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Automation, evolution or revolution
Automation — évolution ou révolution

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Résumé de l'article

La substitution de la machine à l'effort humain n'a rien de nouveau; déjà en 1661, un tisserand de Danzig avait mis au point un métier capable de fonctionner jour et nuit en faisant pendant moins de temps et à moins de frais plus de travail que l'homme. Le gouvernement local avait défendu l'emploi de cette machine pour protéger les travailleurs, mais l'inventeur, persistant dans son idée fut noyé en public par ses compagnons de travail.

Cette tragique histoire n'a rien d'exceptionnel: elle illustre bien les deux aspects du progrès technologique : 1) la substitution de la machine au travail de l'homme et 2) l'opposition agressive des travailleurs devant cette nouveauté qui constitue une menace à leur gagne-pain. Le premier de ces deux aspects nous amène à établir la nature des changements technologiques et le second, à analyser leurs effets et leurs conséquences.

LA NATURE DES CHANGEMENTS TECHNOLOGIQUES

Le motif invoqué par l'inventeur de Danzig en substituant la machine à l'effort de l'homme est caractéristique du changement technologique. Dans toute manufacture ou usine, une certaine somme est investie dans des machines de tous genres et des travailleurs sont assignés à leur opération. Conséquemment, le produit fini est toujours le résultat de la machine et du capital d'une part et de l'effort humain d'autre part.

Avec une machine donnée et un nombre déterminé d'hommes, le système homme-machine est en état d'équilibre et permet d'établir la contribution simultanée du capital et du travail dans la fabrication d'une unité. Si, comme conséquence de l'installation d'un convoyeur automatique, un certain nombre d'hommes préposés à la manipulation doit être éliminé, cela amène un changement qui modifie l'équilibre initial. Ainsi, la contribution du capital dans la fabrication d'une unité augmente en comparaison de la contribution du travail de l'homme.

Dans un tel cas, le changement technologique amène une modification de l'équilibre entre capital et travail.

Cependant, tout ce qui contribue à modifier cet équilibre capital-travail n'est pas dû forcément à un changement technologique. L'équilibre peut aussi être changé par une modification des coûts relatifs du capital et du travail ou par une meilleure utilisation de la machine existante ou suivant une substitution du capital par le travail. Dans ces trois cas, le facteur d'innovation qui est spécifique du changement technologique n'apparaît pas.

Le changement technologique peut être défini comme une modification de l'équilibre capital-travail due à un changement dans les techniques de production d'une entreprise quand le système homme-machine opère à un point optimum, de telle façon que la contribution du capital augmente en comparaison de celle du travail dans la fabrication d'une unité de production.

CONSÉQUENCES

Si le capital se substitue au travail, c'est qu'il est plus économique de procéder ainsi et cela apportera trois conséquences : 1) Le coût de production des produits diminuera. Une réduction sur le prix s'ensuivra et le produit deviendra à la portée d'un plus grand nombre de gens. 2) Si la machine remplace les employés ils seront congédiés, au moins pour une courte période. 3) Les tâches des employés à l'intérieur de l'usine seront modifiées et devront s'adapter à la machine.

Sans trop s'étendre sur les avantages de la mécanisation et de l'automation, il suffit d'ajouter qu'ils ont contribué à augmenter la productivité, à élever le niveau de vie et à placer sur le marché des produits que l'effort de l'homme seul aurait du mal à produire.

L'AUTOMATION ET LES GRADUÉS D'UNIVERSITÉS

Il faut ajouter à tout ceci quelques considérations sur les répercussions que peut avoir l'automation sur nos écoles de commerce et d'administration d'affaires. Il ne faut pas perdre de vue que les applications de l'électronique révolutionnent nos concepts traditionnels d'administration des affaires.

Certains calculateurs électroniques ont des capacités qui s'apparentent aux facultés humaines. Ils peuvent se souvenir, apprendre d'une expérience passée et donner en très peu de temps une multitude d'instructions sur des sujets divers. Leurs capacités dépassent sur un certain point, celles de l'homme. En un instant, ils peuvent donner la réponse exacte à des calculs que ne pourrait établir l'intelligence humaine durant toute une vie.

De telles machines détruisent les vieux concepts de tenue des livres, d'audition, de vérification, d'établissement d'inventaires et d'une foule d'autres opérations routinières dans les domaines fiscaux ou commerciaux. Ces méthodes de travail ont créé une révolution dans la façon conventionnelle de mener les affaires et ont complètement modifié les exigences imposées aux administrateurs d'entreprises.

