technical staff, if not reduced through an adequate method of training, could lead to delays of several years in the process of robots' adoption.



The results presented in Fig. 9 show how the internal learning process is likely to accelerate the period in which it would be convenient to install robots on purely economic considerations. The number of robots to be ideally acquired NROACQ=P reaches it maximum about a year earlier than was the case illustrated in Fig. 4.- when only the effects of external learning curve were considered. The actual completion of the process of robots' installation is however delayed by about 10 years with respect to the moment when it would have been convenient to complete it. The actual number of robots installed and working is illustrated by LIVROB=R. The level of personnel LIVPER=L starts to decrease strongly only about 6 years from the start and continues to do so for about 6 more years.

The delay in massive adoption of robots is due to insufficient availability of skilled technicians as is illustrated in Fig. 10. The ideal rate at which decision to install robots should be taken RINROI=I implies the purchase of all the robots that are economically justifiable at a time. The real capability to purchase and assimilate robots however is limited by the capability to assimilate robots by the company. This is illustrated by CAPROB=C. The rate at which robots become installed and operational is illustrated by RINSRO=B.

Fig. 10.- For about 108 months the rate at which robots can be installed appears limited by the availability of skilled technicians CAPROB=C only later is it limited by robots requirements RINROI=I.

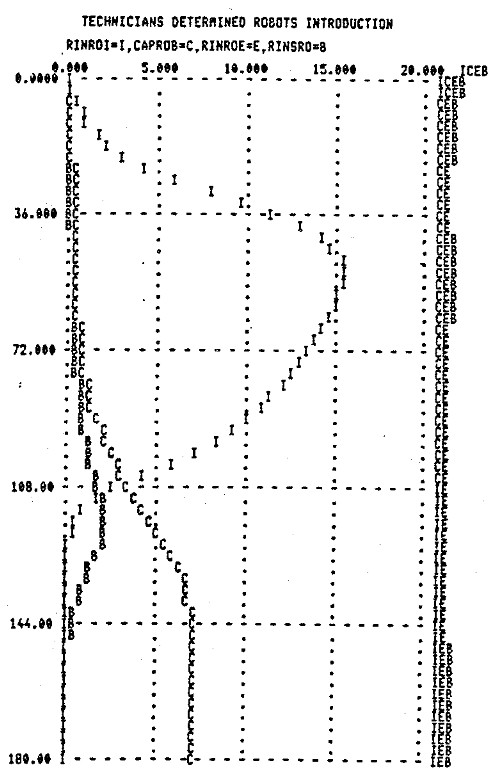
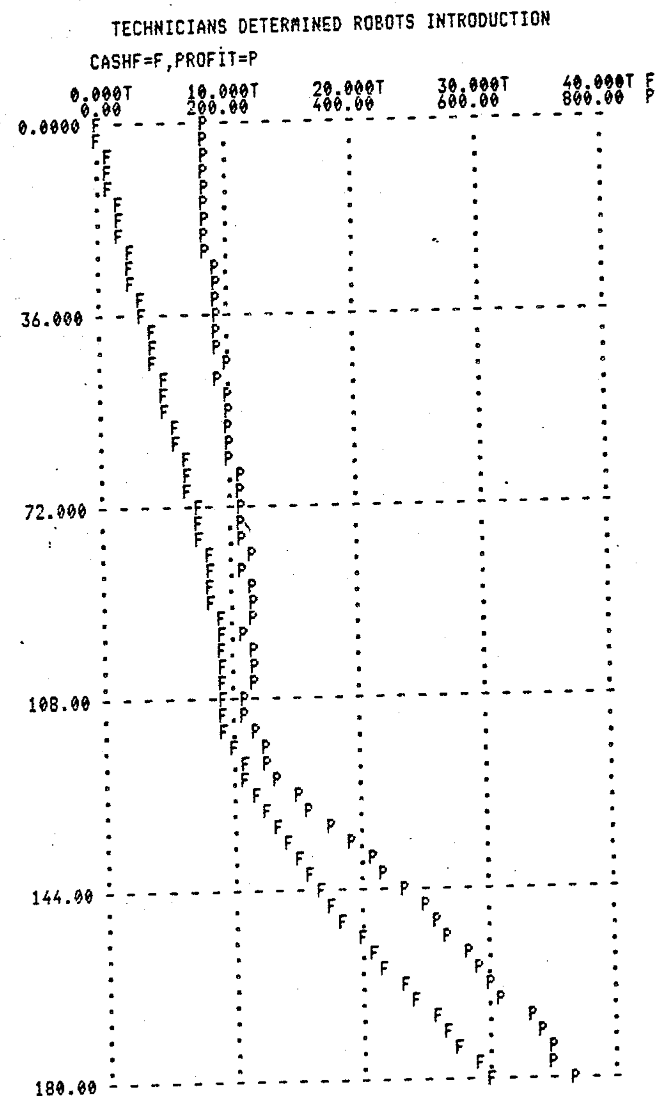


Fig. 11.- The slower rate of installation implies that cashflow and profit considerations are unlikely to be a controlling elements that could slow down the rate of investments



The above simulations suggest that the methods of training technicians for the utilization of robots must be greatly improved in order to produce better results in shorter time periods. The robots' manufacturers and external consultants appear to have a wide field of opportunities in preparing training and design tools that could work effectively in reducing the need for complex training of a large number of technicians. In fact the delay is very sensitive to the period of training and to the effectiveness of training on and off the job.

The issue of future substitution of robots with others belonging to newer generations is not being addressed at this time although it needs to be explored.

CONCLUSIONS.

The massive adoption of robots by the electric appliances industry over the next few years appears extremely probably, perhaps within the framework of flexible manufacturing.

The duration and the effectiveness of the training process for the technical staffs represent a key issue which must be carefully addressed under conditions of limited availability of technical personnel with such skills as are necessary for successfull utilization of robots in electric appliances industry.

The planning of introduction of robots needs to take into consideration the economics of three shift operations and the reality of current one shift or two production by most of the industry in Italy. It also needs to consider carefully the areas where robots will be introduced first in order to allow for a gradual development of skills needed to complete the major transformation of the industry over the next few years.

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