AUTOMATION AND URBAN PLANNING

The literature on automation shows that the field is rife with disagreement. Claim and counterclaim, fact and anti-fact, are all put forth with equal authority and certainty. In recent years, however, doubt appears more often. It is no longer so certain as it was five years ago that the arrival of automation will be gentle, displacing only the dullest jobs, creating new opportunities for all, and heralding an era of unprecedented productivity. One encounters the idea more often that the effects of automation on society are not necessarily self-correcting, and that if the most is to be made of this extraordinary phenomenon, and the best to be gotten from it, its course will have to be guided.

Authorities disagree on whether automation is a part of the stream of mechanization or a new industrial revolution in itself. But in either event, it is now clear that automation has unique characteristics that distinguish it from past developments, and that it has set in motion forces that are seen only dimly at the present time.

Disagreements prevail not only as to the character of automation--what is it?--but also on how fast it is developing, what its effects, short-range and long, will be on employment, and what the effects on the economy and society will be. This much is certain: automatically controlled systems go far beyond the mere machines that displace human muscles. They also displace human sensory systems and human brains. In an increasing number of business and manufacturing operations, automatic equipment is being installed because it accomplishes certain tasks far more rapidly and accurately and often more economically than human operators can ever hope to do.

Essentially, automation is a national problem because it affects the total economy. How it may exercise this effect is indicated by the hearings on Automation and Technological Change, held in 1955 by the Subcommittee on Economic Stabilization of the Joint Committee on the Economic Report. Charged with making continuing studies of matters relating to employment, stability,
and growth in the economy, the Joint Committee has attempted to find out about the influence of automation in such matters as: "(1) the extent of possible and probable displacement of personnel, (2) the possible shifts and distortions which may arise in the distribution of mass purchasing power, (3) the equitable distribution of the expected gains in productivity, (4) the effect upon our business structure, (5) the effect upon the volume and regularity of private investment." (Automation and Technological Change, 1955) Subsequent hearings have also been devoted to this end.

But just as national prosperity is a condition for local prosperity, so the national problem of automation has local manifestations. In the last analysis, the payroll displaced by machines, the old plant abandoned in one community and the new automatic plant built in another are local occurrences. Little attention has so far been given to how these changes and others caused by the automation of industry affect the local economy, and how that in turn affects the course of urban planning.

Although automation is a new phenomenon, enough facts are now available to indicate the ways in which it may affect the local community. This information report will show why the automation movement is so important and will attempt to point out some of the developments of interest to local planning agencies and staffs.

AUTOMATION

As with many new phenomena, controversy waxes over the nature of automation and the word describing it. We cannot enter the controversy, nor can we stem the tide of usage. The noun appears irrevocably to be "automation"; the verb, "to automatize," or, popularly but incorrectly, "to automate."

To what extent the short-cut word "automation" has caused confusion over meaning is hard to say. Many writers on the subject preface their remarks with the observation that automation is just one more link in the chain of mechanization that started centuries ago. The use of machinery in a production process has many automatic aspects. It is easy, therefore, to think of automation as being something that is more automatic--an extension of mechanized production processes. And while this idea is not incorrect, it is fuzzy, and the significance of automation is thereby blurred or not fully realized.

The root of all these words is the Greek word automatos, which means self-moving or self-thinking. In the neuter gender it is automaton, a word that calls up a different picture from that evoked by "automatic." An automaton, in present usage, is a machine that seems in some ways to behave like a human. Like a human being, it is self-regulating. Furthermore, "automaton" is associated with "robot"--a word of Czech origin that implies compulsory service or subjection to a controlling agent.

These two concepts--self-regulation and compulsory service--are embodied in the idea of automation. And if the word had evolved properly, it would be "auto-

1 For complete information on the references given in the text, see the bibliography at the end of this report.
matization." Norbert Wiener has pointed out that the contraction to "auto-
mation" is unfortunate, because the idea of the automaton is lost. This is
the key that makes automation something new and different. But the more man-
ageable word "automation" (an "arbitrary coinage, c. 1949," according to Web-
ster) is here to stay. In using it, we should keep in mind that we are deal-
ing with machines that not only carry out commands but also appear to think
and to communicate.

Feedback, or the 'Closed-Loop'

The thing that makes automation something new, a break with the technological
past, is that it utilizes a principle of nature known as "feedback." All
vertebrates (and most of the lower animal forms) use feedback. Man has de-
veloped the technique to a high degree through the advanced development of the
brain. So absolutely fundamental to automation is the concept of feedback
that an understanding of it is required if one is to appreciate the impact of
automation on society.

Definitions or explanations of "feedback" are nearly as numerous as the books
and articles on the subject of automation. Most easily understood are anal-
ogies to the human body. Comparison is made with the process that takes place
when a person reaches out his hand to touch something. This action involves
the workings of an intricate "machine" system composed of eyes, brain, arm
and hand muscles, and a network of nerves. Although the person is completely
unaware of the process, the system constantly checks back with the optical
center of the brain to learn whether the hand is approaching the chosen ob-
ject. Thousands of imperceptible errors occur along the way, but they are
canceled out, so that the apparent direction of the arm's travel is a straight
line.

Thus feedback control has two essential, linked ideas. One is the idea of
error; the other is the idea of capturing part of a system's output and using
it as part of its controlling input.

Error, a constant threat to the workings of any system, is in the nature of
things, as explained by the second law of thermodynamics. Under the feedback
concept, it is viewed as a part of the learning and control process. In the
words of one writer, error is not "an extraneous and misdirected or misdirect-
ing accident, but . . . an essential part of the process."

In a control system, a command (input) is given at one end, and a condition
changed (output) at the other. The difference between the condition existing
at the controlled point and the condition desired as indicated by the command
point, is known as error. This error can be expressed as "input minus output." Once measured, information regarding the difference is fed back into the con-
trol system, to initiate action that will tend to reduce the error to zero.
A feedback mechanism ceases to work when the error is corrected, and it starts
functioning again when a new error appears.