Avant l'avènement de l'électronique, les informations nécessaires à la marche des affaires étaient fournies laborieusement par les calculs souvent inexacts d'un commis de machines à rendement lent et à capacité limitée. Nous assistons maintenant à une révolution dans la technologie de l'administration. L'administrateur moderne n'a aujourd'hui qu'à peser sur des boutons pour obtenir immédiatement toutes les données essentielles à la bonne marche de l'entreprise. Le cerveau électronique donne une masse d'informations mais il faut encore savoir choisir entre elles.

Parce que le cerveau électronique a donné la réponse à des problèmes qui seraient restés autrement insolubles, de nouvelles techniques d'analyse ont été créées dans l'administration telles que les programmes linéaires, les phénomènes d'attente, etc. Ces analyses qui nécessitent de longues équations mathématiques sont résolues, maintenant, par le cerveau électronique.

Comme le note John T. Dunlop dans son livre: « The Manager of 1970 », « celui qui ne comprend rien aux techniques automatiques d'information est fortement handicapé et de là, la responsabilité des universités de former des hommes qui soient bien informés de ces techniques pour qu'ils puissent efficacement diriger l'entreprise moderne ».

Les opérations de recherches qui peuvent se définir comme le résultat quantitatif d'un problème à partir de ses variables ne sont plus seulement aujourd'hui le lot du physicien ou de l'ingénieur, mais le sociologue, l'économiste et le comptable y sont souvent confrontés. Conséquemment, les nouvelles techniques industrielles exigent la coopération étroite de techniciens, de professionnels et de scientistes spécialistes dans diverses disciplines, mais pour qui les mathématiques seront la formation de base.

Automation evolution or revolution

Jean-Paul Deschênes

In this article, the author analyses certain consequences of automation and its influence on university teaching and research.

Substitution of the machine for human effort is nothing new. Already in 1661, a craftsman from Danzig had invented a loom capable of being operated day and night and of making six ribbons at a time. The local government immediately forbade the use of this machine in order to protect labourers against unemployment. A little later, as the inventor persisted in his idea of replacing man by the machine, he was drowned in public by his fellow-workers.

This tragic story is unfortunately not unique. By quoting it here, I wish to stress the two following aspects: 1) Substitution of the machine for manpower or of capital for labour and, 2) the labourers' aggressive opposition to these technological changes, which constitute a menace to their means of living. The first of these two aspects allows us to establish the nature of technological changes and the second, to analyse their effects and consequences.

Nature of Technological Changes

The purpose aimed at by the Danzig inventor was to substitute the machine for human effort; this is also one of the main characteristics of technological change. In any factory or plant, a specified amount of money is invested in

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machines of all kinds, and workers are assigned to the operation of these machines. Consequently, the final product is the outcome of two main factors, that is, machinery or capital on the one hand, and man or human effort on the other hand.

With a given machinery and given number of men, the man-machine system is in a state of equilibrium which allows one to determine the contribution of both capital and labour in the manufacturing of a unit. If, following the installation of an automatic conveyor, a certain number of men engaged in the transport of material have to be eliminated, this brings about a change which modifies the initial equilibrium between capital and labour, so that the contribution of capital, in the manufacturing of a unit, increases in comparison with the contribution of manpower. In such a case, the technological change would make for a modification of equilibrium between capital and labour.

However, everything that contributes to modifying this capital-labour equilibrium is not necessarily a technological change. The equilibrium may also be modified on account of a change in the relative costs of capital and labour, or due to a better use of existing machinery or following a substitution of labour for capital. In the above three cases, the innovation factor which is peculiar to the technological change does not appear.

For instance, let us assume a case where the minimum production cost to produce 200 units of a given commodity is arrived at by using 10 machines and 20 men and that substitution of labour for capital or of capital for labour is possible. If, then, a scarcity of manpower would occur, causing the cost of same to increase considerably, it may become more profitable to produce the same quantity with 5 extra machines of the same type and a group of 12 men instead of 20. Here the capital-labour equilibrium would have been modified, without technological changes having been brought in.

Another modification of the capital-labour equilibrium may result from a better utilization of existing machinery in such a way as the same number of men, working on the same number of machines, is now in a position to produce 50 units instead of the 35 previously produced within the same period of time. Is that a technological or merely a technical change?

