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Development of Metalworking Industries in Developing Countries

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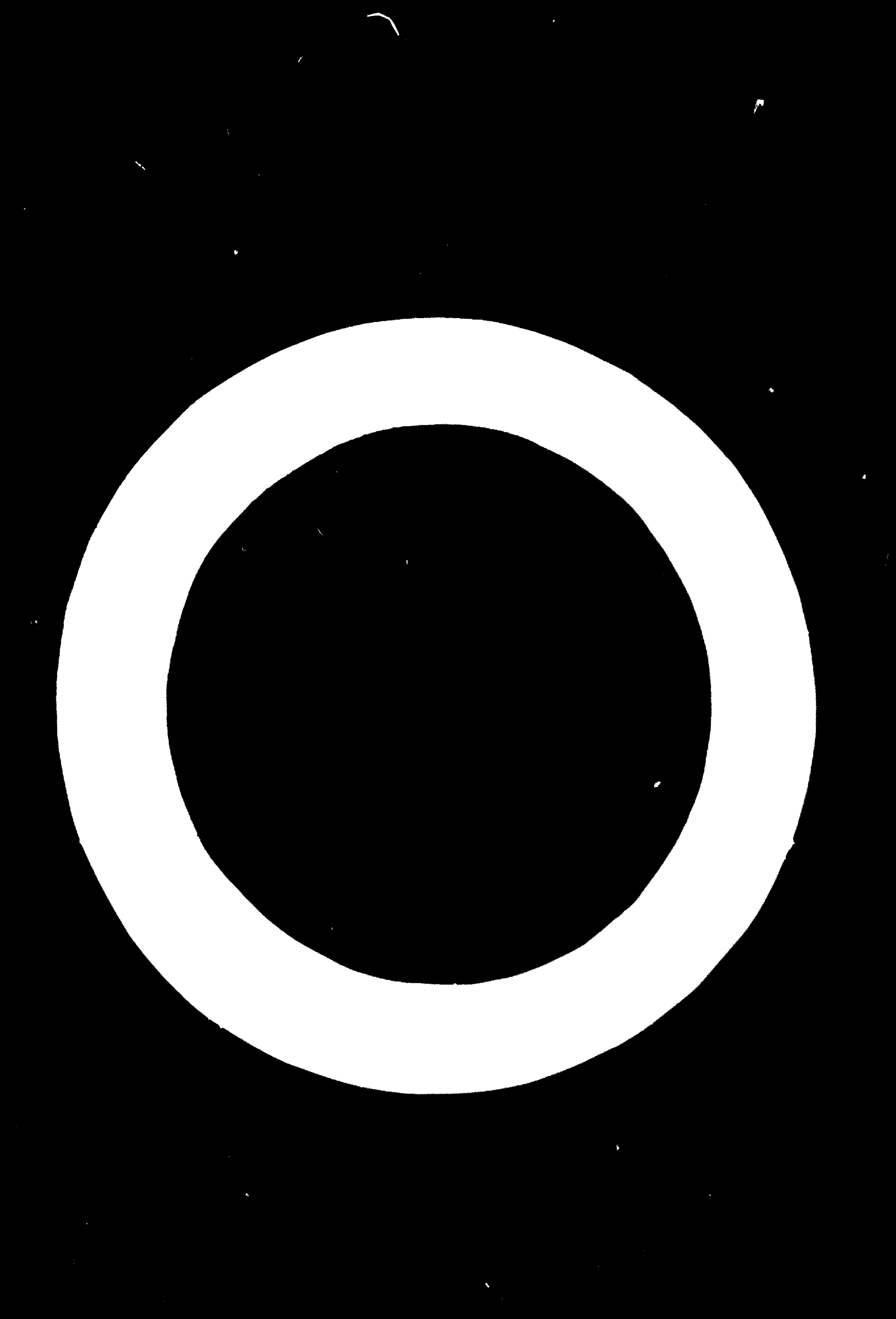