Analogies to human behavior are legion, and they range from the simplest of
muscular actions by an individual to complex behavior by groups of individuals.
And although the feedback principle is fundamental in nature and has been known
for some time, its application to machines and industrial processes has had to

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await the development of instruments sensitive enough to measure error and able to amplify the measurements so that they can be put to work in the controlling mechanism.

There are two general classes of automatic control. A comparison between them will further emphasize the tremendous innovation represented by one of them—the feedback mechanism. The ordinary class of automatic controls, which we are familiar with in many forms, is known as an "open-loop" system. The other is the "closed-loop" system, often used synonymously with "feedback."

Open-Loop. An illustration of open-loop automatic control (from Brown and Campbell, 1948) is a conventional time-operated traffic light. The controls that turn the lights on and off are established, and nothing will change the sequence or timing of the lights except a change in the controls or a defect in the time mechanism that activates the lights. What the lights themselves do, or what the traffic does, cannot affect the time mechanism.2

Another example is the automatic home laundry. In this example, too, the sequence and timing of the operations are set. A human operator can interrupt the operations, or change the sequence by turning a dial (just as a policeman can change the traffic lights by changing the time mechanism), but the degree of dirt in the clothes does not affect the time they remain in the washer.

In an open-loop control system, the control acts in accordance with the dictates of an arbitrary quantity. There is nothing in the mechanism that corrects the operation if the result is not what is desired. To be kept in good working order, open-loop control devices must be calibrated and maintained in calibration against wear and changes in environment such as friction, humidity, and vibration. They require constant attention by human operators.

Closed-Loop. The closed-loop control system utilizes the principle of feedback. It too acts in accordance with the dictates of an arbitrary quantity. But it also acts in accordance with what has happened as a result of the control operation. It constantly measures the difference between the desired performance and the actual performance, and corrects the difference or error so that output tends to be kept in agreement with the command, or input.

To indicate the versatility of closed-loop control systems, we shall mention briefly some of the kinds of things that can be controlled. Essentially, a closed-loop device controls physical quantity. The "controlled quantity" is also called the output. Although there are different ways of classifying controls, authorities seem to agree that there are two important classes:

1. **Position control** (sometimes called kinetic control). The controlled quantity is position, velocity, or acceleration. Position control mechanisms

2Radar-controlled traffic lights are another matter. Here the volume of traffic affects the timing of the lights, because information about the traffic is fed back into the traffic control system. This, in contrast to time-operated traffic lights, is in part a closed-loop system.
include servomechanisms. Examples of members whose position is controlled in accordance with a command are a ship, an airplane, an automobile, a gun turret, a roller in a printing operation, a drum or cutting tool in an industrial operation, and a conveyor in a plant.

2. Process control. The controlled quantity may be temperature, pressure, liquid levels, volume, electromotive force, or chemical composition, among other things. Examples: a valve regulating the flow of heat or the fuel consumption necessary to establish the temperature desired by the command (input); or, a valve regulating the flow of fluid necessary to establish the volume or flow desired by the command. According to one authority (Pearson, 1957), the basic implications of process control are much wider than those of position or kinetic control. Process control also calls for a wider variety of error-detecting devices because of the large variety of physical quantities that are liable to require control in modern industrial processes.

One of the remarkable things about the feedback principle is that it applies to groups of machines as well as to individual machines, as the next section will show. It is this characteristic that leads automation experts, such as John Diebold, to say that "automation is a way of thinking as much as it is a way of doing." Mr. Diebold has emphasized this point in several ways: "the concept of automation is a new way of analyzing and organizing work"; "the concept of the system is most crucial in describing automation" (our emphasis); "the fundamental importance of automation is not so much the connecting of machines as it is the ability to create automatic information and control systems." Other close observers, too, such as Walter Reuther, reflect this view in stating that "not only the technique, but the philosophy of automation is revolutionary, in the truest sense of the word."

AUTOMATION IN INDUSTRY

Although electronic computers and automatic control devices are being used in many types of businesses and industries, this report will deal almost entirely with the manufacturing industries. There are several reasons for this emphasis. One is the limitation of time and space. But more than that, manufacturing industries are the pivot of the economy. Planning agencies recognize this in their studies of the local economy and their use of manufacturing data for many key studies. Nevertheless, it is not the whole picture, and a complete study would show how automation is affecting warehousing, transportation, and the various office functions that now figure more importantly in the local economy than they did in previous years.

Main Types of Automation

When the automation of industry is being discussed, manufacturing processes are often divided into two groups according to the nature of the material

The term "servomechanism" has apparently been used rather loosely in the past. Now, however, the Feedback Control Committee of the American Institute of Electrical Engineers defines a servomechanism as "a feedback control system in which the controlled variable is mechanical position." (Our underscoring.)
being handled. These are batch process and continuous process. It is important to observe this distinction because different types of automation and different evolutionary stages have developed in the two groups.

**Batch Process Industries.** In the batch process industries, the material handled is rigid and solid, and is manufactured in discrete units. The size of the finished product may range from that of a transistor to a printed circuit to an engine block. These vast size differences naturally create vastly different production problems and bring forth different automation techniques. But the essential similarity is that since the material handled is rigid and solid, it is manufactured step-by-step.

In a movement as new as automation, classifications are sometimes conflicting. It is generally agreed, however, that plant automation—the application of automation to the batch process industries—consists of two major types, which are known as "Detroit automation" and "numerical control."

At the 1955 hearings, a Ford spokesman defined automation as "the automatic handling of parts between progressive production processes." In the automobile industry, automation is based on the mass-production techniques of parts standardization and mechanical parts assembly. In "Detroit automation," standard parts are produced automatically, and are assembled automatically. It is easy to see, therefore, why automobile manufacturers favor the view that automation is "just a normal step in our continuous technological progress."