Any machine, considered in itself, is theoritically capable of producing a maximum number of units. Let us take, as an example, the

newsprint machine. On purchasing such a machine, one will be told by the manufacturer that it may produce 1,500 feet per minute. However, with machine and man combined, the maximum production of 1,500 feet per minute will be practically unattainable due to the fact that the man-machine system makes for a decrease in the theoritical capacity of the machine. The actual production will be determined by the man's skill in foreseeing troubles, finding out the causes for breakage, making repairs, etc.

Let us assume that when combined with man's work, this machine is producing 1,100 feet per minute. And then following a re-allocation of tasks among the staff, or an adequate training given the operators on how to run the machine and on the manufacturing of newsprint, you succeed in increasing production to 1,250 feet per minute. The contribution of capital, or of the machine, in the production of one unit has now increased to the detriment of labour contribution; therefore, there has been a modification in the capital-labour equilibrium without any technological change having taken place. There has been no innovation, but merely better utilization of the existing production factors. In other words, an optimum production has been obtained from the man-machine system.

To summarize, let us say that, even if they contribute to the optimum efficiency of the man-machine system and cause, to a certain extent, the same effects as technological changes, the modifications in the capital-labour equilibrium, — due to a better utilization of existing machinery, such as a better disposition of machines, the simplification of tasks, the elimination of bottlenecks, a remuneration system based on production, etc. — are not actually innovations but technical changes, that is, changes that increase the optimum capacity of the man-machine system. As a matter of fact, the ideal optimum capacity is the maximum capacity of the machinery.

Finally another modificatoin in the capital-labour equilibrium may be due to the substitution of labour to capital. While this substitution is possible in theory and may take place in very few cases, it cannot be considered in my opinion, to be a technological change, because it does not agree with the general concept of a technological change, and also because it runs counter to the industrial development which has followed the Industrial Revolution. In other words, this substitution is hardly imaginable in the present context of Capitalism.

As a conclusion to all these considerations, technological change may be defined as a modification in the capital-labour equilibrium due to a change in production techniques in an enterprise where the man-machine system operates at its optimum point, in such a way as the contribution of capital increases in comparison to the contribution of labour, in the manufacturing of a unit of production.

Let us see again, one by one, the constituents of this definition:

a) Change in production techniques, which eliminates the possibility of a lack of equilibrium resulting from a change in the relative costs of capital and labour;

b) In an enterprise where the man-machine system operates at its optimum point, which eliminates the lack of equilibrium resulting from a better utilization of existing machinery;

c) In such a way as the contribution of capital increases in comparison to the contribution of labour, which eliminates the change which would aim at replacing the machine by man, and would constitute an unthinkable step backwards.

Technological changes, as defined, are grouped in two categories: mechanization and automation. In mechanization, the machine aims at replacing manpower. For instance, the electric drill replaces the bit-brace and the ribbon-saw replaces the hand-saw. The facts remains that, in mechanization, man plays an important part, since he controls the machine. In automation, the machine aims at replacing man's control. While, in mechanization, man remains an essential factor, closing the circuit through which raw materials are converted into a finished product, in automation, the circuit is closed by a machine which controls other machines and corrects their deviations. Think, for instance, of the automatic pilot of an airplane that controls by itself the deviations of the plane from its normal course. The machine controls itself without man's intervention; the circuit is closed without man's intervention. In mechanization, man thinks for the machine; in automation, the machine thinks for the machine. In mechanization, the machine does the work but is controlled by man; in automation, the machine does the work but is controlled by another machine.

In other words, automation means that the sequence of control is closed. A closed sequence control incorporates feed-back; that is, the results of its own actions are fed-back to the regulator and modify its further behavior.

Let us specify that automation does not necessarily imply that the whole product is manufactured in closed circuit. It may well happen that some parts of the product are manufactured by means of automation and other parts are manufactured under man's control.

Consequences

Thus, capital is substituted for labour, and providing this is done because it is more economical to do so, one may suppose three consequences: 1) the production cost of the products will decrease and, if a reduction of the sale price ensues, the product will become available to more people. 2) Since they are replaced by machines, employees will be laid off, at least for a short period. 3) The duties of employees inside the plant will be modified in order that they may adapt themselves to the new machine.

It is not my intention to say much about the advantages of mechanization and automation. Suffice it to say that they have contributed to increase productivity, to raise the standard of living and to place on the market products which manpower alone would have been powerless to manufacture.

a) Reduction in prices

No doubt about it, mechanization has permitted considerable reduction in prices and therefore made products available to more people. May we hope that this trend will continue when automation will have made further advances in our industrial world? This question can hardly be answered, since automation is so relatively new!

