The Machine, the Worker, and the Engineer

Robert K. Merton, *Department of Sociology, Columbia University, New York City*

TO SUSPECT THE FULL MEASURE of one's ignorance is the first step toward supplanting this ignorance with knowledge. What is known about the effects of changes in the methods of production upon the problems, behavior, and perspectives of the worker is little indeed; what needs to be known is very great. A short paper dealing with this large subject can at best roughly map out the contours of our ignorance. It is possible only to allude to the order of research findings now at hand, the conditions needed for suitable extension of these findings, and the social organization of further research required to achieve these results.

So widespread and deep-rooted is the belief that technological advance is a self-evident good that men have largely failed to look into the *conditions of society* under which this is indeed the case. If technology is good, it is so because of its human implications, because large numbers of diversely placed men have occasion to regard it as such in the light of their experience. And whether this occurs depends not so much upon the intrinsic character of an advancing technology, which makes for increased capacity to produce an abundance of goods, as upon the structure of society which determines which groups and individuals gain from this increased bounty and which suffer the social dislocations and human costs entailed by the new technology. Many, in our own society, find the pluralistic social effects of the progressive introduction of labor-saving technology to be far from advantageous. Limited as they are, the data on technological unemployment, displacement of labor, obsolescence of skills, discontinuities in employment, and decreases in jobs per unit of product all indicate that workers bear the brunt of failures to plan the orderly introduction of advances in the processes of production.

Research on these matters is not, of course, a panacea for the social dislocations ascribable to the present methods of introducing technological advances; but research can indicate the pertinent facts of the case—that is to say, it can set out the grounds for decisions by those directly affected by the multiform effects of technological change. Social research in this field has been impressively limited, and it will be of some interest to consider why this is the case.

We shall first review the order of findings which have resulted from social research in this general field; then consider some factors affecting the social role of engineers —especially those immediately concerned with the design and construction of the equipments of production—and the social repercussions of their creative work; and finally, suggest some of the more evident problems and potentialities of further research on the social consequences of labor-saving technology.

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Social Consequences of Changes in Technology

Research has detected some of the social repercussions of technological change, a few of which will be mentioned here. These range from the most direct effects upon the nature of work life—the social anatomy of the job—to those which bear upon the institutional and structural patterns of the larger society.

Social Anatomy of the Job

It has become plain that new productive processes and equipment inevitably affect *the network of social relations* among workers engaged in production. For men at work in the factory, the mine, and, for that matter, on the farm, changes in methods of production elicit changes in work routines which modify the immediate social environment of the worker. Modifications of the size and composition of the work team; the range, character, and frequency of contact with associates and supervisors; the status of the worker in the organization; the degree of physical mobility available to him — any and all of these may be collateral effects of the technological change. Although these shifts in the local structure of social relations diversely affect the level of employee satisfaction with the job, they are often unanticipated and unregarded.

The conditions under which such a change is introduced have also been found to determine its impact upon workers. Responding to depressed economic conditions by the introduction of labor-saving technology, management may widen and deepen local pools of unemployment at the very time when workers have few alternatives for employment. Management may thus nourish *the job insecurities and anxieties of workers.* Circumstances such as these understandably lead organized labor to seek a greater part in shaping plans for the introduction of new equipment and processes.

In this connection the tempo of technological change is of critical, though not exclusive, importance. Workers, like executives, seek some measure of control over their

day-by-day lives. Changes imposed upon them without their prior knowledge and consent are regarded as a threat to their well-being in much the same fashion as they are by the businessmen subjected to the vicissitudes of the market or to what they consider "unpredictable decisions" by "those bureaucrats in Washington." Not uncommonly, the worker's stake in the decision has been conscientiously and unrealistically neglected by a management installing labor-saving technology in an effort to maintain or to improve the competitive situation of the firm. It has been observed that an environment of uncertainty, fear, and hostility may be skillfully created by ıickening the pace of unpresaged changes in technology.

Through the *enforced obsolescence of skills*, labor-saving technology produces acute psychological and social problems for the worker. The difficulty does not lie exclusively in the need for learning new routines of work. The need for discarding acquired skills and, often, the accompanying demotion of status destroys the positive self-image of the worker, stemming from the confident use of those skills. Although this human cost of new methods of production can on occasion be reduced for individual workers through the planned reallocation of jobs, this does not preclude basic changes in the occupational structure of industry at large.

