Volume Title: Mechanization in Industry

Volume Author/Editor: Harry Jerome

Volume Publisher: NBER

Volume ISBN: 0-87014-026-4

Volume URL: http://www.nber.org/books/jero34-1

Publication Date: 1934

Chapter Title: Types of Labor-Saving Changes

Chapter Author: Harry Jerome

Chapter URL: http://www.nber.org/chapters/c5241

Chapter pages in book: (p. 27 - 54)

CHAPTER II

TYPES OF LABOR-SAVING CHANGES

SOMETIMES a change is described as 'labor saving' when it merely lessens intensity of effort and does not decrease time spent. For example, a fireman and an engineer are required on a railway locomotive whether it is hand-fired or stoker-fired, and hence the labor that is saved by the installation of mechanical stokers may conceivably consist only in a reduction in firing effort. However, any decrease in the intensity of the labor expended probably makes it possible for a fireman to handle a longer run effectively. Ordinarily saving of effort and of time are closely related. In any event, the use of the term 'labor saving' throughout this discussion will refer primarily to the saving of labor time.

PRODUCTIVITY-INCREASING VERSUS LABOR-DISPLACING CHANGES

Even when so limited, the term 'labor saving' has two closely associated but not exactly similar meanings. The one implies changes that increase the productivity of labor by increasing the units of output per hour of labor; the other implies labor displacement or a reduction in the number of workers required in a specific operation, plant, occupation or industry.

BASES FOR COMPUTATION OF CHANGES IN PRODUCTIVITY

For the first of these concepts, the term 'labor promoting' has been suggested, because it calls attention to the fact that the changes involved promote labor in the sense of making it more efficient in production. We shall use the somewhat more awkward, but also more self-explanatory, adjective 'productivity increasing' when we wish to designate changes that increase productivity—the output per hour of the labor applied.

Labor basis

In computing the effects of productivity-increasing improvements, it is essential to note what labor is included. For this purpose we may distinguish operating, auxiliary, embodied and indirectly required labor. Operating labor is that required directly in a particular process, such as the operation of a brick-molding machine. Auxiliary labor is that required in the plant for such operations as oiling, inspecting, adjusting and repairing the machine—in short, all plant labor that is necessitated by the use of the machine but is not considered as engaged in its direct operation. Embodied labor is the labor applied to the production of the machine itself and the materials of which it is made (prorated over the useful life of the machine), to the production of the materials used in machine repairs, and to the production of the power, oil, grease and other materials, if any, consumed in the operation of the machine. Lastly, we may extend the scope of our comparison still further by seeking to include not only the labor required in the factory production of the given commodity and in the production of the equipment used in the factory but also the additional labor required to put the given commodity in the hands of the final consumer ready for use. It is entirely possible, for example, that by heavy investments in highly-mechanized equipment a few well-equipped brick plants might be able to produce bricks at a greatly reduced unit labor-time cost for plant operations; but the necessity for a wider market, which the augmented production entailed, might result in increased outlays for the longer haul to market and for more intensive advertising and merchandising, so that the labor gains in manufacturing would be offset in part at least by increases in the labor required in transportation and marketing. It is the labor required beyond the manufacturing stage that we have designated as 'indirectly required'. While studies in productivity and labor displacement ordinarily stop short of the point of allowing for all these indirect factors, we should recognize that until they are included we have not ascertained the real change in productivity or the real amount of labor saved or displaced.

If labor saving is used in the sense of productivity increase, it seems at first that almost any pecuniarily profitable additions to equipment would also be labor saving, since the entire sum expended for additional equipment is not paid for the labor embodied in the equipment—some is for rent, interest and profits. Hence if the given change pays for itself in dollars and cents, it will ordinarily reduce the labor-time cost even more than the pecuniary expense. The factory manager does not customarily install new equipment unless he expects it to be profitable; hence we may not unreasonably set up an initial presumption of labor saving (compared with supplanted or rejected alternative methods) for all additions to equipment. But exceptions will appear when attention is directed to the types of labor involved. Some equipment is produced by cheap labor and replaces high-priced labor. In such instances the total labor time may be increased by the addition of new equipment. Because of such exceptions and because of differences in the degree of labor saving and in the channels through which the change in labor time takes place, it is highly important to make a close scrutiny of the concept of labor saving and the types of labor-saving changes.

Time basis

To appraise the relative productivity of two methods it is essential to observe whether the basis is a short period of uninterrupted running time, or an hour, day, week, month or year under actual running conditions. The speed of the cotton warp-tying machine running uninterruptedly (about 250 threads per minute) gives some clue to its possible output, but a more significant figure is a comparison between its output and that of hand tying-in operators during a normal working period that includes customary stoppages and idleness of operators or machines.