Mechanization has favoured monopolies, or at least oligopolies. In view of the fact that only a few people possess the huge sums required for mass production, it may well be that the price now asked for a number of products, is by far higher than what should be paid had the firms concerned been subject to true competition. With automation, requiring as it does fabulous installation costs and calling for tremendous production in order to be economically justifiable, the trend towards concentration of industry might still be accentuated. If such is the case who will profit from a reduction in production costs? Will enterprise discipline itself sufficiently to take only a reasonable part of the profit, and share the rest with the consumer and the worker? Or,

will it be necessary to count on a higher authority to control enterprise?

In any event, it is obvious that mechanization has contributed to raising the standard of living and that automation will probably further develop this trend.

b) UNEMPLOYMENT

Now, insofar as the workers are concerned, does the technological changes mean employment or lay-off? Providing you take care to state to a certain economist, we shall all be dead, you might answer « yes » that your reply is valid on a long term basis, term after which according or « no » to this question and rest assured that some scientist at one time or another was of the same opinion as you.

As a matter of fact, based on the long period, one may well sustain that unemployment deriving from technological progress in a given sector of economy, should be rapidly offset by greater employment possibilities either in the same sector, or in some other sector; also that over-production can be only temporary and that same will be absorbed through re-arrangement of the structure of demand. In fact the commodity affected by the technological change will be produced at a lower cost and therefore sold at a lower price. Given an elastic demand, a drop in price will bring about a larger consumption of the product and with a non-elastic demand, the savings realized on this product will be used to buy other products.

Therefore, it is quite possible, according to this theory, that, in the long period, technological progress will be a source of employment. This is on condition, however, that the sale price of the product be actually lowered and that the savings then realized by the consumer will be affected to purchasing other products and not deposited in the bank or in a wollen stocking.

On the other hand, you may contend that technological progress is a source of unemployment, and still be logical in your reply. In fact, if substitution between capital and labour, or between machine and manpower is low or, in other words, that the machine is a complement to the worker, employment possibilities will be higher or lower according to whether the existing capital (which is turned into machinery

and equipment) is more or less abundant. Employment possibilities are linked to the quantity of existing capital. In other words, where an innovation allows a worker to use a larger quantity of capital (that is to say a machine that has a higher value than the preceding one), those who are laid off have no longer any actual capital, they have no tools at their disposal, in view of the fact that a given machine calls for a limited number of men to operate it, and will not produce more if the number of men is increased. This situation will last more or less according to whether the community is more or less inclined to invest, and to whether the innovation is efficient in increasing productivity and thus in accelerating the capital expansion process. This theory also has its weak point as it starts from the premise that the substitution between capital and labour is difficult. This is not wrong necessarily but has not been tested in practice and implies that one industry cannot grow to the detriment of another.

Is technological progress, in the long period, a cause of unemployment? I have given two opposite replies to this question. Where substitution between capital and labour is easy, the answer is that technological progress does not bring about unemployment. Where such substitution is impossible, the answer is that technological change brings about unemployment. As long as empirical research will not have studied more closely the possibility of substitution between capital and labour, the answer to the above question will remain either negative or positive.

Viewed in a context of production based on mechanization and not on automation, the effects of mechanization, insofar as unemployment is concerned — could well be offset by the increase in demand which follows a reduction in price, in view of the fact that the machine replaced manpower only gradually. But will this compensation take place with automation? In this connection, here are a few statistics. The Ford Company plant at Cleveland owned a machine which carried out 540 operations, producing 100 motor heads per hour, and which employed 41 men instead of the 117 required with the previous method. At Marcus Hook, Pennsylvania, one man only controlled an entire chemical plant. At Chicago, two men in a radio set factory could mount 1,000 sets per day while 300 men were needed formerly. In the Province of Quebec, a two-men team controls a plant making chemicals used in the production of newsprint, a television camera serving as supervisor.

Many writers on the subject believe that automation is simply the continuation of the phenomenon called Industrial Revolution, and that individuals, and social and economic institutions will adapt themselves to this new form of technological progress (that is automation), the same way as they adapted themselves during the years following the Industrial Revolution.

However, I believe that such an optimistic position can be dangerous because it leads to inaction. Indeed, even if mechanization brought moderately quick changes on a sociological and psychological point of view, changes to which individuals and societies adapted themselves without too much disruption, it can't be the same with automation. It has been said that of all scientists of whom civilization has any knowledge, 90 per cent are alive today; half of all the research and development expenditures in the history of the United States have been made in the last ten years.