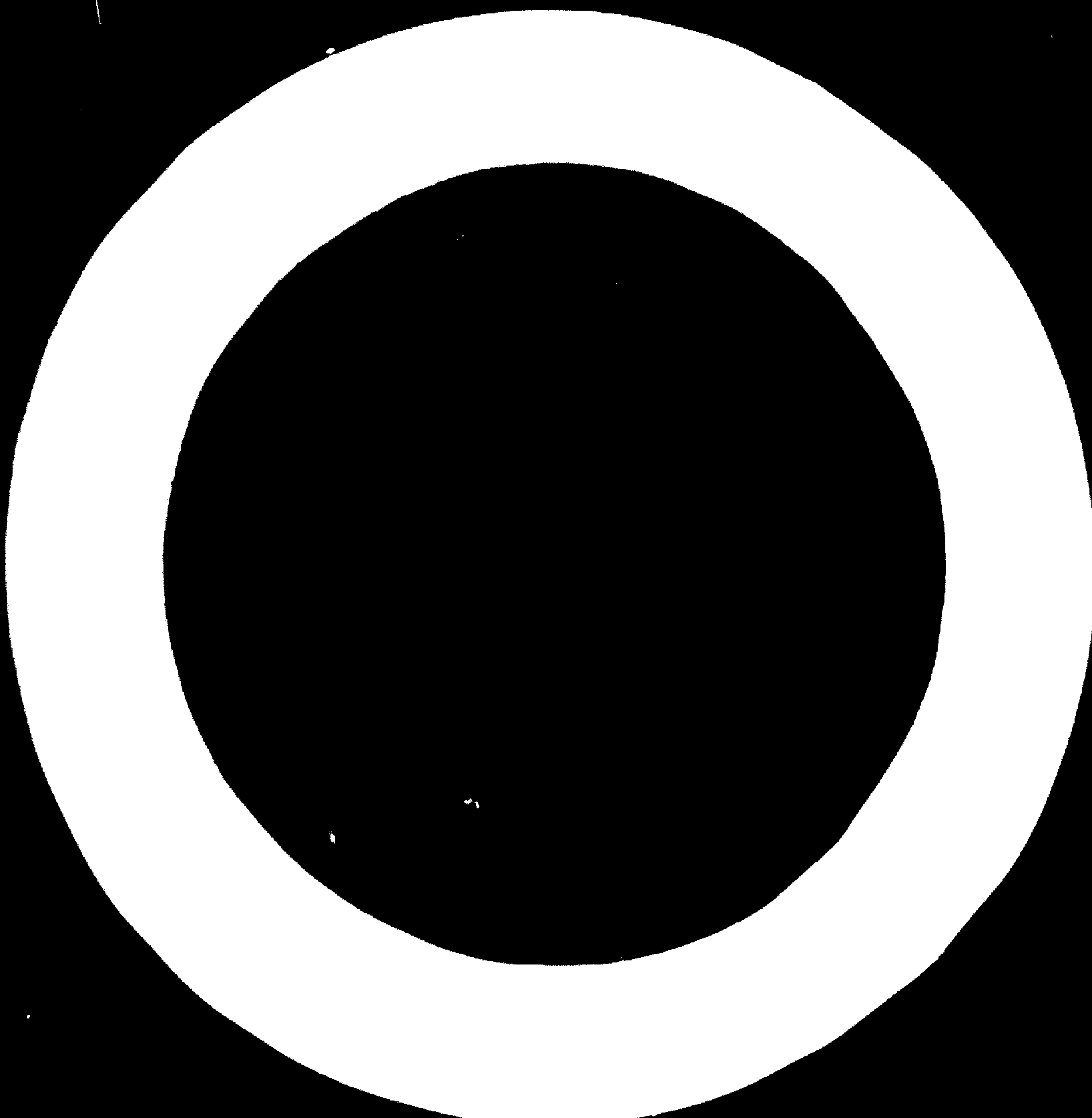

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PRODUCTION AUTOMATION IN DEVELOPING COUNTRIES

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INTRODUCTION

Conflicting reports of social upheaval, on the one hand, and of vast increases in productive capacity, on the other, arise when automation of a process or an industry becomes the point of discussion.

For present purposes, much clarity may be obtained by directing attention to the basic ingredient of all automated processes, rather than to specific details of one application. A machine or process is not automated, in the sense used here, just because it may have some electronic controls, a variety of sensors and actuators, or an impressive array of fixtures although most automated equipment makes use of these devices. The power of automation comes from the design and organization of intelligence, processing skills and control features "within" the equipment, rather than having these necessary ingredients of production added at will by human intervention at the time a product is made.

The more it is possible to rely upon this pre-designed, built-in and self-controlled part of the production operation, and the less decision-making and special action the operator is required to make at the instant of execution, the more automatic, or automated, one may say the process or equipment is. For example, of the wide range of automatic metalworking tools available, such as those displayed at the Machine-Tool Show held in Chicago (United States of America), 26–30 September 1965,[1] those which are more "autonomous" and can work alone would be considered more automated than those which require more immediate direction

This point is central to the thesis of this paper, which is that automated equipment and processes, contrary to popular belief, can provide a net gain to emerging nations in both their economic and their social development. The gain comes when packaged intelligence quickly and inexpensively supplements or provides otherwise scarce or unavailable production and control skills, thereby balancing over-all productive ability and thus increasing in total the number of workers who can be put to work.

Similar arguments have long been made for the selective use of scarce human skills. For example, the division of labour, as proposed by Adam Smith in *The Wealth of Nations*, was to be beneficial because workers who specialized in one job would, by habit and experience, become more proficient and therefore more efficient in that single task because they did none other. In this way, the set-up and learning time required when going from one job to another would be eliminated. This was a forward step in the advance of human productivity, but not the critical point in terms of cost, or in the use of rare skills.

Charles Babbage, who thought in more modern terms, agreed with Smith, but argued more cogently. To him, the real benefit in the division of labour lay not only in the learning-time saved for the average worker, but also in the economical employment of more highly priced talent. When a single worker completed all the operations required for the production of the finished product, he had to be paid at a rate determined by the individual or selective skills needed for the completion of specific job segments. Thus, the worker of highest skill, often required in small quantity of time per unit of production, could be rewarded individually at a differentially higher rate than the worker who performed "ordinary" operations. The net result was to reduce the total cost per unit of the product, since less expensive labour could be assigned to the majority of job segments requiring lesser skills.