BASES FOR COMPUTATION OF LABOR DISPLACEMENT

The term labor saving is perhaps more frequently identified with labor displacement than with increased productivity. Labor displacement is a decrease in the number of workers required in (1) a specified operation, such as operating the brick-molding machine in our illustration above; (2) the plant as a whole; (3) an occupation, such as carpentry, wherever practiced; (4) an industry as a whole.

To illustrate: If, in a hypothetical plant, new brick-molding machines are introduced which, because of greater speed and more automatic features, make it possible for the machines with five operators to turn out the product formerly requiring ten operators—with, let us assume for the sake of simplicity, no change in the total output—then there is an 'operation labor-displacement' of five men, a displacement so far as the particular operation is concerned. If these five men are not assigned other work in the same plant there is 'plant labor-displacement'. If they find work in the same plant or in other plants but in an occupation other than that of operating brick machines, there is 'occupational displacement'. If they find work but in an industry other than brick manufacture, there is 'industrial displacement'. If they find no work at all there is 'complete displacement'. If it arises from a technological change, 'complete displacement', either temporary or permanent, is 'technological unemployment'.

Now labor displacement as above defined does not necessarily arise when productivity increases; nor, on the other hand, is labor displacement always accompanied by increasing productivity. They are boon companions but not inseparable. When increasing productivity is accompanied by an equivalent increase in the total output of the plant, there may be no labor displacement.

SUMMARY

To summarize, labor saving sometimes means an increase in productivity, sometimes a displacement of labor; the two concepts are not necessarily identical. Furthermore, the productivity comparison may be based upon only the direct operating labor or may be broadened to include auxiliary, embodied and indirectly required labor. In like manner, discussions of labor displacement may refer only to the effect on the size of the crew in a given operation, on the labor in the plant as a whole, on the number in a given occupation, in a given industry or in employment of any kind. Finally, there may be displacement of one type of labor, balanced more or less by increase in another type; there may be displacement of skill as well as of number.

As discussed more fully in Chapter X, some increases in mechanization increase the demand for skilled labor, others decrease it. Many recent changes are especially effective in reducing the requirements for semiskilled and unskilled labor. But mechanization has also touched the calculative and artistic activities. Bush's electric integraph accomplishes results difficult if not impossible of solution by the unaided efforts of the mathematician. The rapid spread of the 'talkies' has resulted in a sharp decline in the demand for theater musicians. Examples might be multiplied.

In practice most discussion of labor saving refers to labor displacement or increasing productivity in specific operations or plants, sometimes with and sometimes without allowance for increase in output, but ordinarily not allowing for all of the offsetting increases in embodied and indirectly required labor.

Let us endeavor to clarify the distinctions made in the above paragraphs by resort to a numerical illustration based on hypothetical circumstances. Let us suppose that the owners of a group of brick plants with a daily capacity of two million brick find that their brick-molding machines have depreciated to the point where replacement is necessary. They may install either 40 of the 'old' type similar to those previously used, with a production capacity of 50,000 each per day under actual working conditions (55,000 each if no allowance is made for stoppages), or 25 of a new type with a daily capacity of 80,000 each (90,000 if no stoppages are allowed for). They will presumably base their choice on the estimated relative pecuniary costs of purchase and operation; but we are interested in the labor-time costs, which we will assume to be as set forth in Table 2. The old equipment would require 70 operators and 10 auxiliary workers for

TABLE 2

HYPOTHETICAL CALCULATION TO ILLUSTRATE MEANINGS OF LABOR SAVING

TYPE OF LABOR	NUMBER OF WORKERS REQUIRED OLD	NUMBER OF WORKERS REQUIRED NEW	OUTPUT PER MAN PER DAY OLD	OUTPUT PER MAN PER DAY NEW	PERCENTAGE INCREASE IN PRODUCTIVITY [1]
Molding-machine operators	70	50	28,571	40,000	40.0
Auxiliary workers	10	5			
Total, operators and auxiliary workers	80	55	25,000	36,364	45.5
Total plant force	2,000	1975	1,000	1,013	1.3
Embodied labor	20	30			
Total, plant force plus embodied labor	2,020	2,005	990	998	0.8
Indirectly required labor	200	215			
Total, plant force plus both embodied and indirectly required labor	2,220	2,220	901	901	0

[1] Assuming a total output of 2,000,000 brick per day, both with the 'old' and the 'new' equipment.