Moreover, we would be inclined to think that scientific discoveries, and their application to the industrial field, progress closely according to a geometric progression if not according to an exponential progression. It is not easy to forecast what the future will be in such conditions.

For the future, one can foresee with very slight chances of error, the most extraordinary results from automation. To own a summer residence on Venus, for instance. In this field, too conservative forecasts might later on prove ridiculous. In June 1908, Professor W.H. Pickering of Harvard Observatory wrote in « Aeronautics » : « People often dream of huge flying machines, filled with travellers, alike our modern liners and spinning along at high speed over the Atlantic. Such ideas now appear completely absurd. And supposing that a machine could cross the ocean with one or two passengers aboard, the transportation fees would be prohibitive to all except, maybe to the capitalist who can afford to make this trip in his own yacht. Another error is to anticipate vertiginous speeds. And still another is to imagine that a flying machine could drop bombs on the enemy in a period of war ». This was Mr. Pickering's opinion in 1908.

Let us formulate the same question as above concerning unemployment, based this time on the short period and not on the long period. The answer is that technological progress will bring about unemployment. And this short period is more particularly important in view of the fact

that it goes by during the life of the machine operator, the office clerk, the maintenance man, who depend on their weekly salary for paying rent and debts as well as for feeding and clothing their family.

Within the short period, technological progress means unemployment for the very reason that this progress aims at replacing man by the machine ; to produce more with a smaller or equal staff. Let us assume that due to mechanization, manufacturer « A » is able to sell refrigerators at $200.00, when the average price quoted by his competitors for this item, same standards, stands at $250.00. It is very likely that, after a certain time, all refrigerators produced by « A » will have been sold and demand will keep increasing. It is not as probable, however, that « A » will sell his surplus refrigerators the very next day after his announcement of a reduction in price. There will be a period of readjustment and it will be only gradually that consumers will buy manufacturer « A »'s refrigerators. During this readjustment period, several employees will be compelled to look for work elsewhere or manufacturer « A » will have to pile up his product. On the other hand, should competitors also use mechanization on a larger scale and be able to sell their refrigerators at $200.00, then manufacturer « A » would no longer be in a privileged position and his status would be the same as prior to his announcing a reduction in the price of his refrigerators.

As mentioned above, in the long period, a lower sales price is liable to bring about an increase in quantities sold. 200 years ago pins were selling at $0.08 each and now sell 100 for $0.08 and the number of jobs in the pin manufacturing industry has grown considerably, due to the drop in prices which made for an increase in sales. Let us not forget however that worker « X » in factory « Y » can hardly afford being laid off as a consequence of increased production, even if, in 100 years, the price of the product on which he works should be 99% lower and the number of employees manufacturing it should have tripled.

And even if it were the enterprise's policy not to lay-off any employee and to count on the regular staff-rotation to eliminate any unnecessary personnel, unemployment would still prevail, as the young people trying to enter the labour market would see the plant closed to them.

Everybody will admit that the advantages of technological progress are far more important than the disadvantages it brings about and, as said before, it is unthinkable that we should move backwards. We must not,

however, remain passive observers of these disadvantages and do nothing about them.

In the short period, there will be unemployment because the machine has replaced man ; some people will be unemployed because they are no longer adapted to the new machine or equipment. It is true insofar as these are concerned, that they will be replaced by younger men, more competent and better trained and this will restore the balance. However, it is to be noted that the young man looking for work is much more mobile and adaptable than his older counterpart who has been laid off.

In both cases, that is for those who are laid off because there is no more work for them in the plant and for those who are laid off because they are no longer adapted to the new machinery, re-education is necessary. To those who can be kept, the enterprise should give all facilities of acceding to new functions. Costs of re-education will probably, reduce for a certain period, the advantages deriving from innovation, but the enterprise would thus have an opportunity to make up for the social and economic disadvantages which it brings about in the community.

As for laid off persons, the responsibility for their re-education does not rest with the enterprise only. The government, technical and specialized teaching centres, the community, the labour unions, business, should all coordinate their efforts towards providing sufficient and adequate training facilities in order to enable displaced employees to divert their productive abilities towards other industrial sectors of industry capable of absorbing an increase in labour. Fortunately, all sectors of industry do not suffer simultaneously, not to the same extent, the effects of mechanization and of automation.