For the purposes of this paper, the argument proposed by Babbage can easily be extended to cover over-all productivity. If the highest skill required for the production of a given product is in scarce supply in the face of abundant "ordinary" labour, then this scarce skill becomes the limiting factor or bottle-neck in the total productive potential of the operation. Not only can the higher skill that is scarce be highly rewarded in this instance, but any strategy that will make available more of the scarce skill will also multiply the total productive ability of the economy. Greater employment of more ordinary skills, as required in the usual technological distribution of job segments in a total job, follows naturally as the obstacle to total productive potential is removed. Moreover, the more rapidly such an obstacle can be removed, the more rapidly can such productive potential be realized and the more rapidly can the average citizen (who may be unemployed or employed "unproductively" if the rare skill is absent) improve his lot.

If the rare skill is not present in the developing country and if the time required to produce that skill is long, then the use of an automated device or process which can supply the needed skill in a package (by virtue of the intelligence designed into the machine or stored in programmed instructions within the machine) provides a powerful strategy for accomplishing the ends Babbage had in mind. In those terms, many unbalanced productive

[1] For a report, see *Business Week* (25 Sept. 1965), pp. 47–53; and *Control Engineering* (Nov. 1965), pp. 109–113.

operations and many emerging nations with an unevenly developing economy find themselves in the position of Shakespeare's King Richard, shouting for "A horse! a horse! my kingdom for a horse!" The use of automation to provide a selective, yet a rapid infusion of scarce skills into the productive enterprise or developing economy, may be the "horse" that is needed; and, in this sense, the use of automation provides one obvious area of interest for planners who are beset with the dilemma we have described above.

§ 1. Operation of Automatic Controls

To emphasize the implications of this thesis, one may mention some examples from the metalworking industries. In what way does an "automated" machine tool provide scarce skills? How is "intelligence" stored in these machines? How can they be "taught" skills in a flexible, swift and economic way?

As an example, consider the numerically controlled machine tool, so-called because it receives instructions on a step-by-step basis from a pre-recorded list which may be stored on punched cards, in the holes of a paper tape, in the magnetic spots of an oxide-coated film or in other media.[2] The simplest and smallest of these devices (which is used for simplicity of illustration rather than for other reasons) is the numerically controlled punch press (or drill press) which is used to create holes or other shaped apertures in a metal sheet. This is a "point-to-point" machine, since the operator (or the tape instructions) must provide only the specific hole locations (x and y co-ordinates) to which the tool or the work must be indexed before the tool operation (a z-co-ordinate motion) takes place.

With such machines, construction design normally fixes the vertical tool axis rigidly above a table which is free to move in both the x and y directions relating to the tool axis. Actuators, usually with "feed-back sensors" to assure correct table position, move the table in response to co-ordinate information provided by the input tape. To perform work, the workpiece is bolted firmly to the movable table (which is usually a frame that allows tool penetration through the workpiece), the table is indexed to the x-y position specified by an input instruction, the tool is actuated to produce a hole and the table moves to the next specified x-y position, continuing the pre-recorded or stored input programme of steps until the job is done.

The physical construction of the machine is less important to the present discussion than is the construction of the programme of steps the machine is to follow. For example, suppose four ¼-inch holes are to be punched in a 10-inch × 10-inch metal plate. Assume also that the machine operator has set up a ¼-inch punch in the machine, so that workpiece positioning is the only remaining operation required. If one sets the lower left-hand corner of the workpiece as the reference point $x = 0$, $y = 0$, and if one wished to punch the holes with a centre 1-inch in from each edge at each corner, one could prepare a series of instructions as follows: "x1.00, y1.00, z; x1.00, y9.00, z; x9.00, y9.00, z; x9.00, y1.00, z".

In the sequential list of instructions, the table would assume the stated x and y positions (in inches from the origin), the tool motion would then be actuated by the z-instruction; and the subsequent movements and tool operations would follow in order until the list was completed. By constructing the machine with a turret containing a number of different tools and selecting the desired tool by an appropriate z-instruction, such as $1z$, $2z$ etc., the versatility of the machine could be enhanced, and a variety of products could be made without the need for manual tool change.

Now the important point in the operation of this machine is that the machine's programme of instructions, once written, need never be written again. If the operator wants to produce more punched sheets of the same type, he simply places new sheets on the table and runs the instruction list through the machine's control "reader" (a device that converts the input tape into table and tool motions) again and again. The skill needed to cause table movements to precise locations is not left to the operator, but is built into the machine and the programme of machine instructions.

It is, therefore, possible to produce reliably and accurately identical products and to predict the time required to produce each of them, since the control of the machine is left to the instruction list and the machine, not to the whims of the operator. Even further, in specifying how the product is to be made, its designer may eliminate the usual blue print and the operator does not have to consult one: everything that needs to be known is contained in the instruction list and a few simple material loading instructions. Even though some skill might be needed to set the original reference point $x = 0$, $y = 0$, this can be fixed for a large class of products (say, all rectangular sheets of metal within the table capacity of the machine) by providing precision steps at the origin, which are set once by the manufacturer or by an expert set-up man.