oiling, repairing, adjusting the machines, etc.; the new-type equipment, only 50 operators and 5 auxiliary workers. Assuming that none of the other departments in the plant is affected by the choice between the old- and new-type molding machines, the total plant force would be 2,000 with the old, and 1,975 with the new-type. But, let us assume, more labor is required in the production of the new-type machines (30 instead of 20 men).[1] Furthermore, we assume that the

[1] This means that when the labor involved in the production of the machines is prorated over the useful life of the machine, the share estimated for one year is equivalent to the labor of 20 men for the year.

use of new-type machines necessitates the resort to more distant markets or in some other way increases from 200 to 215 men the indirect requirements for labor to get the product to the final consumer. The latter assumption would be more reasonable, perhaps, if we had also assumed an increase in total output; but even if not obviously plausible under the other circumstances we have assumed, the allowance for indirectly required labor will serve to illustrate allowances that should be made whenever a given change does result in greater labor requirements in the subsequent steps of getting goods to the consumer.

Now, it will be noted that the results are quite different, either in terms of productivity or labor displacement, according to what basis we take for the comparison. If operators of the molding machines alone are considered, the new-type equipment represents a 40 per cent greater productivity; if auxiliary workers are added, the differential is still greater —45.5 per cent; but if the entire plant force is considered, the gain is only 1.3 per cent. If embodied labor is brought into the computation, the differential shrinks to 0.8 per cent; and if the increase in indirectly required labor is also considered, the differential disappears. Still other differentials in productivity are obtained if we exclude from the computations plant labor not used in the specified machine operation or auxiliary thereto but include the 'embodied' labor and the labor required indirectly outside the plant.

Similarly, the new method represents an operation labor displacement of 20 men and a plant labor displacement of 25. When the industry as a whole is considered it appears at first that there is no net displacement, for the losses in the plant are offset by increases in the machine-producing, transporting and merchandising industries. However, we have no assurance that the additional men represented by embodied labor and the indirect increases in labor requirements will be either the same men replaced in the plant or even men of the same occupation or skill. There may be occupational and industrial labor displacement with possibly some technological unemployment, even though the total demand for labor in the industry is unchanged. There may be numerous shifts that result in increasing employment for some individuals and types, and decreasing employment for others.

If no allowance for stoppages is made, the differential of the new-type machine is even greater than computed in Table 2, for we have assumed a one-ninth loss of capacity through stoppages for the new type and only one-eleventh for the old type.

Labor-Saving Ratio

The ratio in which labor requirements are reduced by a change in equipment or methods may be algebraically stated thus:

$$S = 1 - \frac{N}{OP}$$

Where,

S=the labor-saving ratio
N=the number of workers required under the new method
O=the number of workers required under the old method
P=the ratio of the total output under the new method to the total output under the old method.

For example, if a new method reduces the crew required from 20 to 10 and doubles the total output, the labor-saving ratio is

$$S = 1 - \frac{10}{20} \times \frac{1}{2} = 3/4$$

If the 'P' factor is omitted we are measuring the labor displacement regardless of change in total output; if it is included, we are expressing the ratio between the labor required under the new method and the labor which would be required under the old method to produce the same total output. This difference measures a constructive rather than an actual displacement of labor, for ordinarily we cannot assume that the total output would have been the same if the old methods had been retained.[2]

As previously noted, 'N' and 'O' may for some purposes include only direct operating labor; for others they are broadened in scope to include auxiliary, embodied or indirectly required labor. If embodied labor is to be included, the necessary computation may be algebraically stated thus:

$$E = \frac{M \times F}{W}$$

Where,

E=the number of workers required for the production of the materials, equipment, etc., for one year of operation

M=the money cost of such materials, equipment, etc., for one year (total cost prorated over useful life)

F=the fraction of money cost that represents payments for labor, including all stages of the industrial process

W=the average earnings per year of workers in the industries in which the 'embodied' labor is employed.

In *The National Income and Its Purchasing Power* Dr. W. I. King has estimated the distribution of the income of the people of the United States among wages, salaries and the payments going to entrepreneurs and other property owners. Basing our conclusions in part on his estimates we reach a rough approximation of the figure that should be

[2] For illustrations of constructive displacement see Ch. X.

taken for F (the fraction of money cost which represents labor) as about 70 cents on the dollar (50–55 for wage earners and 15–20 for salaried workers).[3] For 'W' we suggest $1,416, this being the average annual earnings of employees (salaried workers and wage earners) in manufacturing in 1925. If used for other years suitable adjustments may be made for changes in average earnings.

Non-Mechanical Changes

This survey is primarily concerned with the causes, volume and effects of mechanical changes in industrial technique —in increasing mechanization—but this limitation should not blind us or our readers to the great significance and tremendous potentialities of non-mechanical changes leading to increased labor productivity. It is pertinent, therefore, to list some of these non-mechanical changes even though we do not pretend to measure their extent or effects.