With technological advance, the growing subdivision of work tasks creates numberless new occupations for which, as Roethlisberger has observed, "there exist no occupational names that have any social significance outside of the particular industry, factory or even department in many cases." The splintering of work tasks involves *loss of public identity of the job*. Who but a chosen few, for example, can distinguish a fin sticker in an automobile plant from other radiator-core assemblers? Or, to take a more homely instance, what distinguishes the pride in work of a doughnut sugarer from that of a doughnut pumper, who successfully injects jelly into fried doughnuts with a jelly pump? To the outside world, these esoteric specializations are all of a piece and, consequently, for the outside world there must be other marks of status and significant work activity that count. The alienation of workers from their job and the importance of wages as the chief symbol of social status are both furthered by the absence of social meaning attributable to the task.

Increased specialization of production leads inescapably to a greater need for predictability of work behavior and, therefore, for *increased discipline in the workplace*. The meshing of numerous limited tasks requires that the margin of variation of individual behavior be reduced to a minimum. This trend, first made conspicuous in the beginnings of the factory system by the rebellions of workers against the then unfamiliar discipline of factory life, has become steadily more marked. In practice, this comes to mean an increasing quantum of discipline which, under specified conditions, becomes coercive for the worker.

Institutional and Structural Effects

The political and social, as well as the economic, by-products of an advancing technology variously affect the structure of society at large. This wider context suggests that workers' attitudes toward the new technology are not determined by it *per se*, but by the collateral uses to which it can be and, at times, has been put as an *instrument of social power*. Technology has been employed not only for the production of goods but also for the management of workmen. It has, in fact, been repeatedly defined as a weapon for subduing the worker by promising to displace him unless he accepts proffered terms of employment.

In the present day, this tactical use of technology in the 'price war' between management and labor need not be phrased as a threat but merely as an observation on the self-contained workings of the market. In an address before this Conference, for example, it has been stated that "among the compelling pressures that now stimulate management to increased mechanization and technological improvement in the processes of production are fantastic increases in money wages, the abandonment or reduced effectiveness of incentive wages, the intransigence of many labor groups, and an abundant supply of cheap money. Process engineers, tool designers, tool makers are now and will be in demand as never before. Invention and innovation will be at a premium without precedent."

A hundred years ago, these political implications of technology (and of the role assigned to engineers) were somewhat more plainly drawn by enterprisers and their representatives. Andrew Ure, for example, could then describe the self-acting mule as a "creation destined to restore order among the industrious classes. . . . The invention confirms the great doctrine already propounded, that when capital enlists science into her service the refractory hand of labor will always be taught docility."

It would be instructive to learn if the avowed or tacit use of technology as a weapon in industrial conflict does in fact break the "intransigence" of workers or instruct them in the virtue of "docility." It is possible, of course, that the planned efficiency of a new machine or process is at times unrealized when its collateral function is that of keeping workmen in their place. Quite conceivably it may be found that the exercise of naked power no more produces a stable structure of social relations in industry than in other spheres of human behavior.

Advances in methods of production, as Elliott Dunlap Smith and Robert S. Lynd, among others, have observed, may enlarge the social cleavage between workmen and operating executives. It may produce a sharper *social stratification of industry*. As the complexities of the new technology make technical education a prerequisite for

the operating executive, the prospect of workers rising through the ranks becomes progressively dimmed. To the extent that opportunities for higher education are socially stratified, moreover, managers come increasingly to be drawn from social strata remote from those of workers. Also, since technically trained personnel enter industry at a relatively high level, they have little occasion to share the job experience of workers at an early stage of their careers and tend, accordingly, to have an abstract *knowledge about* rather than a concrete *acquaintance with* the perspective of workers. Finally, with the increasing rationalization of managerial procedures, the relations between operating executives and workmen become increasingly formalized and depersonalized.

These several patterns—progressive closure of opportunities for promotion, the polarization of social origins of workers and executives, the insulation of managerial personnel from workers' outlooks through changes in their typical career patterns and depersonalization of contact—may in composite contribute to a secular trend toward growing tensions between the men who manage and the men whom they manage.

The impact of technology upon the social organization is not, of course, confined to these subsurface trends in class structure. The interdependence of the industrial structure, tightened by applications of science to industry, infects the decisions of large industrial firms with the public interest. In consequence, government comes increasingly to regulate and to supervise these decisions, at least at the margins where they plainly affect the larger community. This trend toward "big government" forces upon popular attention what analytical observers have long recognized: the spheres of economic and political behavior, far from having only tangential relations, overlap considerably. Labor and management deal not only directly with each other through collective bargaining and administrative decision but also indirectly by exerting pressure upon government. Following in the footsteps of entrepreneur and management, labor enters politics.