Continuing with the same example, suppose that in addition to the instruction list given above, the operator had available to him a file of instruction lists, reduced to the paper tape form the machine could read. Then, as various kinds of plates were required, the operator could extract from his file the appropriate instruction list and material-loading instructions for each product, load the machine with material and programme, set the machine in motion and so produce the variety of products needed without further intervention. The file or "memory" of jobs for which instructions are available could, of course, be augmented by the product designers as time went on so that a large library of possibilities would be available to the operator. The instruction tapes, which could be prepared anywhere in the world and dispatched to the operator in compact form, provide the intelligence for operating the machine.

In addition, the designer of new products benefits from

[2] The historical antecedent of the numerically controlled machine tool is the Jacquard loom, which is used to weave intricate patterns in cloth under the direction of holes punched in cards. Although this device works mechanically to feel the pattern holes in the cards, rather than through electrical signals as do the modern numerically controlled machine tools, the concept of the "stored programme" is the same.

the stored instruction lists which have already been prepared. New product designs that contain major "pieces" of old designs (as is usually the case) can be "pieced together" by editing and "pasting up" combinations of what has already been done. There is no need to repeat the clerical drudgery already accomplished; thus, both design and production lead times are drastically reduced. (This form of product design may be compared to "adult learning" which usually proceeds by combining large blocks of previously acquired knowledge, rather than the bits-and-pieces combined by the infant.)

The example of the simple numerically controlled point-to-point machine illustrates how intelligence can be built into the automatic machine by a combination of machine design and programmed-instruction design and storage. Although somewhat more complex in application, the same concepts may be extended to metal-removal tools that operate continuously over a surface, for example, milling machines, and to the design of machines that combine point-to-point and continuous abilities.[3]

For example, using the intermediate services of an electronic computer, it is possible to create the specific step-by-step instructions required numerically to direct a "continuous" milling machine according to the requirements of a mathematical formula. Such machines can cut complex mathematical sections having far greater quality and precision (with respect to the mathematical specification) than even the most skilled machinist could hope to accomplish by "hand" direction. Therefore, these machines have wide application in the production of aircraft parts, turbine blades, die sets and other products requiring mathematical precision at every point on a surface.

II. Organization of work of automatic machines

It is now convenient to extend the discussion of automatic machines to the organization of the work and the tools used. The purpose of this detour is to illustrate the range of flexibility available with different forms of automated organization.

In the mass production of a single product that has both high volume requirements and a stable demand, the automation of the process follows the organization of an assembly line.

For example, in high-volume metal-removal processes, it is common to develop highly specialized tools which are "fixed" in a given physical location. The work is then moved from one fixed tool-station to the next. The capacity at each station is adjusted so that a smooth flow of work can be achieved. When the material handling can be mechanized, so that there will be a synchronized movement of work between stations, the total production line can be made automatic, with automated self-control features built in as desired. The "transfer machines" commonly used in the motor-car industry (to produce the many operations required to machine an engine block) are an example of this route to automation.

[3] For illustrations and case studies of the use of this type of equipment, see H. C. Morse and D. M. Cox, *Numerically Controlled Machine Tools* (American Data Processing, Inc., Detroit, Michigan).

At this extreme of automation, the intelligence of the productive process is designed into the fixed specialized tooling and the fixed sequence of work flow. Thus, although this product flow arrangement results in the lowest production cost per unit at high volumes of production, the set-up is rigid. The automated line can produce products with only a small variation in design, if any. Small changes in design require variations in tooling (which is not possible when the tools are extremely specialized and fixed in position). Furthermore, any change in product type usually "unbalances" the line, even if the same specialized tools could be used on different products.

The initial cost of this approach to automation (which corresponds by analogy to the installation of a chemical-process plant, which produces volume, as opposed to the operation of an apothecary shop, which produces variety) is also relatively high — in the millions of dollars for typical installations.

Nevertheless, the "rigid" approach to the automation of an entire process has its place in the production of basic raw materials (steel, glass, synthetic materials), utilities (water, electric-power, sanitary disposal) and widely used consumer goods (radios, electric-meter housing, water-pumps). It is in automation of this kind that one becomes concerned about the gross elimination of jobs.

Thus, the "rigid" approach to automation may be appropriate in an emerging economy if there are a certain few "high-volume" industries or processes which limit the productive possibilities of the rest of the economy.

In such cases, the complete elimination of that bottleneck—even though automation would eliminate job possibilities in that sector of the economy—can have a beneficial over-all effect. Even though one may have to deal with larger "blocks" of automation, a deliberate search for the large, critical blocks which deserve complete automation in the economy is sensible strategy if there is a large imbalance in the productive system of the country. Indeed, the complete, rigid-automation approach may be the only possible alternative for those productive sectors of the economy which are not easily improved by adding more human workers, regardless of their skill (e.g., in electric-power generation).

By contrast, the numerically controlled machine tool, previously discussed, is a flexible machine. The organization of the machine follows the work pattern of the individual craftsman. In most designs, the workpiece is fixed, and general-purpose tools are programmed to come in sequence to the single workpiece and to operate upon it.

For example, a machine tool (the NumeriCenter-H) made in the United States of America by the firm of Giddings & Lewis provides as many as sixty-three different milling, drilling, boring and tapping tools from a turret ring to operate upon the workpiece under instructions from the control tape.