Basically, "Detroit automation" consists of transfer machines, which automatically carry parts from one machine to another, and positioning mechanisms, "which index the part, position it, turn it, or rotate it, depending on the requirements of the succeeding operations." (Davis, in Automation and Technological Change) At one Ford Motor Company plant, in operation since 1951, six-cylinder engine blocks are produced from rough castings in 14.6 minutes, compared with 9 hours in a conventional plant. Forty-two automatic machines, linked together by transfer devices that automatically move the blocks through the complete process, perform 530 precision cutting operations and borings. From start to finish along the 1,545-foot line, no operator touches a part. (Diebold, in New Views on Automation)

But ingenious and satisfactory as "Detroit automation" is for certain industries, its inflexibility prevents its being used in others. Initial costs are high, and long-term, single-item runs are mandatory if the system is to be economical. Consequently, this type of automation is not considered suitable for the estimated 80 per cent of American small industry that produces in lots of 25 or fewer individual pieces, nor for industries that frequently redesign their products.4

The second type of automation applicable to some batch process industries is "numerical control"—defined by Diebold as "the use of tape and other automatic control devices to direct the operations of machines and machine systems."

(Diebold, in New Views on Automation) This technique has been developed without the use of computers, but recent innovations in computer design give prom-

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4Because of yearly model changes, automation is not feasible for some operations in automobile production.
ise of a new era in job-shop automation. (See next section.) In a numerical control process, engineering drawings are translated into mathematical formulations, which are recorded on tape or punch cards. The tape or cards are plugged into the control unit on a machine tool, which then performs its task automatically.

Numerical control is expected to have an impact on the metalworking industry. Its chief use will probably be with the multipurpose machine tool, which can produce a short run of one product, and then simply by having the tapes switched, produce a few more units of an entirely different product. (Same tool, different tapes.) One such multipurpose, tape-fed machine tool, the Milwaukeematic, "can interchange 31 different cutting tools and perform hundreds of operations in sequence without a touch from a machinist." (quoted in "Problems of Automation") Also being marketed are tape-controlled, single-purpose machines, which can be switched from job to job in a matter of seconds.

Numerical control has been applied with success in the aircraft industry. At Republic Aviation Corporation, for instance, 1,500 hours had been needed to produce a template by hand for a complicated part. In contrast, preparation of the controlled tape required only 645 hours. Machining time for the same part was reduced from 37 to 6 hours. Another measure of the savings due to numerical control is the report to Republic's stockholders that tooling and machine costs had been cut an average of 75 per cent during 1959 as a result of full-time use of five tape-operated milling machines. ("Problems of Automation," 1960)

Although still in a developmental stage, numerical control automation has grown rapidly in the six years of its existence. Because prices are within reach of a fairly large group of manufacturers, and because machine time is greatly reduced and quality increased, tape or card controlled machines are expected by some observers to have an impact on small shops with short runs of greatly varying products--the typical job shops.

Continuous Process Industries. In the continuous process industries--usually shortened to "process industries"--the material flows continuously. It may be a liquid, a gas, electrical energy, or a solid in crushed or powdered form. It flows through chambers, tanks, and pipes without stopping. Examples of process industries are those involving chemicals, petroleum, synthetic fibers, plastics, some foods, electric utilities, and atomic power.

The following description of process in a chemical plant, somewhat condensed from a statement made by John J. Grebe, of the Nuclear and Basic Research Department, Dow Chemical Co., Midland (New Views on Automation), illustrates the use of numerous automatic controls in the continuous process industries:

The chief chemical raw materials are water, salt, oil, and coal. Water is brought a distance of 75 miles; salt brine is pumped from deep wells; coal, as the energy source, is transformed by boilers and condensing turbines into electrical energy and process heat.

Water has a vast number of impurities. The elaborate treatment plant mechanically is a complex aggregate of tanks, pipes, valves, and pumps. Operationally, it is almost completely automatic. A central control room receives
signals of measured quantities from all parts of the system. Changes in all the important variables, such as impurities and flow rates, are transmitted and recorded automatically. The control instruments then send back orders to servomechanisms, which open and close valves, adjust weights, pressures, temperatures, and so on.

In the power plant is another complex assemblage of instruments and controls. They measure temperatures and the chemical constituents of the stack gas, temperature of water fed to the boiler, pressure and temperature of the steam produced, and the precise speed of the turbine. They control and allocate loads on the various machines, watch bearings for overheating, and check condensers for leaks.

This is only a start. The average chemical plant consists largely of fluid transportation--liquids and gases--flowing through a system of piping and tanks. At hundreds of points instrumentation must measure and adjust pressure, temperature, flow rate, and composition.

Some of the more complex processes require controls that will replace and improve on human judgment. The central brain (inanimate) receives signals from many instruments and meters. It studies their relative values and tests them against prescribed criteria built into the machine. From this it decides what is to be done and sends out electronically the orders to servomechanisms, which execute these orders. Finally, another device, known as feedback, reports the extent to which the ordered action failed to create the effect desired. The central brain then sends out corrective orders.

Thus, in industrial apparatus, fluid chemical systems, or aggregates of pipes, tanks, valves, and pumps, the direct sensing and controlling elements are connected to meters, valves, and pump motor controls on pumps, to produce the desired changes.

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The "central brain" mentioned two paragraphs above is the computer. Its use in a production process is a fairly new development, which will be discussed in the next section. But even without the computer, some of the process industries--chiefly oil and chemicals--have been highly automatized for some time. Direct feedback devices that control the four major variables of pressure, temperature, level, and rate of flow, have been widely used in the ways described by Mr. Grebe. A modern oil refinery, for instance, is considered to be 80 to 90 per cent automatic. The central process of calculating the proper relationships among the variables and setting controls has, until recently, been carried out by human operators.