The growing requirements of work discipline, deriving from technological integration, go far toward explaining the strategic role of the "big union" in our society. "Big industry" has been finding it more expedient or efficient to deal with unions than with large masses of unorganized workers. For industry has come to learn that discipline is often more effectively achieved with the aid of unions of the workers' own choosing than through exclusive resort to the managerial and supervisory apparatus. Moreover, a condition of technological tenuousness in which the stoppage of any one sector of production threatens to paralyze the entire industry modifies the constellation of power relations. All this confers heightened power and responsibility upon labor.

This cursory review of certain consequences of changes in the techniques of production helps sharpen the moral dilemma involved in the choice of problems for social research in this field. Research focused solely on the impact of new technology upon the *immediate work situation* in a plant leads primarily, if not exclusively, to findings which can be readily adapted for making the technological change more acceptable to the individual worker, though it may, in fact, have adverse consequences for him. The scientific problem may be inadvertently construed as one of discovering methods for accommodating the worker to the change, almost irrespective of the mosaic of consequences which it entails for him and his associates. Capital may also enlist *social* science to teach the worker the value of docility. On the other hand, only through this close study of immediate effects upon work life is one likely to discover methods of introducing changes in methods of production which may appreciably mitigate consequences unfavorable to the worker.

Attention solely to the effects upon *the larger social structure* has its limits as well. Research oriented wholly toward secular trends—for example, the pattern of increases in productivity outrunning increases in total employment—diverts attention from ways and means of minimizing the present impact of technological change upon the worker. This type of research, however, does locate the central sociological problem: discerning the features of our social organization which militate against technological progress resulting in "greater security of livelihood and more satisfactory living standards."

Implications for "The" Engineer

New applications of science to production by the engineer, then, do not merely affect the methods of production. They are inescapably social decisions affecting the routines and satisfactions of men at work on the machine and, in their larger reaches, shaping the very organization of the economy and society.

The central role of engineers as the General Staff of our productive system only underscores the great importance of their social and political orientations: the social strata with which they identify themselves; the texture of group loyalties woven by their economic position and their occupational careers; the groups to whom they look for direction; the types of social effects of their work which they take into account—in short, only by exploring the entire range of their allegiances, perspectives, and concerns can engineers achieve that self-clarification of their social role which makes for fully responsible participation in society.

But to say that this poses sociological problems for "the" engineer is to make a reference so inclusive and vague as to mean little at all. The large and multifarious family of men called engineers have a far-flung kinship, but they also have much that marks subgroups off, each from the others. There are military, civil, mechanical, chemical, electrical, and metallurgical engineers, and so on down through the hundreds of titles found among the members of national engineering societies. But whatever

their specialty, so long as they are concerned with the design, construction, or operation of the equipments and processes of production, they are confronted with social and political implications of their position in our society.

A nascent trend toward full recognition of these implications is curbed by several obstacles, chief among which, it would seem, are (1) the marked specialization and division of scientific labor, (2) the applications of professional codes governing the social outlook of engineers, and (3) the incorporation of engineers into industrial bureaucracies.

Specialization

The intensified division of labor has become a splendid device for escaping social responsibilities. As professions subdivide, each group of specialists finds it increasingly possible to "pass the buck" for the social consequences of their work, on the assumption, it would seem, that in this complex transfer of responsibility there will be no hindmost for the devil to take. When appalled by resulting social dislocations, each specialist, secure in the knowledge that he has performed his task to the best of his ability, can readily disclaim responsibility for them. And, of course, no one group of specialists, the engineer any more than the others, alone initiates these consequences. Rather, within our economic and social structure each technological contribution meshes into a cumulative pattern of effects, some of which none has desired and all have brought about.

The Professional Ethic

Deriving in part from the specialization of functions, engineers, not unlike scientists, come to be indoctrinated with an ethical sense of limited responsibilities. The scientist, busy on his distinctive task of carving out new knowledge from the realm of ignorance, has long disclaimed responsibility for attending to the ways in which this knowledge was applied. (History creates its own symbols. It required an atomic bomb to shake many scientists loose from this tenaciously held doctrine.)

So, in many quarters, it has been held absurd that the engineer should be thought accountable for the social and psychological effects of technology, since it is perfectly clear that these do not come within his special province. After all, it is the engineer's "job"—note how effectively this defines the limits of one's role and, thereby, one's social responsibility—to improve processes of production, and it is "not his concern" to consider their ramified social effects. The occupational code focuses the attention of engineers upon the first links in the chain of consequences of technological innovation and diverts their attention, both as specialists and as citizens, from succeeding links in the chain as, for example, the consequences for wage levels and employment opportunities. "But we have to include consequences impartially"—this is John Dewey putting the issue in more general form. "It is willful folly to fasten upon some single end or consequence which is liked, and permit the view of that to blot from perception all other undesired and undesirable consequences."