Although this type of equipment is not usually economical for high-volume production of a given item (various studies show that optimum production runs with such equipment are in the range of 50–100 units, depending upon the job), it does allow the greatest flexibility for producing a variety of items at essentially no set-up cost other than the one-time cost of preparing the instruction tape for each product type. Clearly this form of tool organization is ideal for job shops where change-over time usually reduces effective machine capacity, where the length of the production run will not justify special tooling and where extreme precision and quality may be required.

The numerically controlled machine tool, in addition to its flexibility of application, is an order of magnitude less expensive to acquire than the transfer machine or "packaged process". Prices currently quoted in the United States of America range from $10,000 to $300,000. For example, the price of the Kearney & Trecker Milwaukee-Matic Model Eb, a numerically controlled machining centre with some contouring ability, averages about $117,000; the Pratt & Whitney Tape-O-Matic point-to-point Model C tape-controlled drill is about $25,000, with some types costing less than $10,000. Semi-automatic equipment of the same type is, of course, correspondingly less costly.

Moreover, jobs are not necessarily eliminated by this type of equipment. One numerically controlled machine tool may be used to provide the skills which will amplify the ability of many manual portions of a production process. The effect is usually to shift the required job skills, however, from the manual operation of the machine itself to the preparation of the instruction tapes for new jobs, if these are done locally.

Finally, as an intermediate between the two extremes mentioned above, one may have semi-automatic devices to serve as semi-specialized work-stations that yet may be arranged flexibly in the production work-flow to eliminate bottle-neck operations.

Typical of this class are the inspection and test stands which are often inserted in a production sequence to assure quality, to maintain dimensional tolerances and to provide other production tests which may require higher than average consistency, precision or skill.

Use of such equipment with some programmed features often permits a complex test to be reduced to a simple "yes-no" result, or permits a series of such tests to be performed without human intervention.

Moreover, general-purpose equipment of this type can be made more efficient by the use of specialized, yet inexpensive, jigs and fixtures that allow the worker to adapt manually the general machine to the specific requirements of a given product. For example, precise optimal comparison of the dimensions of a part may be made against a template that provides the dimensions for that part. The intelligence for use of this type of comparator, a general-purpose device, resides in the template prepared and in the file of templates which would be provided for checking a variety of parts.

The semi-specialized work-station machine is another order of magnitude which is less costly to acquire than the general-purpose numerically controlled equipment. In this class, one may include semi-automatic lathes, specialized work-stations for critical steps in a work flow and many mechanized material-handling machines. Comparable purchase cost for such equipment is in the range of $2,000 to $50,000.

This class of equipment is also in many ways the most effective in increasing the efficiency of a manual series of steps, if the level of the economy or other consideration dictates that only a small block in the process can be automated. Usually, the majority of job skills are not affected by the introduction of such devices; only the operator of the specialized station must be trained to use it, and the relatively inexpensive automation of the selected step in the process may enhance the over-all productive capacity of the manual system, so that in the end the number of manual positions available may be increased.

With this background, one may conclude that the latter two classes of equipment are of more interest if one is seeking to balance or partially to automate a given production process, rather than completely to automate a critical industry.

Moreover, it may be possible to find a critical step within a critical industry that, when automated, will doubly multiply the over-all result for the economy. Given the industry, the methods for selecting those process operations which should be automated are work-flow analysis, studies to pin-point critical scarce skills and isolation procedures to indicate the process steps which require great precision or which currently generate undue waste of scarce materials.

When one can find critical steps in a productive process which—when automated—will greatly amplify the results of the automation effort, the introduction of automatic devices may proceed on a step-by-step basis, with major attention being directed to a few critical steps in a process. When one cannot find such critical steps, it may be necessary to abandon the idea of automation or to turn to the more heroic measures of complete automation of the entire process.[4]

In summary, there is a wide range of automation possibilities in terms of equipment types, methods of organizing automation efforts and configurations of automated steps. Thus, it should be clear that the first problem encountered when introducing automation is in decision-making. The key to the effective automation of an industry or a process is to select from the wide range of possibilities the degree of automation and the point of automation in a given economy or process that will provide the greatest returns for the effort expended. This selection process and the difficulties associated with it represent an essential planning step, particularly in the emerging economy, since random automation is seldom beneficial and may, by its consumption of scarce resources

[4] Historically, the mechanization of industrial operations has usually gone forward on a piecemeal basis, with an improvement in organization here and a new piece of equipment there. Without some care, however, this approach can lead to unbalanced development for the production system as a whole, and recent trends are to apply systems analysis to the problem of mechanization and automation, so that over-all improvements may be realized in a controlled manner. See M. K. Starr, *Production Management: Systems and Synthesis* (Englewood Cliffs, N.J., Prentice-Hall, 1964) and V. C. Hare, Jr., *Systems Analysis—A Diagnostic Approach* (New York, Harcourt, Brace and World, Inc., 1967).

in an unproductive manner, be ruinous when capital is limited.