Much has been accomplished by a better organization of factory work, often without any major additions to mechanical equipment. Re-routing to obtain a straight-line flow often not only reduces the handling labor but also materially increases the output in the processing operations. Greater subdivision of operations may increase productivity and not involve mechanical changes. A better balancing of equipment, perhaps by the elimination of a superfluous underworked unit, may economize labor. Substantial savings in labor have been accomplished by the multiple-machine or 'stretch-out' system, that is, by such reorganization of the work that one operator can handle more machines without an equivalent increase in auxiliary labor.[4]

[3] For methods of arriving at these estimates, see Table 31 (Ch. VIII).

[4] *Cf.* discussion in Ch. III, Cotton Yarn and Cloth section.

It has long been recognized that a slave economy was always handicapped by labor inefficiency. But studies in industrial psychology and working procedures are now making clear that even under a free labor system the most has not been realized from our industrial workers. Much depends upon personal efficiency. Better training for his job, better working conditions,[5] better conditions at home and opportunities for healthful and stimulating recreation—in brief, all conditions that strengthen the morale and improve the mental attitude of the worker are significant factors affecting productivity. Without passing judgment on a mooted point, we may call attention in this connection to the belief held by some students of the problem that part of the increased productivity of the post-War period may be ascribed to the effects of legal prohibition.

Changes in the type of product demanded affect the proportion of labor required. The substitution of the machine-made cigarette for the hand-made cigar is a case in point.[6] On the one hand are the demand for quality goods and the tendency to style changes that limit the development of quantity production and the consequent lowering of unit costs; on the other, the movement for standardization and simplification, fostered and encouraged by the Federal government and many trade organizations.

Changes in the quality of raw materials affect the productivity of machine operators. The weaver working with good thread that will not break frequently is able to turn out more cloth because his looms are more continuously in operation.

[5] For example, in laundries where the steam pressing tables, hot irons and hot water create an unnatural heat, the productivity of the worker may be substantially increased by an adequate air-washing and ventilating system.

[6] The introduction of a new line was the chief factor making it possible for one clothing manufacturer to dispense with 150 cutters.

Of high importance are those factors which, without necessarily making any alterations in the equipment or processes of industry, promote a fuller use of the available equipment by reducing, in one way or another, the idleness of men and machines. Here we may place the steps towards the elimination of seasonal fluctuations in industry,[7] also the efforts to stabilize cyclical variations and, for the single plant, a better balancing of its various departments,[8] improvements lessening losses through stoppages due to breakdowns, and other similar economies in the use of equipment and men. If fully successful these measures would release large numbers of workers for useful production in other industries. We may reduce railroad labor by organization designed to lessen the number of idle cars; far more laborers are engaged in mining than would be required if kept steadily employed; and many other examples of useless work or unproductive idleness could be cited.

Not all current tendencies in industry point to increased economies in the use of the available supply of labor. Some operate to lessen the supply. The movement for the five-day week or a shorter working day are steps tending to lessen the aggregate hours of labor normally available for production.

That equipment changes are not by any means the sole type of betterment in industry may be illustrated by a summary from a compilation of 97 instances of improvement in manufacturing operations published by Mr. L. P. Alford in *Manufacturing Industries,* September 1926. A dozen or more

[7] See *Seasonal Variations in Industry and Trade,* by Simon Kuznets (National Bureau of Economic Research, 1933).

[8] Several of the plants inspected by our agents were overmechanized in some departments. Thus one brick plant had steam shovel and industrial railroad capacity for a production three times its usual output; another had so many brick machines that the shovel and hauling locomotive could not keep them supplied with clay.

of the instances described by Mr. Alford might be classified on two or more bases, but utilizing as the criterion for classification only what we judge to be the major change, it appears that of the total 97 instances only 45 deal with equipment changes and 52 with changes in methods of operation and control. Of the 45 equipment changes 32 are concerned with conveyors, industrial trucks and other materials-handling equipment. Of the 52 betterments not primarily mechanical 16 are ascribed to production control, time and motion studies, and scientific management in general; 11 to budget control and study of the order market and forecasting; 9 to changes in cost systems and other accounting changes; 7 to methods of selecting workers and determining wages; and the remaining 9 to miscellaneous changes such as improvements in shipping methods, salvage and waste reclamation, improvements in service departments and tool control, and in inspection and office methods. Doubtless this list is not exactly representative, in that manufacturing concerns probably do not reveal changes in their processes quite so freely as they do other changes, but it is noteworthy that less than one-half of the betterments reported were equipment changes.