Bureaucratic Status

The employment of large numbers of engineers and technologists in industrial bureaucracies further shapes their social perspectives. Knit into a bureaucratic apparatus, many engineers take their place as experts in a subaltern role with fixed spheres of competence and authority and with a severely delimited orientation toward the larger social system. In this status, they are rewarded for viewing themselves as technical auxiliaries. As such, it is not their function to consider the human and social consequences of introducing their efficient equipments and processes or to decide when and how they are to be introduced. These are matters for administrative and managerial concern.

The grounds for assigning these concerns to administrators in business and industrial organizations have seldom been stated as lucidly and instructively as in the following passage by Roethlisberger: "... physicists, chemists, mechanical, civil, chemical engineers have a useful way of thinking about and a simple method of dealing with their own class of phenomena. Within this area their judgments are likely to be sound. Outside it their judgments are more questionable. Some of them recognize quite clearly this limitation. They do not want to be concerned with the human factor; they want to design the best tool, the best machine to accomplish certain technical purposes. Whether or not the introduction of this tool or machine will involve the layoff of certain employees, quite rightly, is not their concern as engineers... These men are invaluable to the administrator in any industrial organization."

Max Weber and Thorstein Veblen, among others, have pointed to the danger that this occupational perspective, involving the rationalized abdication of social responsibility in favor of the administrator, may be transferred by engineers beyond the immediate economic enterprise. From this transference of outlook and the resulting trained incapacity for dealing with human affairs there develops a passive and dependent role for engineers and technologists in the realm of political organization, economic institutions, and social policy. The citizen-self threatens to become submerged in the occupational-self.

As technical specialists thus attend to "their own" limited tasks, the over-all impact of technology upon the social structure becomes nobody's business through default.

The Needs of Social Research

Engineers may well continue to abjure any direct concern with the social effects of an advancing technology as

long as the effects cannot be anticipated and taken into account. To the extent that social scientists have failed to address themselves to this problem, there is no informed basis for the most socially oriented of technologists to act with due social responsibility. Only when those equipped with the skills of social research make available an adequate body of scientific knowledge can those working with the skills of engineering extend their sights from the individual business enterprise to the larger social system.

Just as men for centuries neglected the problems of soil erosion, in part because they were unaware that erosion constituted a significant problem, so they are still neglecting the social erosion ascribable to present methods of introducing rapid technological changes. There is a severely limited market for research in this field. It seems safe to suppose that fewer man-hours of research activity are devoted to the intensive investigation of these problems central to our technological age than, say, to the design of alluring packages for perfumes and other such basic commodities or to the planning of competitive advertisements for the tobacco manufacturers of the Nation.

The inauguration of a vast program of social inquiry proportioned to the scale of the problem need not wait upon new research procedures. Methods of social research have been advancing steadily and will undoubtedly become developed further through disciplined experience. The effective development of this program does wait, however, upon decisions concerning the organization of the research teams, sponsorship of the research, and the directions of inquiry.

Organization of the Research Team

Disparate and uncoordinated inquiries by diversely skilled groups have not proved adequate. The problems in this area call for the complementary skills and knowledge of engineers, economists, psychologists, and sociologists. Once this focus of joint inquiry is recognized, systematic efforts to institute a program of collaborative investigation could be begun by representatives of the several professional societies. Common universes of discourse would probably be lacking at the outset, but, as the experience of the TVA suggests, patterns of collaboration between engineers and social scientists can be evolved. The walls insulating the several disciplines raised up by the division of scientific labor can be surmounted if they are recognized for the temporary expedients that they are.

Sponsorship of the Research

Of the limited body of social research in industry, the greater part has been oriented toward the needs of management. The problems selected as the focus of the inquiry—high labor turnover and restricted output, for example—have been largely those defined by management, sponsorship has been typically by management, the limits and character of experimental changes in the work situation have been passed upon by management, and periodic reports have been made primarily to management. No matter how good or seemingly self-evident the reason, it should be noted that this *is* the typical perspective of social research in industry and, as such, limits the effective prosecution of the research.

These remarks do not, of course, impugn the validity and usefulness of research oriented toward the needs of management. From the fact that this research continues to be sponsored by management, we can conclude only that it has been found eminently useful and valid, within the limits of the definition of problems. But an intelligence staff for one stratum of the business and industrial population may in due course find itself focusing on problems which are not the chief problems confronting other sectors of that population. It may happen, for example, that devising methods of reducing workers' anxieties through sympathetic and prolonged interviews or through appropriate behavior by supervisors is not among those researches which workers regard as central to their interests. They may be more concerned with having research men uncover the varied consequences, for themselves and for others, of alternative plans governing the introduction of technological changes.