For example, to decide upon the priority of investment in a given equipment type, or for given points in a process or economy, one must be able to rank or scale the available alternatives by a "measure of effectiveness" or a merit rating showing the contribution of each alternative to over-all investment or to social goals. With such a measure of effectiveness, one would then usually prefer first that alternative which, for a unit of capital invested, produces over a given time period the greatest marginal increase in the chosen measure of effectiveness, assuming that the absolute increases possible are not unduly restricted. A somewhat simpler criterion would be to eliminate from consideration all those alternatives which produce less than a threshold or cut-off value in the measure of effectiveness, which might be, in the simplest case, a minimum return on investment of X per cent, or a minimum increase in productivity of Y per cent.[5]

In either case, it is necessary to know the benefits and drawbacks of automation which will, to a greater or smaller degree, affect the measure of effectiveness, and one must know some of the major constraints of the economy or process that will either require minimum performance or limit maximum potential.

III. Economic considerations

A. *Advantages of automation*

In addition to the rapid acquisition of advanced technology and productive output in selected areas of need, the advantages described above may be amplified.

Thus, the quality and precision of a given operation, the reliability of production schedules, the length of design and production lead times may all be improved by automation. In many cases, the cost of jigs and fixtures, and the skill required to make them, may be eliminated or reduced. Moreover, the "programme of instructions" prepared for an automated machine does not wear out like the usual jig or fixture, so an accumulation of technical, cost and control data becomes available for management use as a by-product of continued use of programme-controlled equipment. Each new job adds a permanent increment of growth to the versatility of the operation.

Other advantages include reduced factory-space requirements, improved safety and the elimination of finished inventory losses due to engineering changes (since the product may be made very nearly to order). With stored programme equipment, the need for blue prints, costly templates, process sheets and detailed drawings is eliminated, and the machine programme that replaces these production instructions may be prepared anywhere and acquired in large blocks or files which provide immediate machining capability. When the automation of a critical process step results in a high degree of utilization of the automated step (as it must to justify automation), the productive output of the equipment rapidly amortizes the investment made in it.

The total cost of machines for a shop may also be reduced by the selective use of automation, since one automated machine may replace many others. Since the output of the automatic machine is predictable within narrow limits, management ability to control the automated application is enhanced, cost estimates are more accurate, machine loading and scheduling problems are alleviated and cost-accounting practices can be sharpened.

Automated equipment using stored programmes of instructions permits the production of a wide variety of products in short runs at almost "mass production" costs. This fact is important to the industrialized economy (in the United States of America, an estimated 75 per cent of all items machined are in runs of seventy-five units or less) and even more important to the developing economy, where short runs are likely to be even more prevalent. The development of marketing strategy, vendor and subcontractor relationships, research and development practices and factory management methods are all affected by this new ability to handle variety economically.

Although it is not possible to give a general prescription for the mixture of advantages that will be more relevant in a specific application, a review of the benefits suggested will usually reveal those which are of most value. As a general statement, the ability to share world technology and management science rapidly and at low cost (by virtue of the acquisition of stored programmes of machine instructions) would come near the top of such a list. Although operator training is required for the automated equipment, the time required for that training is measured in months, not years, and far fewer workers need to be trained. Moreover, as will be seen later, the training differs substantially in kind from the historical tradition, which, with the current "state of the art", is obsolete.

B. *Disadvantages of automation*

Several constraints limit the advantages of automatic equipment, and these should form another phase of analysis in any application. Automatic equipment, when used in a process step, produces a high volume of output and depends for its profitability upon the efficient use of the equipment, either by itself or by removing an obstacle and increasing the potential of a larger productive system. Certain prerequisites to this result are apparent. The equipment must receive adequate, reliable and consistent input volume, either of raw materials or semi-finished products from a previous production stage. The equipment must have maintenance to keep it in operation. Furthermore, the equipment requires "service" supplies, such as electric power, lubrication and coolants, which are reliable and stable to specification. The automatic machine or process must also find consumers who can

[5] These points are well made from the economists' viewpoint by R. Dorfman, P. A. Samuelson and R. M. Solow in *Linear Programming and Economic Analysis* (New York, McGraw-Hill Book Co., 1958). The same arguments are stated in military terms by C. J. Hitch and R. McKean in *The Economics of Defense in a Nuclear Age* (Cambridge, Mass., Harvard University Press, 1960), at the decision-making problems of the developing country operating under a limited total national budget are essentially similar.

absorb its large output, so that the flow of production may be maintained at a high total value (even though the total may consist of a variety of short runs).

These constraints suggest several organizational requirements in using automatic equipment. The source of raw material must be reliable. If great distances and variable transportation times intervene between the process and the raw-material source, some raw-material inventories will be required to support the automated operation. The maintenance and service supply requirements (as well as transportation requirements) also suggest a geographical clustering of automatic equipment in a given locality so that scarce maintenance facilities, personnel and parts may be shared and the clustered volume of service needs can justify or exploit adequate power and similar resources. Even in industrialized economies, such industrial clustering is found for similar reasons. As a simple example, if scarce maintenance personnel must travel between distant service locations, not only will their effective capacity be reduced, but the equipment to be serviced will be idle longer and peak crises will be more difficult to avoid.

Although the basic constraints outlined are stringent, they are not insuperable. They do argue again, however, for the selective use of automation first in critical process steps and industries, and then in locations where the stated constraints may be satisfied.

After selection of the step and location which are the potential subject for automation, two additional problems arise: they are financial and social. The latter is the more serious.