Again, there may be no question of moving backwards, to substitute labour for capital, to eliminate new production techniques which contribute to lowering prices and to making possible the marketing of products which could not be manufactured were it not for mechanization and automation. The fact remains however, that technological progress should be the servant of man and not his master. So, it must be controlled in order to lessen its adverse effects.

We have just mentioned, as a palliative, the re-education of displaced employees ; it is also possible, to orientate and to further humanize technological progress.

A better planning — on behalf of industry — of intended technological changes would allow for a better orientation of employees subject to displacement. It is true that scientific discoveries are unforeseenable, that a newly-invented machine may become obsolete even before it is marketed. Nevertheless, in most cases, an innovation can be foreseen, discussed and applied at a convenient moment.

Reducing working hours and granting longer holiday periods would enable a larger number of employees to work within the same period of time.

An extended seniority plan, at the level of the enterprise and not of the department, more rational and better-adapted procedures for the laying-off, hiring and promotion of workers could also lessen the adverse effects of technological change on workers and the community.

c) AUTOMATION AND UNIVERSITY GRADUATES

Let us now add some considerations on the effects that automation might have on our schools of Commerce and Business Administration. Those schools cannot afford not to take into account electronic computers which are revolutionizing our concepts of business administration.

« Electronic computers have certain capacities that are almost human, such as remembering, learning from past experience, recalling and quickly using a multiplicity of facts and instructions ». On the other hand, « they also have superhuman qualities, especially the ability to perform a million acts of addition (or substraction) in one second. Such machines render obsolete the old process of book-keeping, inventory control, payroll handling, and many other business and fiscal operations ».

In this particular area, the office, automation——or the presence of electronic computers has already caused a revolution so that it seems certain that the routine clerical worker will finally disappear long before his opposition number in the workshop vanishes.

If we go a step higher and consider the sector which was formerly governed by the rule of thumb, the decision-making process, computers have completely modified the requirements imposed on managers.

But before considering the role of computers in the decision-making process, let us analyse briefly what is a manager.

The executive responsible for a line division or part of it, in other words the administrator, is not necessarily a specialist, or, if he is one of them, it is only in a particular area and not in all the areas in which his function is exercised. In other words, if he is an administrator, it is not because he is a specialist in a specific domaine but because he is able to manage a group of men, because he can consider a series of variables, weigh them and take quickly the right decision, because he has a reliable judgment. In summary, he is a manager because he is a generalist.

I said «generalist» and I must explain it. We cannot create an administrator out of nothing because the administrator must possess some innate qualities. He has it or he does'nt. We can teach the principles of administration, we can teach some sciences in order to stimulate the administrator's mind, we can give methods and techniques which he has to know. However, judgment, initiative, the capability of taking adequate decisions quickly are required of the manager and those we cannot impart to those who do not have them. These requirements can be developed only if they are latent in the administrator make-up.

I will not go as far as saying, although I would be inclined to, that specialization is incidental to an administrator. Specialization in a particular area permits him to acquire a discipline which is necessary in the accomplishment of his duties. Moreover, the closer we get to the level of execution and the more we get away from the level where objectives and policies are elaborated, the more the manager has to be specialized.

Moreover, with automation, with this radical transformation of production methods, with the ever increasing complexity of problems of coordinating, diffusing and distributing, the personal qualifications of an administrator, with regards to a given specialization, play only a secondary function. In other words, the manager cannot at the same time be an administrator and a specialist, that is, continue to follow and to understand new and often fantastic developments taking place in his own sphere.

Even in a specific science, a higher specialization becomes more and more necessary. An economist, for example, can be specialized in international trade, in fiscal theory, in transportation problems etc..., and, even in transportation problems, he can be more specialized on tarriffs, or on costs and efficiency, or on markets. Similar examples can be taken in the medical field or in the field of applied sciences.

According to the above comments, a specialist who becomes an administrator cannot follow any more rapid developments taking place in his own discipline because he must spend more time on forecasting, coordinating and controlling. His science becomes less important.

It is evident, however, that innate personal qualities are not sufficient to be a competent administrator. One has to possess basic knowledge in order to understand and control all the elements entering into an industrial problem. This is a necessary condition if one wants to make correct decisions.

Before the advent of computers, available information necessary in the decision-making process was handled by clerks using pencil calculations and simple machines with slow speed and limited capacity. Now we assist at a revolution in the technology of business administration. Instead of waiting to the end of the month or the end of the semester to obtain necessary information, the administrator has only to press a button on the mechanical brain to obtain the actual picture of the firm. The only danger is that he can be flooded by a mass of unecessary information unless he knows how to handle it.