Mechanical Changes

In discussing the nature of mechanical improvements we may first note that mechanization is not synonymous with regimentation; it is by no means true that all routine operations are machine processes.

In the first place, even in the most highly regimented industries many of the workers are engaged in hand operations. The automotive industry has come to be taken as synonymous with mass production reduced to a simple routine; but in the automotive plants there are many hand workers. Even on the well-known Model-T Ford assembly belt, although some nuts were screwed down with the aid of air-driven tools, many of the operations were manual. In fact, most assembling, in automobile plants and elsewhere, is hand work.

Likewise, a large part of inspection and testing work is done without the aid of mechanical contrivances; and no small part of the work of packing and otherwise preparing for shipment consists of manual operations.

Nor does a high degree of mechanization always mean that the worker's function is a dreary unthinking repetition of a few simple motions. In fact, with completely automatic machines the function of the operator often becomes largely that of watching and repairing. In the use of automatic lathes, for example, part of the labor required is in adjusting the machine for a new job. Likewise in the weave room of a modern cotton factory many of the employees are 'loom fixers' whose function is to keep the looms in order and adjust them for new work.

MEANING OF 'MECHANIZATION'

In the broadest sense we mean by mechanization the use of tools or equipment of any kind to aid the human brain and muscle, and by 'increasing mechanization' we refer to any change in methods or equipment that tends to lessen reliance on the unaided mental and manual endowment of the worker. In this broad sense the transition from plows pulled by men and women to the horse-drawn plow is a step in mechanization, as well as the later replacement of the horse by the power tractor. Our interest centers chiefly, however, in *power mechanization*—in the increasing reliance on equipment driven by generated power, be it steam, electricity, compressed air or gasoline that furnishes the motive power. We return in Chapters VI and VII, in connection with the measurement of mechanization, to a further discussion of its nature.

TYPES OF LABOR-SAVING MECHANICAL CHANGES [9]

Aside from changes so general that comparison can be made only in terms of the net results—and these may be very important—we may note four fairly obvious ways in which changes in equipment may reduce the labor requirement, relative to the output, on specific operations, namely, by: (1) eliminating one or more hand operations; (2) increasing the speed of the machine; (3) enlarging capacity (through greater physical size) without corresponding increases in the labor requirements for feeding and attention; [10] (4) substituting a different process requiring less labor, such as the substitution of electric welding for riveting.

The use of better materials or a greater durability of machine parts has, by keeping the machine in steadier operation, substantially the same effect as making the machine faster or larger.

Elimination of Operations

Labor saving by the elimination of one or more manual operations is a common type of development. Oil burners replace the firing and coal-wheeling operations and eliminate ash removal. Wick oiling or other automatic oiling devices replace or reduce the hand oiling operation. Automatic looms differ from the non-automatic chiefly in that full bobbins or

[9] We are dealing here chiefly with those changes which are modifications in an existing plant, and not with the rising level of efficiency which may come from the building of newer modern plants and the scrapping of older plants. See discussion in a subsequent section of this chapter.

[10] *Cf.* discussion of increasing speed and unit size in Ch. VI.

shuttles are inserted automatically so that it is not necessary for the machine to stop while bobbins or shuttles are changed by hand; automatic feeds on presses and other machines may not change the actual speed of a machine during its running time, but may keep it in more continuous operation and eliminate or reduce hand feeding. One paper manufacturer reports that automatic feeders replace one man on each machine and require only the occasional attention of a foreman, with a one hundred per cent increase in production. Serial arrangement of machines often provides automatic feeding by carrying material directly from one machine to the next. On the newer types of soft-mud brick machines the hand-dump feature of older models is replaced by an automatic dump; in a cotton mill the Morton automatic distributors to the pickers reduce the labor required in the feeding operation. The use of pulverized coal or a change from hand to mechanical stoking, or from produced to purchased power reduces or eliminates the powerhouse crew so far as the manufacturing plant is concerned.

Frequently mechanical changes that eliminate or alter specific operations constituting only part of a process have little effect on total output, but operate rather to reduce the crew required. Thus in blast furnace operation the introduction of automatic filling or the pig-casting machine tends to reduce labor rather than to increase the output of the stack.[11]

Sometimes alterations in methods, or in equipment, at one stage in fabrication make possible the elimination of a set of machines in another stage. In cotton manufacturing there has been some tendency in the decade under discussion to eliminate one of the picker processes, owing in part to better 'opening' equipment in the preceding process. Replacement of electricity by waste-heat boilers in the cement

[11] B. L. S., Ref. 37, pp. 29-30.

industry is one example of the reverse tendency, that is, alterations in equipment or technique that add operations requiring manual attention and thus increase the crew.