The Role of Computers in Manufacturing

Most people think of the electronic digital computer as a super-calculating machine that can perform innumerable computations almost instantaneously and without error. And although this view is not inaccurate, it only scratches the surface. One writer has said that the reason computers do not normally perform more than simple routine operations is because they are not given the opportunity. He compares computers to a man who has been locked up in a room
by himself for his entire life and taught nothing but how to add up interminable grocer's bills. "Such a machine, or such a man, could hardly be accused of showing no initiative." (George, 1959)

In addition to making calculations, electronic computers can store and manipulate large numbers of observations. This asset is considered more important than their mathematical ability. But when these abilities are utilized jointly, and when a computer is connected with a number of automatic control devices, it becomes another species of machine—sometimes referred to as an "information machine." In this capacity a digital computer can order and supervise the way in which work is done. Thus it can be used as a control device, giving instructions, receiving and recording information about performance from sensory devices, comparing that with its store of information, and issuing corrected instructions where necessary.

It should be observed in passing that the computer is itself a closed-loop system. In a control position it receives information from intricate measuring and recording instruments, from open-loop and other closed-loop systems, and integrates these many systems into a unified closed-loop system. This integrated system may be a production line, or ultimately, the whole of a company's major operations.

Just as a human supervisor makes numerous decisions about a production process, so can computers. And, if a recent issue of Fortune augurs correctly, they eventually "will take over decision making in areas that vice presidents deal with." (Boehm, 1960)

The potential management abilities of computers have been realized for some time. But until the development of solid-state electronics, bringing components that neither burn nor wear out, the possibilities were only theoretical. Even then, high costs made computer operating control unfeasible. But about three years ago, according to Fortune, it became possible to build, at reasonable cost, "a computer that would work twenty-four hours a day, seven days a week, with a reliability of more than 99 per cent." This phenomenal reliability sets "control computers" off from most business and scientific computers. Also, they need relatively small capacities for storing information and changing programs, which helps to keep them fairly cheap ($100,000 to $500,000).

This Fortune article is devoted to a description of "computer process control" (CPC), which represents the "penultimate step toward complete automation at all levels, from the production line on up." The industries that so far have started with CPC are continuous process industries: electric power generation, steel rolling and plating, petroleum refining, and chemical manufacture—where automatic control systems are already well developed. In time it is expected that routine decisions regarding purchasing, production and production scheduling, inventory control, distribution, marketing, and perhaps even finance, will be made by a chain of electronic computers linked together by CPC machines and in consort with business-data computers.

It is not uncommon for computers to be described in anthropomorphic terms. And while anthropomorphism in technical writing is decried, it is almost irresistible when discussing computers. Thus, in describing their place in the steel industry, Business Week stated (November 5, 1960): "Computers first
went to work on the same sort of data-processing as in dozens of other industries: accounting, inventory control, production scheduling, research. They began moving into control of production operations only about four years ago." This issue and the Fortune article are recommended for a description of the present role of computers in the continuous process industries and for a glimpse into the future.

If the digital computer has moved automation into a new era in the continuous process industries, it has also been responsible for a major breakthrough in numerical control—which, as we have seen, is already the most promising development in the automation of certain batch process industries. In the words of a report prepared by the International Association of Machinists:

Another development of striking significance ... involves the use of computers and a special kind of computer language to produce the tapes which direct the machine tools. Heretofore, the calculating required to prepare the tapes was a major bottleneck, consuming the efforts of many calculator operators for at least several weeks. Now, under the new system and as has been stated elsewhere, "Experienced machinists' directions for producing a part can be converted in a few minutes by the computer into the hundreds—or even thousands—of machine tool positions necessary to do the job... The computer calculates the tool positions ... and spews out a punched tape which can direct the machine tool control system." ("Problems of Automation")

Various observers have commented that the automatic assembly line has been slow in coming, but it seems probable that techniques of computer control learned in the continuous process industries will have appropriate applications in the factory. Already, an electronic control system to "mastermind" an entire line of machine tools and transfer devices has been put to work at Boeing Airplane Company and Republic Aviation, making it possible to turn out in a few days a parts order that otherwise would take weeks. ("Problems of Automation")

Certain it is that computer system production and sales will rise rapidly in the next ten years. Business Week, in November 1960, predicted that the sale of computers, with their input and output equipment, would amount in 1960 to about $20 million in the industrial field. By 1970, it is estimated that sales will be somewhere between $200 million and $500 million a year. Other measures of the growing importance of computers in the automation of industry are presented by Diebold in New Views on Automation.

Office Automation

Although this report concerns automation in the manufacturing industries, a brief section on office automation is included because of the rising proportion of white-collar workers, the growing need for record-keeping in industry, and the increasing prominence of the service industries in the local economy.

The key to office automation is the fact that many office operations are essentially mathematical in nature and can therefore be adapted to computers.
Although the extent of computer use in office operations is apparently not known, it is believed that, theoretically at least, the computer can be applied to almost any kind of business and record-keeping function. Costs of installing computer systems will be a deterrent to their widespread use for some time yet. Two developments however—the production of small-scale computer systems designed for small businesses, and the growth of computer service bureaus and data processing centers—are expected to extend computer use in the near future.

This technological change in office work is occurring at a time when the occupational structure of the labor force is undergoing a basic change. Traditionally, the percentage of blue-collar workers has exceeded that of white-collar workers. But in 1956, for the first time in history, according to the Bureau of Labor Statistics, white-collar workers exceeded blue-collar workers in number. The trend in this direction is indicated by the following BLS figures: In 1910, 1 out of 20 persons employed was in a clerical or closely related job; by 1940, 1 out of every 10 was so employed; but in 1958, the proportion had grown to 1 out of every 7. By 1956, women comprised 67 percent of the total white-collar group.

The increase in the number of white-collar workers has been associated with the increase in paper work both in commercial and industrial establishments. And a business or manufacturing concern that has a large and growing volume of paper work is inclined to take advantage of economies that can be achieved by automation.