The block of capital required as an initial investment in automatic equipment may represent a substantial commitment for an emerging industry (or economy) as a percentage of the total reserves currently available. This fact, coupled with political unrest, raises immediate questions about the stable growth of the emerging economy (or industry) which will undertake the commitment for purchase or lease of the equipment. Possible local and international instabilities raise risk questions for both the seller and the purchaser of automated equipment.

As one solution for the seller, to date, most machine tool producers in the United States of America make sales chiefly to divisions of large international corporations which, in their total operations, provide the financial stability required and protect the seller from local upheavals. Other sources of automatic equipment, which today are numerous, have effected similar guarantees in the form of raw-material commitments, trade concessions and the like.

Apart from the acquisition problem, which is again discussed below, the problem of capital commitment must also become an important question for the purchaser, who, in the face of instabilities in raw-material supply, market or political regulation, may decide on the grounds of risk (rather than average increases in production potential) not to exploit the possibilities that automation can provide. Stable economic growth is, then, another prerequisite for automation—as it is for any major capital investment in a single facility.

Several social problems also plague the proposed use of automatic equipment.

In many countries where capital equipment is scarce, a pride of personal ownership develops, which runs counter to the efficient use of capital equipment. The artisan owns his own tools and lets no one else use them. Frequently, this attitude carries over to capital equipment. The owner of the only motor-car in town may refuse to let others drive it for fear of damage; and, unfortunately, operators of locomotives, aircraft or automated machine tools may, by tradition, also adopt the same attitude, limiting the use of scarce equipment to those hours when personal attention of the single operator or crew can be provided. Since continuous utilization is required of most large-scale capital equipment, this social pride of possession must be overcome to employ the equipment successfully in the developing economy.

Next, the development of the semi-specialized skills required to operate and manage the automatic equipment often produces a thin layer of *élite* workers and managers, leaving a vast gulf of education, experience and income between the *élite*, whose efforts and decisions are multiplied in effect by the machines, and the vast majority of workers in the population who cannot comprehend the objectives, actions and attitude of the *élite* segment. In short, the introduction of automated equipment into a developing economy can aggravate the relative disparity between one social group and another, which may already be the cause of much economic and political instability in the society. Indeed, this result may occur even though the absolute lot of the average worker is improved, because the relative spread in social and economic positions of the average and the *élite* workers has increased. Symptoms of increasing relative deprivation appear in the early history of most economies undergoing industrialization, as conspicuous power, affluence and control are embraced by the few. The more rapid industrialization offered by automation can heighten the rate at which the relative distance between groups increases and make the gap more apparent. Measures to offset the social instabilities caused by this gap must usually be taken by administrative officials. As a tragic extreme, the failure of Louis XVI and his officers to notice and care for the motivating effects of relative deprivation ended in the French Revolution and his death.

The manner in which the training necessary for uplifting an economy shall be administered is a final point to consider in view of what has just been said. One problem occurs with the *élite* group mentioned above and another with the average worker.

Most frequently, the *élite* group's training or education must be conducted abroad, because of the limited resources of the developing country concerned. These few workers, upon whom the success or failure of the automation effort rests, always acquire some of the social tradition and attitudes of their hosts, in addition to their technical skills. Moreover, later dependence upon the producers of the automatic equipment selected (usually the host country) for technical advice, repair services and further instruction may lead to a political and social loyalty which is foreign to the desires of the developing economy. This is an ever-present problem in training, not unlike the concerns of a father who sends his son away to school. Again, however, automated equipment and its possibly critical nature in the economy heightens a normal worry into one that can become a major concern in the introduction of automation into an emerging economy. With extreme automation, control of the *élite* technicians means physical control of the productive facilities, and the administration and placement of this control may decide the political fate of the economy. There may also be difficulties in maintaining the physical presence of the trained *élite*, as well as their loyalty. Since there is a world market in technical talent, there will be substantial pressures for the *élite* to seek the highest wage for their new skills—and the source of the highest wage usually will not lie in the developing country.

For the average worker, the administration of training presents problems no less severe. In planning for the development of a society, there is always the conflict between the desire to upgrade the general level of the population, on the one hand, and the desire to develop selected areas of the economy quickly, on the other. With limited resources, this conflict is heightened.

In particular, for the average production worker, the following question arises: should an attempt be made to gain over-all increases in productivity by increasing the skills of a large number of production workers by a small amount or by increasing the skill of a few workers by a large amount?

Although, for many social reasons, the former choice may be preferred, the advances in world technology argue against it. Thus, if the productive economy is to compete in the world market, it is competing with the most advanced technology available to all. As a consequence, to follow historically time-consuming and technologically obsolete steps in industrial development and training is to subject the economy to a constantly worsening disadvantage in the market-place. In short, a substantial "jump" in the level of technology is required, and even in the most industrialized societies, such a jump is difficult or impossible to produce except in selected areas of the economy. Although the problem of education for the general society remains, education for the technologically skilled few, with its attendant problems, is often of first priority and corresponds to the necessities of automation as well as world marketing.

C. *Need for selective automation*

Although some of the major obstacles to automation in the developing country have not been mentioned, they do not set aside the present theme: that selective automation can not only be beneficial, but indeed may be necessary. If a developing economy is to make the gains in technology which are required for it to compete in a technologically developed world market, automation of selected steps in a process or selected industries in the economy may be the only route to survival. And by careful handling of selected cases, many of the constraints and possible disadvantages can be handled.