This reminds us that social research itself takes place within a social setting. The social scientist who fails to recognize that his techniques of participant-observation, interviewing, sociogramming, and the like represent an innovation for workers and supervisors greater, perhaps, than technological changes in the plant would indeed be a dubious believer in his own findings. Resistance to this innovation can be anticipated, if only because it is remote from run-of-the-mill experience of most people. Those who have engaged in social research among workers and administrative personnel need not be told of the mingled suspicion, distrust, uneasy amusement, and, often, open hostility with which they were initially met. Unfamiliarity with this type of inquiry, coupled with its apparent inquisitiveness into tension areas and private affairs, makes for some measure of resistance.

If the research is subsidized by management and if the problems dealt with are relevant primarily to management, the resistance of workers will be all the greater. It is small wonder that in some quarters of organized labor the preliminary efforts at social research in industry are regarded with a measure of suspicion and distrust comparable to that which attended the introduction of scientific management studies in the 1920's. For if workers have occasion to identify the research program as a newfangled academic device for countering labor organizations or for scientifically substituting symbolic for material rewards, it will create rather than locate problems.

Social research in industry, therefore, must be conducted under the joint auspices of management and

labor, irrespective of the source of funds for the research. The cooperation of large numbers of workers will not be achieved unless they know that they will be beneficiaries of an application of scientific method to a field where rule-of-thumb has largely prevailed.

The Directions of Research

The initial task of these research teams would be to search out the specific problems which demand attention. The very fact that they undertake the research would indicate that they are not possessed by the opaque faith that forward strides in technology, howsoever applied, must lead to the common good. They would be expected to think dangerous thoughts. They would not hold cultural and institutional axioms to be beyond inquiry. The focus of their attention would be the institutional arrangements adequate to incorporate the full potentialities for production of an unevenly but continuously advancing technology with a socialization of gains and losses contained in these advances.

During the last decade there has occurred a reaction among social researchers against the earlier tendency to focus on the economic consequences of advances in technology. The center of research attention was shifted to workers' sentiments and social relations on the job. This new emphasis, however, has the defects of its qualities. It is not only the sentiments of workers which are affected by technological change; it is not only their social ties and their status—it is also their incomes, their job chances, and their economic interests. If the new research on human relations in industry is to have maximum pertinence, it must be meshed with the continuing research on the economic implications of labor-saving technology.

Nor can the research be effectively confined to studies of "the worker." To single out the worker as though he represented a self-contained sector of the industrial population is to do violence to the structure of social relations which actually obtains in industry. Presumably, it is not only the worker who is subject to preoccupations, obsessive reveries, defects and distortions of attitude, and irrational dislikes of co-workers or supervisors. It might even turn out that the behavior and decisions of management are appreciably affected by similar psychological patterns and that these, as well as a clear-cut sense of economic interests, go far toward determining decisions on the introduction of labor-saving technology.

In the absence of research jointly sponsored by labor and management and aimed at commonly agreed-upon problems of the role of technology in our society, the alternative is to pursue the present pattern of piecemeal research, directed toward those special problems which it is in the interest of special groups to have examined. It is possible, of course, that this alternative will seem preferable to some. It is altogether possible that the several interested groups will find no basis for agreement on the sponsorship and direction of social research in this field. But then, this too would serve its backhanded purpose. Should research by technologists and social scientists under the joint auspices of management and labor be rejected on these grounds, it would be a significant diagnostic sign of the state which industrial relations have reached.

The Federal Government and the Shortage of Scientific Personnel

Charles V. Kidd
President's Scientific Research Board Staff, Washington, D. C.

THE RESEARCH AND DEVELOPMENT program of the Federal Government is, for a number of reasons, as large as, and in many fields larger than, during the war. Current expenditures on research and development, which are at about 20 times the 1940 level, will approximate $1,500,000,000 during the year from July 1946 to July 1947, excluding expenditures on the Manhattan Project. This means not only that the Federal Government is conducting or financing a very large share of the total research and development now undertaken in the country but that Federal policies with respect to research affect, directly or indirectly, every industrial laboratory, university, and individual scientist.

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The distribution of these expenditures, as well as their total volume, is significant. Since about 90 per cent of the total research and development expenditures of the Federal Government are accounted for by the War and Navy Departments, development bulks heavy in the Federal program. Construction of prototypes and similar work is very expensive when compared with expenditures on fundamental research, and the armed forces have a direct and primary interest in those applications of science directly related to improvement of the ability of the services to fight an effective war. This concentration of Federal expenditures on developmental work raises significant questions relating to the