A recent article in the Harvard Business Review (Hoos, 1960) has pointed out that while an increasing number of men and women will be looking to office work as a means of livelihood, the types of routine clerical work they are equipped to do are the very ones most adaptable to electronic handling. Furthermore, "workers, supervisors, and higher executives are all directly affected." Banks, insurance companies, the government service, public utilities have been among the first to install electronic data processing (EDP) systems, but the possibilities are not limited to these fields, since computers can carry out any routine clerical function, simple or complex.

What the net effect of office automation will be on numbers and percentages of persons employed in white-collar jobs is almost impossible to determine at the present time. On a long-range basis, however, the Department of Labor foresees office automation causing a slackening of the growth rate of white-collar employment, with the possibility that a leveling-off has already occurred. But here again, conflicting statements mount. Many variables—such as rising population, expanding production, and rising purchasing power—affect the picture. On the one hand are statements such as the following: "Despite the swing to more and more automation in the office, there seems little prospect that great numbers of workers will be thrown out of jobs." (U. S. News & World Report, May 4, 1959) On the other hand, sober observations regarding the impact of EDP on the number of jobs are now appearing: "The quantitative aspect is likely to be obscured because wholesale dismissals rarely take place. . . . Nevertheless, the general thrust of EDP is becoming increasingly clear. . . . It appears to be a fair estimate . . . based on their experience [19 organizations in the San Francisco Bay area that had introduced EDP] thus far that for every 5 office jobs eliminated, only 1 is created by automation; and those which do not disappear undergo drastic change." (Hoos, 1960)
EFFECTS OF AUTOMATION ON EMPLOYMENT

Of all the conflicting views on automation, none differ more than those dealing with its effect on employment. Where statistics should be able to give the answer, they are offered instead to support opposing answers. Examination shows that the arguments often run parallel rather than head-on—even though the conclusions collide. One group of observers, made up of labor union spokesmen and several independent observers, such as university professors, supply employment statistics and case studies. The opposing group, made up of plant managers and management consultants, supply what are on the whole different sets of figures. Also, they rely heavily on analogies to the past.

In candor it must be said that the views of the first group—labor leaders and independent investigators—are more convincing. The data presented appear to be more factual, the statistics more concrete and specific. Nevertheless, the views of the second group must be considered because of the experience and knowledge of the management spokesmen.

The question of automation's effect on employment is critical for planning agencies. Manufacturing employment is a key factor in a city's economic growth and well-being. Manufacturing employment data are an important factor in various planning studies. And while we cannot come up with any firm conclusions in this report, we shall try to sort out the salient areas of agreement and disagreement.

Also we should say that the discussion that follows greatly oversimplifies the problem. Even in retrospect, the influences of technological change on society—or any segment of it—are complex. And at this point we are at the beginning of the story, not the end.

Automation and Worker Skills

One aspect of the problem is the question of the effect on skills. Those who argue that automation upgrades the worker claim that more demands are made on his attention and his understanding of complex machines. Thus automation gives the worker "relief from the degrading and stultifying effects of dull repetitive work, humiliating work in which there is no satisfaction of accomplishment. . . . The unskilled worker is being made into a highly-trained maintenance man, the skilled tradesman into a technician." (Cross, 1960)

Another explanation is that the production worker is upgraded because he moves from routine work into white-collar jobs. Those who support this view cite employment figures showing an increase in the total number of professional and white-collar personnel in the United States compared with a decrease in the total number of production personnel. (See Bolz, in New Views on Automation)

But over against these optimistic statements—of which the above are only two of many—is the view presented in the Harvard Business Review. (Bright, 1958)
The author spent several years conducting a study of automatized plants, and concluded that there was more evidence that "automation had reduced the skill requirements of the operating work force, and occasionally of the entire factory force including the maintenance organization." He examined the various measures of skill, and found that although certain operations did demand more of the worker in skill and level of responsibility, the countervailing trend was to reduce--"or at least not to increase"--the demands for skills and abilities on the part of the labor force.

Walter Buckingham, who examined a number of studies, concluded that "automation has improved working conditions but, contrary to popular belief, it does not seem to have upgraded workers." He cited several case studies, similar to that made by Bright, which came to similar conclusions. Furthermore, he found that "newly automated plants frequently hire inexperienced workers and give them only limited training." And "some case studies show that former machine operators tend after automation, to become only machine 'monitors.'" (New Views on Automation)

Independent observers who have examined the problem closely are convinced that automation does not upgrade the blue-collar worker. Unskilled jobs usually decline considerably when a plant is automatized. A few skilled workmen may be required to handle more skilled operations, but most are not. The real requirements for skill are in the engineering, technical, and professional groups--not the worker.

Does Automation Displace Workers?

This question is really two questions. One concerns the displacement by automatic controls of workers in a plant or an industry. The other concerns the displacement of workers from the employed labor force, that is, the creation of unemployment.

Displacement by Automatic Controls. If we look at examples of a particular automatized industrial process, we find that, almost invariably, output per worker is increased, costs reduced, quality of product improved, and the number of workers drastically reduced. This statement can be easily and fully documented. The various published hearings of the subcommittees on automation of the Joint Economic Committee contain dozens of examples offered by industry as well as by union spokesmen. Furthermore, automation, as we have seen, is intended to turn over to machines the tasks that they can do better than men. This is the reason for automation.

But if we ask what happens in a plant beyond what has happened in a particular process, the answer is not quite so simple, and we begin to get contradictory reports. According to one view, the workers displaced from the line by machines are usually absorbed elsewhere in the plant. John Diebold, for instance, has said that in his firm's experience, the installation of automatic equipment does not lead to mass layoffs (our emphasis). "Through the means of retraining, natural attrition, transfers and retirements, dislocation of personnel is minimized. . . . Not in all cases could layoffs be avoided. In certain instances, employees were not capable of learning new skills that would be required of them. Where transfer possibilities were not available, termination of employment eventually proved necessary. Even here, I found, in
several instances, where management maintained the employment level of an operation significantly above what was necessary after the automation equipment was installed." (New Views on Automation)

Doubtless many employers have made efforts to ease the brunt of the change on workers currently employed. But many firms, according to statements offered by others, have either been unwilling or unable to keep displaced workers on the payrolls.