With the advent of computers and mostly because computers facilitate calculations, which would have been otherwise unfeasible and uneffective, new analytic techniques where developed in administration such as Linear programming, Dynamic programming, Queuing theory, game theory, etc. These tools of analysis, which require a set of mathematical equations, can be solved most of the time only by computers.

As it was pointed out in a book edited by John T. Dunlop, « the manager of the 1970's who does not understand the capabilities of automated information-processing techniques will be handicapped. He will run the risk of becoming the servant of the professional experts of the new theology. He will be incapable of bringing rational judgement to hear on proposals for investment in computer hardware. He will not understand how to adapt organization structure and administration process of the new tools ». [1]

The advent of the computer and of new quantitative analysis techniques are a challenge not only to managers but also and primarily to uni-

(1) Automation and Technological Change, Edited by J.T. Dunlop, Prentice Hall, 1962, pp. 82-83.

versities. Operation research which can be defined as the quantitative solution of an industrial problem taking into account all the variables entering in such a problem, has brought together the physicist, the sociologist, the economist, the engineer, the accountant, etc... to find an optimum solution. Consequently with computers and new techniques of information-processing, close cooperation between technicians, professionals and scientists is necessary and a sound knowledge of mathematics is the first science which will link them together.

As we can see, each specialist working in an industrial concern must know something about computers, mathematics, linear programming, research, etc... At this point I would like to ask a question : « Which faculty or school can effectively take the lead and control of what we might call administrative sciences ? Schools of engineering ? Schools of business administration ? School of commerce ? Faculties of sciences ?Departments of economics ? Or each one of them according to their needs and interests ?

I do not think that we can afford to develop appropriate programs in each one of the schools interested in the subject of automated information-processing techniques. We would not have the qualified personnel to meet all the requirements.

On the other hand, I do not think that one particular school must control all the teaching on the subject. In such cases, programs adapted to one school might be inappropriate for another. I would rather suggest that universities create institutes whose main concern would be teaching and research in administrative sciences. These institutes could be governed by an inter-faculty council and would take into account the orientation of interested faculties and departments. Consequently, a student in engineering, economics, sociology, business administration etc... interested in enrolling in the institute would find appropriate curriculum to fill his needs and interests.

Following the Industrial Revolution, universities had a tendency to overspecialize their students and now we must reverse the trend and reformulate our programs so that the students will have a better understanding of mathematics and a better knowledge of other basic sciences.

This is a real challenge to engineering schools and universities, and « the training must cut across many separately established discipline — a

tendency to be welcomed as it will react against the current trend toward even greater specialization ».

It is impossible to teach our students all the technical developments taking place today. Therefore, our teaching must be based on general principles and basic sciences, not on techniques whose principal characteristic is their perpetual evolution.

AUTOMATION — ÉVOLUTION OU RÉVOLUTION

La substitution de la machine à l'effort humain n'a rien de nouveau ; déjà en 1661, un tisserand de Danzig avait mis au point un métier capable de fonctionner jour et nuit en faisant pendant moins de temps et à moins de frais plus de travail que l'homme. Le gouvernement local avait défendu l'emploi de cette machine pour protéger les travailleurs, mais l'inventeur, persistant dans son idée fut noyé en public par ses compagnons de travail.

Cette tragique histoire n'a rien d'exceptionnel : elle illustre bien les deux aspects du progrès technologique : 1) la substitution de la machine au travail de l'homme et 2) l'opposition agressive des travailleurs devant cette nouveauté qui constitue une menace à leur gagne-pain. Le premier de ces deux aspects nous amène à établir la nature des changements technologiques et le second, à analyser leurs effets et leurs conséquences.

LA NATURE DES CHANGEMENTS TECHNOLOGIQUES

Le motif invoqué par l'inventeur de Danzig en substituant la machine à l'effort de l'homme est caractéristique du changement technologique. Dans toute manufacture ou usine, une certaine somme est investie dans des machines de tous genres et des travailleurs sont assignés à leur opération. Conséquemment, le produit fini est toujours le résultat de la machine et du capital d'une part et de l'effort humain d'autre part.

Avec une machine donnée et un nombre déterminé d'hommes, le système homme-machine est en état d'équilibre et permet d'établir la contribution simultanée du capital et du travail dans la fabrication d'une unité. Si, comme conséquence de l'installation d'un convoyeur automatique, un certain nombre d'hommes préposés à la manipulation doit être éliminé, cela amène un changement qui modifie l'équilibre initial. Ainsi, la contribution du capital dans la fabrication d'une unité augmente en comparaison de la contribution du travail de l'homme.