Moreover, the developing country has greater ability to use automatic tools at a faster rate than has the developed economy which is already equipped with many non-automatic tools and a large current investment. The developed economy must dispose of this older, possibly obsolete equipment before introducing new automatic tools. This necessity has often slowed down industrial automation in developed countries. Sectors of the economy can be tied not only to old machines, but to traditional methods of production. This is not the case in developing economies, where the first introduction of mechanized equipment can represent the latest technological advances without loss of previous investments. This difference in automation in old and new industries, and in old and new industrial locations, is strikingly illustrated by a tour of any highly industrialized nation. The newest equipment, latest technology and greatest automation are to be found in the newest industries located in the most recently developed industrial areas. In the new setting, the acquisition of new tools provides a fresh start.

In conclusion, consideration may be given to the problem of acquisition of a given automated machine, for which a process step or industry has been selected. First, it should be mentioned that most manufacturers of automatic equipment have not yet taken advantage of modern construction principles, such as rigid standardization of design, modular construction, interchangeable parts between machine types and standardization of material-loading and programmed-instruction formats; nor have they mass produced a narrow product line which would provide a reliable, easy-to-service, inexpensive automatic tool.

In the past, most machine tool builders have created specially designed, custom-made, custom-serviced machines. The result has often been ingenious—but expensive. Only the scarcity of the custom-made machine created real benefit for the owner, who could increase his output and reduce his cost, yet control his price because of his technological monopoly. And machines are often specialized and designed to that end.

In other industries, such as electronics, design practice has been different. Attention has centred on modular design, standardization of practices and the use of various combinations of standard components (which are relatively few) to obtain the variety of final devices desired (at a drastically reduced price and increased reliability).

Although many automatic tools may be justified at current prices (based on the substitution of rare skills in a bottle-neck operation, as outlined above), the important point here is that when the steps of modular design, standardization and mass production are finally exploited in the automatic machine tool field, the range of applications available to the developing country will be vastly increased. In the trade between skilled-labour hours at the bottle-neck and machine hours, the machine will become increasingly more attractive.

The fact that the same type of automatic tools will become also progressively more attractive to the technologically developed countries (and at a possibly faster rate) provides both a warning and a substantial opportunity for the developing economy, for if no automated installations are contemplated and made early, the technologically developed economies will further spread the difference in productivity. If the developing economy does exploit the selective areas which can use automated tools and does so rapidly (insisting on standardized, modular, mass-produced, reliable equipment) the desired technological and economic jump may be achieved. It certainly will not be achieved by the use of traditional methods. Thus far, the acquisition of automatic equipment by developing economies has usually progressed in one of two ways:

(*a*) A co-operative effort or joint venture with a major international corporation;

(*b*) A government purchase, loan or guarantee. At the current time, manufacturers usually require an escrow payment to be delivered upon shipment of the equipment or the credit standing of an international corporation (or a Government) to back payment.

The sources mentioned above are also the most common since the use of automation may require a broader view of a production process or an economy than may be available to a small manufacturer without technical assistance.

In the joint-venture approach, the developing economy may induce an international corporation to construct and operate an automated plant in the country by providing trade, tax, material or other concessions. Various degrees of domestic and foreign ownership are also possible and vary widely from one economy to another. However, the point is that instead of purchasing the equipment or technology directly, it is purchased by concession, partnership or other form of payment in lieu of immediate cash. Various limited versions of this approach are also in use, such as royalty agreements in exchange for technical advice and some tooling, the exchange of products for tools and the like.

In the second approach, a Government, convinced that a proposed automation project is of long-range social benefit or immediate monetary benefit, provides the purchaser with a loan, or the seller with a guarantee. This Government may be either the buyer's or the seller's. Usually, the transaction then takes place through normal banking channels.

For example, in India, Air Refrigeration Co., a locally owned firm manufacturing compressors and other refrigeration equipment and situated about 200 miles from Bombay, installed in late 1965 a Pratt & Whitney Tape-O-Matic Model C tape-fed numerically controlled machine tool at its plant.[6] This equipment, which sells for about $25,000, is to be used to drill and process compressor-head top-plates and for similar applications. Financing was handled through the Export-Import Bank (Washington, D.C.), which provided the manufacturer with escrow funds payable upon shipment. Air Refrigeration also is reported to have licence agreements with a foreign refrigeration manufacturer to provide technical information. In this example, the drilling steps require repetitive precision and the value of the casting is relatively high, so that operator mistakes and inaccuracies are highly undesirable. This critical spot in the production process thus provides a typical subject for packaged technology or automated equipment.

By relying on the built-in skills transferred to the operation by the programmed tape, the operation benefits today from the application of automation by multiplying the effects such added skills can produce in one production operation of a developing economy.

[6] In the United States of America, Pratt & Whitney has moved farthest in the standardization and use of modules, and in mass production of a limited line of module types. The result has been drastic cost reduction in numerically controlled machines, with one point-to-point machine priced in the vicinity of $8,500, which is 30-40 per cent less than the price of their closest competitor in that country.

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