Walter Buckingham, of the Georgia Institute of Technology, has said that displacement caused by automation takes several forms.

1. A worker is permanently laid off with loss of seniority and other job rights. ("This kind of displacement from automation seems to be relatively rare.")

2. The displaced worker is transferred to another department of the same firm. (This seems to be fairly common.)

3. Indirect displacement due to vertical integration. (For example, when Ford automatized its stamping plants, no Ford employees were displaced, but 5,000 Murray Body Company employees lost their jobs when Murray lost its Ford business.)

4. Indirect displacement when automation causes horizontal integration by increasing optimum plant size to the extent that smaller firms are forced out of the market by competition. (For example, the Studebaker plant in South Bend could not compete with the more highly automatized General Motors and Ford plants in Detroit.)

5. Hidden unemployment of downgrading: old skills are rendered obsolete, and workers cannot move up into the new jobs.

For several reasons it is difficult to find out just what happens to automation-displaced workers. If automation is introduced in a time of expanding business, the argument that workers are hired elsewhere in a plant appears to hold up. But if business conditions are on the downturn, layoffs due to automation can be blamed on "bad times." Thus, according to Buckingham, there are about 160,000 unemployed persons in Detroit "who will probably never go back to making automobiles, partly because the industry is past its peak, and partly because automation has taken their jobs." Also, steelworkers returning after the 1958 recession found the same work being done by 20 per cent fewer men.

Another reason for conflicting reports is that so far, automation has proceeded slowly enough that normal turnover disguises some of its effects. A plant with a high turnover rate can automatize its operations without layoffs and reduce its personnel simply by not hiring.

**Technological Unemployment**

If enough automation-displaced workers fail to find jobs in other pursuits, or find their old jobs gone after a temporary layoff, then unemployment exists, and it can be said to be caused by technological advances. Signs indicate
that this already has happened in some segments of the economy. For instance, it is pointed out by one observer that "it is significant that much more than a proportionate share of the hard-core unemployment in our 'distressed areas' is composed of workers whose last job was in manufacturing." (Killingsworth, 1960)

Another observes that the persons most vulnerable to displacement from automation are older workers, women, and Negroes. People in all of these groups, for one reason or another, are less able than others to learn the new skills required in an automatized plant and are less able to compete for those jobs. At the same time, the percentage of older people and Negroes is rising in the labor force, and the number of women seeking employment is increasing. (Buckingham, in New Views on Automation)

But perhaps the most serious reports are those from the Bureau of the Census and the U. S. Department of Labor. For the period between April 1953 and April 1960, the number of production and maintenance jobs declined noticeably in industries involving food and textiles, chemicals, oil refining and coal products, basic steel, electrical machinery, automobiles, and aircraft. In some of these industries—food and textiles, chemicals—production at the same time is rising. In others, it has dropped. But all are industries in which automation is taking place at different rates of speed and different degrees. (See figures reproduced in the statement of George Meany, in New Views on Automation.)

The Secretary of Labor, though hopeful about the future, points out that, due to recent technological changes, "some groups of workers, once displaced, have serious difficulty in finding jobs... Unemployment rates are particularly high for operatives, farm laborers, and unskilled workers. Mining, agriculture, and nondurable manufacturing industries as a group have relatively high rates." (Mitchell, in New Views on Automation)

Long-Range Effects

One of the fascinating and still unresolved questions regarding the effect of automation on the economy in general and manufacturing employment in particular is what will happen in the long run. A frequently encountered opinion is that since automation is a step in technological change, society and the economy will adjust to it as they have to past technological advances.

Among the proponents of this view are the director of the Bureau of the Census, who believes that the whole picture shows that automation is "a continuation of an evolutionary process rather than the beginning of a revolutionary one." (Burgess, in New Views on Automation) Long-range trends ranging from 1899 to 1958 are described to show the increase in production workers in the machinery industries and in all manufacturing industries. One significant over-all figure shows that the number of production workers employed in manufacturing industries increased 160 per cent between 1899 and 1958, although the total increase in population was only 128 per cent.

The crux of the problem seems to be whether recent trends will be absorbed in the long-range trends, or whether they mark a change of direction. Projections indicate that the labor force will increase by almost 20 per cent between 1960
and 1970, but that most of the increase will come in the group of workers under 25 and over 45 years of age. And in the past seven years, the labor force grew by 6 million persons, but employment increased by only 3.9 million. At the same time, since 1953, the volume of total national production has risen at an average yearly rate of only about 2½ per cent.

To offset these recent decelerating forces and to find employment both for persons displaced by automation and for the growing labor force, observers seem to agree that the rate of economic growth will have to be sped up. But again, there are two schools of thought: one holds to what might be called the "concentric ripple" theory—namely, that automation stimulates long-term growth of investment, creates new industries, new markets, and new jobs. Certainly this has been true with past technological change. Against this view is the one holding that the adjustments to automation will not necessarily be automatic. Or if adjustments do come, they will be so slow that hardship will affect too many people in the meantime. This group believes that government and private groups will have to make a conscious effort to ensure an expanding economy.

The unresolved question of the long-range effects of automation on the economy is of particular interest to planning agency staffs because studies of the local economy rely heavily on national and regional trends.

AUTOMATION AND URBAN PLANNING

Automation developments affect the local community in many ways. An important influence is their effect on the number of workers employed in local manufacturing industries.

This figure is of interest because it is a measure of employment opportunity and hence of the economic health of the local community. But it is also widely used as an index of other factors. One is the ratio of service workers to production workers—a relationship that is undergoing some change nationally, as we have seen. Manufacturing employment is also used as a predictive component of future population. Thus it is a critical factor in estimating future needs for public services and facilities and future revenue sources. And while these relationships can seldom be reduced to exact formulas, they are useful as approximations and preliminary estimates.