Dans un tel cas, le changement technologique amène une modification de l'équilibre entre capital et travail.

Cependant, tout ce qui contribue à modifier cet équilibre capital-travail n'est pas dû forcément à un changement technologique. L'équilibre peut aussi être changé par une modification des coûts relatifs du capital et du travail ou par une meilleure utilisation de la machine existante ou suivant une substitution du capital par le travail. Dans ces trois cas, le facteur d'innovation qui est spécifique du changement technologique n'apparaît pas.

Le changement technologique peut être défini comme une modification de l'équilibre capital-travail due à un changement dans les techniques de production d'une entreprise quand le système homme-machine opère à un point optimum, de telle façon que la contribution du capital augmente en comparaison de celle du travail dans la fabrication d'une unité de production.

CONSÉQUENCES

Si le capital se substitue au travail, c'est qu'il est plus économique de procéder ainsi et cela apportera trois conséquences : 1) Le coût de production des produits diminuera. Une réduction sur le prix s'ensuivra et le produit deviendra à la portée d'un plus grand nombre de gens. 2) Si la machine remplace les employés ils seront congédiés, au moins pour une courte période. 3) Les tâches des employés à l'intérieur de l'usine seront modifiées et devront s'adapter à la machine.

Sans trop s'étendre sur les avantages de la mécanisation et de l'automation, il suffit d'ajouter qu'ils ont contribué à augmenter la productivité, à élever le niveau de vie et à placer sur le marché des produits que l'effort de l'homme seul aurait du mal à produire.

L'AUTOMATION ET LES GRADUÉS D'UNIVERSITÉS

Il faut ajouter à tout ceci quelques considérations sur les répercussions que peut avoir l'automation sur nos écoles de commerce et d'administration d'affaires. Il ne faut pas perdre de vue que les applications de l'électronique révolutionnent nos concepts traditionnels d'administration des affaires.

Certains calculateurs électroniques ont des capacités qui s'apparentent aux facultés humaines. Ils peuvent se souvenir, apprendre d'une expérience passée et donner en très peu de temps une multitude d'instructions sur des sujets divers. Leurs capacités dépassent sur un certain point, celles de l'homme. En un instant, ils peuvent donner la réponse exacte à des calculs que ne pourrait établir l'intelligence humaine durant toute une vie.

De telles machines détruisent les vieux concepts de tenue des livres, d'audition, de vérification, d'établissement d'inventaires et d'une foule d'autres opérations routinières dans les domaines fiscaux ou commerciaux. Ces méthodes de travail ont créé une révolution dans la façon conventionnelle de mener les affaires et ont complètement modifié les exigences imposées aux administrateurs d'entreprises.

Avant l'avènement de l'électronique, les informations nécessaires à la marche des affaires étaient fournies laborieusement par les calculs souvent inexacts d'un commis de machines à rendement lent et à capacité limitée. Nous assistons maintenant à une révolution dans la technologie de l'administration. L'administrateur moderne n'a aujourd'hui qu'à peser sur des boutons pour obtenir immédiatement toutes les données essentielles à la bonne marche de l'entreprise. Le cerveau électronique donne une masse d'informations mais il faut encore savoir choisir entre elles.

Parce que le cerveau électronique a donné la réponse à des problèmes qui seraient restés autrement insolubles, de nouvelles techniques d'analyse ont été créées dans l'administration telles que les programmes linéaires, les phénomènes d'attente, etc. Ces analyses qui nécessitent de longues équations mathématiques sont résolues, maintenant, par le cerveau électronique.

Comme le note John T. Dunlop dans son livre : « The Manager of 1970 », « celui qui ne comprend rien aux techniques automatiques d'information est fortement handicapé et de là, la responsabilité des universités de former des hommes qui soient bien informés de ces techniques pour qu'ils puissent efficacement diriger l'entreprise moderne ».

Les opérations de recherches qui peuvent se définir comme le résultat quantitatif d'un problème à partir de ses variables ne sont plus seulement aujourd'hui le lot du physicien ou de l'ingénieur, mais le sociologue, l'économiste et le comptable y sont souvent confrontés. Conséquemment, les nouvelles techniques industrielles exigent la coopération étroite de techniciens, de professionnels et de scientistes spécialistes dans diverses disciplines, mais pour qui les mathématiques seront la formation de base.