Discussion of the reduction of labor requirements by increasing the size and speed of machines—important tendencies in the current march of mechanization—is deferred to Chapter VI.

Imitation of Hand Procedure

Some mechanical substitutes for manual methods radically alter the operation; others are close imitations of the hand processes. The evolution of the bumping and dumping mechanism in the automatic-dump brick machine was an adaptation of the identical principles that were employed in bumping and dumping the molds by hand. Likewise, in the production of window glass the cylinder-machine process is similar to the hand method of blowing a long cylindrical bubble of glass, which, when cool, is split open and flattened. The cylinder machine is simply a mechanical glass blower. In the sheet process, on the contrary, a flat sheet of glass is drawn directly from a forehearth containing a semicooled mass of glass, thus eliminating the splitting and flattening of the cylinder.

Obviously some developments can be considered only as indirect substitutes for hand methods, in that the machines accomplish tasks scarcely performable by manual effort. A freight locomotive pulls a heavy train at a speed that no group of men, however large, could equal. We have, in fact, ceased to consider a freight train as labor saving; yet it is conceivable that the goods now transported in railway trains might be carried on the backs of human beings, as is still done to a large extent in China. From that point of view, a railway train is a substitute for unskilled labor. However, we are concerned not with fine-spun distinctions but with the more definite problem of the substitution of machines in operations now manually performed, or in changes in machines that reduce the volume or change the type of labor required. We are particularly interested in those machines which perform operations customarily carried on by the common or unskilled laborer.

Mechanization by Conversion

Mechanization is frequently advanced by the addition of attachments to existing equipment. Many non-automatic looms have been converted to automatics. Likewise, to many hand-power section cars motors have been added.

New Construction

Our field survey dealt chiefly with those types of labor-saving changes which take the form of alterations in existing plants. A highly important phase, however, is the raising of the general level of mechanization by the construction of new, better equipped plants; the older, less efficient plants are gradually abandoned and the high-cost producers 'go to the wall'. This form of evolution to a higher degree of mechanization is especially favored by readily available capital.

METHODS OR EQUIPMENT DISPLACED

Does mechanization progress chiefly through the substitution of power equipment directly for hand methods or does it in most instances take the form of labor-saving improvements in operations already mechanized? The available evidence is inadequate both in form and quantity for a conclusive answer, but we may gain some idea of the relative importance of direct substitutions of mechanical for manual methods. To this end we classified 608 labor-saving changes upon which information was obtained in our survey, and also 234 instances reported in various technical journals.[12] Of this total of 842 instances 47 involved the displacement of horse-motivated equipment by generated power; 536, the displacement of hand equipment and methods; and only 259, improvements in power equipment.

The displacements of horse-motivated equipment were chiefly substitutions of motor trucks and tractors for horses in highway construction, the mechanization of haulage in mines and in brick yards, and the substitution of power trucks with self-dumping devices for horse-drawn wagons in retail coal yards.

Displacement of Hand Methods

Over half of the instances reported, both in our survey and in the articles in technical journals examined by us, involved the direct displacement of hand methods by mechanical. This seems strange in an age that is reputed to be highly mechanized, and the proportion may be considerably overestimated owing to the tendency for informants to recognize more readily as labor saving a change that directly substitutes a mechanical for a hand process; that is, much labor is saved indirectly from improvements in processes already mechanized. Moreover, when displacements were reclassified by us according to whether they arose in handling or in processing operations, it was found that nearly half of the substitutions of mechanical for hand methods arose in

12 Excluding 256 instances in our survey or in the technical journals examined which were not classifiable on the bases here used.

handling operations, which have been, and still are, largely manual.[13]

The 186 instances from our field survey which we classified as the displacement of hand methods by mechanical in the processing operations include the substitution of power molding machines for floor or bench molding—even if the floor or bench molding was done with the aid of pneumatic sand rammers (35); the introduction of machines for preparing the mold sand (6); warp-tying machines for hand tying (7); steam pressing machines for hand irons in garment shops; automatic proportioning and metering systems in the cooking of paper pulp (5); the introduction of machine finishing in highway construction in place of men with strike boards (20); various wrapping, packing, labeling and filling machines, which largely replace female labor (11); power screening plants in retail coal yards (4); various wood-working machines; paper-box stitching and wood-box nailing machines; hydraulic core-removing and sand-reclaiming devices; paint-spray guns (3); various garment-working devices, such as basting, stitching, felting, and rotary cloth-cutting machines (5); and mattress-making machines.