If automation substantially reduces the number of manufacturing employees relative to unit of manufacturing output, or relative to capital investment in plant and equipment, then the assumed value of these various ratios will change. On the other hand, if automation at the same time stimulates the growth of new industries, as has been claimed, the net effect on local population growth may be the same. At this point there is almost no information that casts light on these questions, except what can be inferred from the behavior of automation in general.

Another use of manufacturing employment is to calculate worker or employee density. These figures in turn are used as units of measurement for estimating land area needs for future industrial areas in the community. And as a
factor in future employment population estimates, they also have a bearing on land area needs for residential and commercial uses. Here we are on slightly firmer ground, since signs indicate that as a plant becomes more automatic, it employs fewer workers. But the facts regarding the net effect on worker density are sparse, and all that legitimately can be done is to raise the question.

Along these lines, one more question comes to mind. If the ratio of employees to unit of land area is modified by automation, at what point does this measure lose its value for estimating future land needs? If the significant determinant of plant size is the process itself, why not use it directly? But again, we can only raise the question.

Despite the lack of information on these particular aspects of automation and urban planning, some material is available on two other features that have a bearing on local planning programs. These are the effects of automation on plant characteristics and plant location. The material is far from complete, but at least it indicates tendencies and furnishes clues.

**Plant Characteristics**

Studies of plant characteristics made since World War II show that the modern plant is generally one-story, and seldom more than two. Interior floor areas are frequently large and have widely spaced columns to permit flexibility in use of space and to accommodate large equipment. Off-street parking and loading areas are supplied on the site, and acreage is often added for plant expansion.

Single-story plants apparently will remain the rule when automatic controls are installed, but it is not yet clear whether the size of plants and the plant sites will be approximately the same as under conventional production methods, larger, or smaller. The examples cited below may be indicative of what happens when a plant is automatized, but there is insufficient information to come to any conclusions whatsoever at this time.

David G. Osborn made a "before and after" examination of 12 industrial plants to see, among other things, how automation had affected the area occupied by buildings and structures. He found that space per unit of output was reduced in all cases, and that the mean amount by which it was reduced was 58.8 per cent. The range extended from a 94 per cent reduction for a lard rendering plant to 12 per cent for printed circuit fabrication—where only part of the assembly line had been automatized.

Also examined was the effect of automation on employee density. Among the 12 plants studied, there was an average increase in amount of space (floor area or acreage) per employee of about 28 per cent. It is interesting to note that although the amount of space per unit of output and the number of employees

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5Floor area was the measure used where appropriate. In some cases, such as a grain sorghum plant and a railroad classification yard, the measure was acres of land.
per unit of output both decreased; the reduction in number of employees was more drastic; the mean of the reductions in number of employees per unit of output was 63.4 per cent. (Osborn, 1953)

One writer illustrates the effects of automation on plant characteristics with the example of what happened in a plant manufacturing the bodies of rifle grenades. (Bittel, et al., 1957) No other examples are given, but the authors apparently consider this one representative.

<table>
<thead>
<tr>
<th></th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operators</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>Floor area</td>
<td>10,800 sq. ft.</td>
<td>600 sq. ft.</td>
</tr>
<tr>
<td>Production rate</td>
<td>900 units/hr</td>
<td>900 units/hr</td>
</tr>
</tbody>
</table>

When an existing plant is automatized, it is usually accomplished within the structure of the building. But when a new plant is designed for the installation of a particular system of automation, a different building concept is dictated. According to Engineering News-Record (December 1, 1960), production buildings are designed around an automatized production line, rather than a production line being designed to fit a building.

The production potential of automatized plants may require more space for storage of raw material and finished products than required in less automatic factories. Facilities for handling process effluents likewise are relatively larger. But employee facilities such as washrooms, cafeterias, and parking lots take proportionally less space "since less manpower is required to achieve equivalent output." Also, it has been found that in factories that are being converted, it is frequently necessary to reallocate space from what had been production and employee areas to raw material and finished-goods areas, "because of the greater productive capacity of the automated equipment per unit area."

Plant Location

Under plant location theory, labor supply is one of the factors in management's decision to move a plant or build a new one in a particular location. According to one authority, labor for some companies is "the greatest single influence motivating plant location." (Yaseen, 1956) Local labor cost, availability, stability, and productivity often determine branch plant selection too.

To what extent does automation affect the importance of labor as a factor in plant location? In the past, the presence of a "pool" of skilled workmen was important. But the National Resources Planning Board in its study, Industrial Location and National Resources, found that technological changes tended further to reduce the location pull of highly skilled labor—which even then, for the bulk of manufacturing industry, was low compared with the pull of natural resources and markets. If it is true that automation reduces the general skill requirements for production workers, then it is probable that a supply of
skilled workers has become a much less significant consideration in plant location, even for the "labor-oriented" industries.

If management does not seek skilled workers, and if labor is an important constituent in a plant's production process, then the other factors mentioned above become more important. Studies made within the past several years show that for some plants, labor is still an important consideration in deciding on a site. For instance, of 752 firms surveyed in 1954, 81 per cent ranked "wages and salaries" second in a list of 34 factors, and "abundance of general labor supply" third. (Greenhut, 1960)

But it seems only reasonable to conclude that as production workers become less important in a production process, other factors will loom larger.

As far as we know, the relationships between automation and plant location policies and factors have not been thoroughly studied. Observations have been made, however, by people acquainted with developments in automation. These are submitted, not as final or authoritative statements on the situation, but rather as indicators of trends that may possibly be taking place at the present time, or that may take place in the future.

A professor of industrial management at Stanford University (Shallenberger, 1952) emphasizes the dependence of the automatized plant on markets and the need of accurate program production schedules in advance of plant construction. Since these comments were written eight years ago, they may have been more predictive than factual. Nevertheless, some interesting views are stated:

- Plant location will no longer be dependent upon availability of labor. A guaranteed and stable market for the product will be essential. In most cases, the break-even point will be high, and cut-backs will be costly. Workers can be laid off, control mechanism and overhead cannot. At the same time, production increases will be difficult. Since fixed costs will be high, the automatic factory will operate 24 hours a day. Expansion of production will be impossible for a plant which is already working around the clock.

- This lack of flexibility and emphasis on full utilization indicates a need for better than usual sales effort, directed first of all to an accurate determination of the market potential before the plant is built and secondly to a steady sale of the product.

The study on geographical features of automation mentioned earlier (Osborn, 1953) concluded that at that date, automation had had only a "slight effect on location." Since only 12 plants had been studied, the findings on this point were inconclusive. But considering the processes involved, the author believed that in the future, automation would tend to "free plant location somewhat from the controlling importance of land and labor force." This conclusion followed from the observation that automation, generally speaking, "diminished both the amount of space required and the labor force necessary to turn out a given unit of product."

Osborn also observed that since automatized plants rely heavily on instruments of all kinds, it is desirable to be in an area where facilities are available...
for servicing of the instruments. And Shallenberger, too, observed that "re­
lations with suppliers will take on added importance."

Several of the papers submitted to the Subcommittee on Automation and Energy
Resources mentioned the tendency to abandon an old plant and build an entirely
new one in a new location when automation was undertaken. Thus Secretary
Mitchell said that "Since the full benefits of automation may require exten­
sive changes in plant layout, some companies prefer to take advantage of their
modernization programs to build entirely new plants in other localities."

Others, in mentioning this tendency, emphasized the effect of plant removal
on the community as a whole. Among them was Walter Buckingham:

In view of the rapid growth of automation there may be an increased
likelihood of abandonment of plants and the creation of depressed
areas. There are several such areas already in Pennsylvania,
Michigan, and West Virginia. If one large firm adopts automatic
operations, other firms in the industry may have to scrap or sell
undepreciated machinery and adopt similar techniques or be squeezed
out of the industry by the lower costs of their automatized rivals.
Entire communities could become ghost towns if this happens.

George Meany also observed that "since automatic equipment requires little
direct labor, there should no longer be any compelling need to locate automatic
production near large population centers." But other considerations do affect
plant locations:

The new technology frequently makes it less costly for a company
to build a new automated plant in a new area than to automate an
old plant. In addition, changes in costs that are related to the
new technology may convince many companies to move their plants
closer to consumer markets or central geographical locations,
rather than to remain close to raw material supplies or supplies
of semiskilled manpower. Furthermore, radical and rapid changes
in technology speed up the decline of some industries and the
growth of others, with direct effects on one-industry towns.

George Buckingham, too, speaks of the relative independence of automatized op­
erations from large population centers and points to possible influences on
decentralization:

Although a sizable concentration of capital is normally necessary
before a firm can achieve the economies of automatized operations,
there is reason to believe that automatic control devices may lead
to decentralization of plants. The growth of electric power trans­
mission technology and the introduction of lightweight fabricating
materials have already permitted plants to be located at great
distance from power and supply sources. Since automatic equip­
ment requires little direct labor, there should no longer be any
compelling need to locate automatic production near large popula­
tion centers. The generally reduced labor requirements due to
automation have resulted in a trend toward the construction of
relatively smaller plants, more widely decentralized, by many of the
largest firms including General Motors, General Electric, Philco,
United States Steel, and Alcoa.
CONCLUSIONS

Although more information is needed, we have now had enough experience with automation to see that it is a technological movement of significance for the local community as well as for the nation as a whole. Automation touches many aspects of urban economic life. On some it has left only a mark, but others it has modified in a fundamental way.

It is hard at present to evaluate the impact of automation because it has so many different forms and is being applied at so many different levels. Also, a number of unknown variables in the picture make it difficult to tell how fast automation is coming. Things that are theoretically possible may not be realized for years because of engineering or materials problems to be solved. Unforeseen practical difficulties may retard its application in particular businesses and industries or impair its usefulness in others.

Nevertheless, it is hard to avoid the conclusion that automation, with its theoretical partner, cybernetics, has tapped a resource so rich that we are only now beginning to reap its benefits. This resource is the knowledge that the organizational structure of a system is essentially that of a communications network. In capturing this knowledge and putting it to work with all of the advanced machinery and devices at our command, we have unleashed forces whose limits we cannot possibly see at the present time.

Planning commissions and their staffs, whose interest in economic matters ranges from broad trends to detailed statistical data, should watch automation developments closely. If it has the dynamic nature attributed to it by many observers, then it can be expected to disturb the steady assumptions on which community forecasts are usually based.

Automation is generally viewed as of tremendous potential benefit. But a number of observers also think that the benefits will not be realized unless the economy is expanding. Automation is seen as a causative factor in an expanding economy. But there is no general agreement that it will inevitably act in this way.

Although local communities cannot deal with over-all effects of automation, they can to some extent be prepared to cope with local manifestations. One of these lies in the realm of public facilities. As human labor is freed by machines from many of the hard, dangerous, and unrewarding tasks that are part of production processes, there will be more emphasis on other pursuits. In this respect, at least, automation continues a trend that has been going on for many years. George Meany, in a statement in New Views on Automation, pointed to the need for more cultural opportunities. He was speaking particularly of the lessons to be learned from the effects of automation on economically distressed communities, but his views are equally applicable to other localities:

It is essential for industrial communities to recognize that their educational, cultural, recreational, and community facilities must
be maintained on an adequate level for economic growth. Such com-

munity facilities are needed in an attempt to prevent skilled man-
power and managerial talent from leaving for other areas. Such
facilities are needed, too, to maintain and attract skilled man-
power and management and to retain workers in new skills. This is
particularly true in this age of radical and rapid technological
change, with its emphasis on education and new skills, on engineers
and technicians, on research and development.

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