Displacement of Mechanical Equipment

The labor-saving changes in the compilation just mentioned which involved the substitution of one mechanical device for another in handling operations were largely the replacement of steam hoists or power shovels by the electric type (6); of steam shovels, hoists or industrial locomotives by the gasoline type (6); alterations in conveying systems (9); new motor trucks with the power-dump feature for older

[13] For the importance of the handling operations and the proportion of labor-saving instances that pertain to handling, see Ch. V.

types of trucks in retail coal handling (12); and the substitution of caterpillar tread for wheel tread on power shovels.

Between a fifth and a sixth of the total labor-saving instances classified are changes in mechanical methods of processing, including in that term practically all operations not covered by the phrase 'handling operations', such as fabrication, assembling, packing and packaging, and the production of power and heat. As previously suggested, it is our belief that the proportion indicated considerably underestimates the relative importance of this group of changes in the increasing efficiency of our industries. This underestimation is in part at least due to the indirect ways in which much of the labor saving from improvements in processes already mechanized arises.

Indirect Savings of Labor

Changes in industrial technique not altering materially the amount of labor involved in the operation immediately affected, may, nevertheless, alter substantially the labor required in other processes; for example, through a reduction in the floor space required, in reduced waste of materials or damage to product, or through savings in fuel, power, supplies, or wear and tear on machinery. All these—floor space, materials, equipment—require labor in their construction, and any economies in their use have an indirect effect on the demand for labor.[14] Thus the electrification of the power department of a factory may reduce maintenance labor owing to the absence of belts and shafting.

One excellent example of the saving of labor through reduction of waste in the use of materials is afforded by the improvement in the utilization of fuel in the production of

[14] For further discussion of these indirect savings, see Ch. X.

power. According to estimates of the Geological Survey, from 1919 to 1929 the average quantity of coal required to produce a kilowatt-hour of electricity has decreased from 3.2 to 1.7 pounds.[15] This refers to the production of electricity by public utility power plants in the United States, and inasmuch as the consumption of coal or coal equivalent of other fuels in the production of such power amounted in 1929 to 52,574,000 net tons, it may be estimated that the reduction in the amount of fuel required for a kilowatt-hour from 3.2 to 1.7 pounds is equivalent to a saving of about 46 million tons of coal, which, of course, lessens the need for coal-handling labor not only in public utility plants but also in the transportation and mining stages.

Classification of Machines

OPERATION IN WHICH USED

For our purpose a significant distinction is between equipment used in handling and in processing, in converting materials into different forms or combinations. Handling equipment includes, for example, conveyors, overhead cranes and trucks (*cf.* Ch. V). Processing equipment includes a great variety of devices used in converting materials into different forms or putting them into different combinations such as: metal-working machines, wood-working, painting, labeling, wrapping and packaging equipment and devices for lubrication and cleaning. Here also we may, broadly speaking, include the equipment for power generation and transmission, though for some purposes we may wish to differentiate power equipment from both handling and processing equipment.

[15] Ref. 31, p. 198, and *Commerce Yearbook, 1930*, I, 271.

DEGREE TO WHICH AUTOMATIC

A higher degree of mechanization does not necessarily mean recourse to completely automatic machines. In fact, relatively few machines are completely automatic in all phases of their operation, especially if feeding of materials and the removal of their products are included. The distinctions between non-automatic, semiautomatic and automatic do not in practice follow rigid rules and their meaning must be examined in each particular instance.

The non-automatic loom, for example, is really a semiautomatic piece of machinery which requires hand operations in refilling with full bobbins when the thread has been exhausted. Again, a piece of equipment may not be automatic at all in the sense that it is driven by generated power, and yet it may save labor. Witness the Barber and Boyce knotters, used by textile weavers, which are merely devices to facilitate the hand tying of knots.

Not all automatic equipment is labor saving. Thus automatic train control is generally regarded as a safety device.

TYPE OF POWER

The mechanized unit is most commonly one that is driven by generated power of some kind—steam, electricity, water, gasoline, waste heat, compressed air—but when we speak of the progress of mechanization in the broadest sense, we hesitate to exclude the substitution of wind power (windmills) or of horse power for hand power.

The progress of mechanization may be either extensive or intensive. The former describes a wider use of a given type of equipment, the latter, the transition to more and more automatic types in a given process. Such a transition is seen in the substitution, first, of non-power driven simple tools for the unaided hand, then the addition of horse power, and finally of generated power devices of an ever-increasing degree of automatic operation.

AGENCY BY WHICH PRODUCED

If we classify by origin, we may distinguish three types of labor-saving equipment, which may conveniently be designated as 'homemade', 'tailor-made' and 'ready-made'.

'Homemade' devices are machines, attachments or adaptations worked out by the machine user himself. Many of the larger machine-using factories maintain a staff whose chief function is the development of new equipment for their own use. Even when a machine is manufactured by a specialized machine-producing plant, its perfection, particularly in the initial stages, is often due partly to the suggestions contributed by the user who is thus a co-inventor. In fact, many machines are first developed in crude form by users, perhaps under the pressure of emergency, and then later improved and commercialized. The cotton sled, for example, was at first a homemade device. An enumeration of a few of the many machines found in our field investigation, that had been built by the users, will illustrate their diversity: a machine for pipe core making; a device for pulling out the cupola drop in a foundry cupola; finishing wheels for spinning-frame rolls in a textile machinery factory; paper folders in a paper factory; twisters in a carpet factory; trimmers in the cloth room of a sheeting factory; strike boards in the placing process on highway construction; a homemade hand pavement finisher; homemade pile drivers; homemade subgraders; adjustments for applying pressure in tire core-building; a feeding device for the calendering machine in a tire factory. The *Brick and Clay Record* publish a little book entitled *101 Ideas for Improving the Clay Plant,* which is a compilation of short items describing miscellaneous machines, equipment and apparatus, many of them homemade, that manufacturers have installed in their plants to improve certain processes. We surmise that the relative importance of such homemade improvements is minimized in most studies of the extent of labor-saving changes, for the users are often reluctant to reveal the nature of their specialized machinery. As the manager of one plant wrote us, "we make our own labor-saving machinery. We do not care to give out any information."

Probably the most significant labor-saving changes in equipment in the decade just past have been 'tailor-made' by engineering firms whose special function is the designing and installation of mechanical equipment. True, as noted in the above paragraph, there are thousands of appliances and adjustments worked out by machine users, but these are not likely to be extensively adopted by other concerns until improved and more or less standardized by machine manufacturers. As one prominent agricultural engineer expresses it, progress cannot "wait for the accident of genius; research has taken the place of inspiration." In the installation of conveying systems, particularly, the work of specialized engineering concerns has been an important factor in recent labor economies.

'Tailor-made' equipment has some of the elements of secrecy characteristic of 'homemade' equipment. In reply to our inquiries concerning labor-saving machinery produced by it, one concern engaged in making machines to order writes: "In regard to the numerous special machines that we manufacture under contract, these machines are practically all of the labor-saving type, but in most cases the design is furnished to us by the customer and built in accordance with the customer's blue prints and specifications. We are not at liberty to disclose what these machines are nor what their production record is."

'Ready-made' equipment is produced in more or less standardized units, in varying sizes perhaps, but sufficiently standardized so that some degree of quantity production is possible on the part of the machine producer. Here we may list such equipment as portable conveyors, trench diggers, steam shovels, automatic looms, paving mixers, paint-spray guns, pneumatic hammers, electric trucks, domestic sewing machines, vacuum cleaners, brick-molding machinery—all equipment whose use has become so general that it is not necessary to build a machine to order for each user. The extensive development of a 'ready-made' machine-producing industry is dependent upon a reasonably certain large market for the product. The 'tailor-made' machine builder relies on a smaller number of more diverse orders. Consequently such stimulus to the machine-producing industries as has arisen from the immigration restriction of the War and post-War periods has probably been most influential in the development of the 'ready-made' branch of the industry.

Perhaps to the three types mentioned should be added the sporadic output of the 'born inventor'. The manager of a plant manufacturing nationally-advertised products of diverse types stated that in their processes the device of the outside 'born inventor' seldom worked; that a machine prepared for a particular task by a company specializing in making such devices seldom works at first but must be gradually modified to fulfill its particular function. The best results come from devices perfected by their own staff.

In general, the typical new machine that becomes of wide use goes through an evolution starting perhaps with the genesis of an idea in the mind of an individual, is experimentally developed as a 'homemade' or 'tailor-made' machine, tested by users with adaptations on the basis of working experience, and finally becomes sufficiently standardized to pass over into the 'ready-made' class.

SUMMARY

We shall have accomplished our major purpose in the present chapter if we have made it obvious that the phrases 'labor-saving', 'labor displacement' and 'increasing mechanization' have many shades of meaning which may advantageously be distinguished though none can be arbitrarily selected as solely appropriate for use; furthermore, that the agencies by which labor saving, labor displacement or increased mechanization may be accomplished are of almost unlimited variety. This multiplicity of agencies and processes in labor saving explains the diversity of approach in the subsequent chapters and the difficulties in reducing the problem to simple statements and solutions.