PRZEGLĄD TECHNICZNY

Pierwszy międzynarodowy kongres naukowej organizacji pracy

PRZEGLĄD TECHNICZNY

Harmonizacja jako jedna z głównych podstaw organizacji naukowej.

PRZEGLĄD TECHNICZNY

I Międzynarodowy kongres mechaniki technicznej

Harmonization as one of the main foundations of scientific organization (1924 Article Series)

Forward to the English edition:
In this series, Karol Adamiecki identifies the lack of coordination or "harmonization" between departments and work cells as the biggest waste in industry; contributing to idleness and underwork in some areas, while leaving the machines and workers in others overutilized and overburdened. Just as in musical harmony, the goal of the plant manager is to ensure "each sound is played at the right time, neither earlier nor later. In this regard, the role of the composer is similar to the role of the manager: both aim for harmony, the musician in terms of the harmony of the sounds, the manager in terms of the harmony of the work elements."

The article is divided into three parts, covering the following topics:

1. *Introduction and attempt at harmonizing actions: The importance of proper coordination and timing in work processes.*
2. *Cost of time: The significance of time costs in production systems, as well as the importance of level-loading.*
3. *Harmony in the selection of cells and harmony in action: The interconnectedness and interdependence of elements within a production system.*
4. *Analysis and planning of collective work using graphical methods: Introduction to the "Harmograph" visual management tool for planning and better understanding of plan versus actual.*
5. *Laws of economics as the basis of the science of organization: The article concludes by discussing the role of harmony as a fundamental law of economics, which influences work organization and efficiency.*

In addition to the theoretical aspects, Adamiecki includes case studies and outcomes from utilizing his methods of graphical analysis and harmonization. These examples provide valuable insights into the practical application of his ideas in real-world settings.

Part I

Technical Review [*Przeglad Techniczny*], 1924, Vol 62, No. 49, pp. 551-554

Works cited:
Chapman J. C.: Trade Test. Henry Holt, New York 1921. Cowdrick E. S.: Industrial History of the United States, Ronald Press Co. New York, 1923; also, Manpower in Industry. Henry Holt, New York, 1924; Fleming and Pearce: Research in Industry. Henry Holt, New York, 1924; Link H. C.: Education and Industry. The Macmillan Co, New York, 1923; also, Personnel Administration. McGraw-Hill Press Co. New York, 1923. Mann, C. R.: A study of Engineering Education. Carnegie Foundation, New York; Thompson S. E.: Underground Management in Bituminous Coal Mines, 1923: Yoakum and Yerkes, Army Mental Tests. Henry Holt, N, Y.. 1920. Other references: The Applications of Psychology to Industry; Atlantic Monthly; Bulletin of The Taylor Society; Chemical and Metallurgical Engineering; Journal of Industrial Hygiene; Psychology in Business

(Annals of The American Academy of Political and Social Science); The Psychology of Vocational Selection; Vocational Guidance.

Paper I presented at the International Congress of Scientific Organization of Labor, in Prague in 1924.

Note [original]: The text includes historical and technical terms that may require additional context for a complete understanding.

I. Introduction.

In March 1903, F.W. Taylor presented his principles and methods for the first time, stating that the fundamental issue of organizing work should be solved based on scientific principles, rather than relying solely on intuition, as it had been done previously.

Coincidentally, in February of the same year, during a lecture I gave at the Technical Society in Ekaterinoslav [Dnipro] (the center of the South Russian mining and metallurgical industry), I expressed the same idea and presented the main outline of the method of organizing collective work. This lecture was a report on my first works and research in this direction, which had started in 1895.

Since these studies later led to the establishment of a general principle based on one of the three fundamental laws of economics that guide organic nature towards the highest economy, and since this principle, when applied in practice, either by me or my colleagues, always led to a significant increase in work efficiency and savings in costs, and because this principle, as I believe, is still little known and underdeveloped, I am encouraged to present it for further development and application of the science of organization.

II. Attempt at harmonizing actions.

My research in the field of organization began with a seemingly trivial issue: I had to solve the problem of increasing the production of a small ironworks unit. The daily production of the team of workers involved in rolling thin sheet metal seemed too small to me. At first, I thought that the reason for this was the sluggishness of the workers, especially since the foremen, brought in from outside of the country and considered to be first-class specialists, saw this as the reason for the low productivity, sharply criticizing our workers. This hurt my sense of national pride, especially when upon closer observation, I realized that the workers were working diligently.

I began to study more closely and search for other causes, taking note of the time required for each individual operation with the help of a stopwatch with a second hand. The research was not easy, as I had to do it surreptitiously so that the workers would not think badly of me and harm my reputation as a young assistant to the chief engineer. Over several months, I gathered a lot of data, but I could not make sense of it until one day I came up with the idea of plotting it on charts. I immediately noticed a major cause of the large amount of time wasted due to the lack of coordination among the various operations.

I plotted my data on charts in the form of a series of parallel lines, similar to those used on the perforated paper rolls of mechanical pianos (pianolas, angelus, etc.). This chart showed several areas of congestion and large gaps, but most of all, it showed a great deal of variation. It was clear that even minor delays in some of the less significant operations would later cause significant gaps in other operations or excessive crowding. In other words, the root cause was a lack of coordination in the timing of individual movements and operations.

The factory involved in this study used two pairs of rollers and three furnaces, operated by a crew of 16 workers.

As is well known, this work involves rolling flat iron of the appropriate weight and dimensions, subject to multiple heating and rolling until the material reaches the desired dimensions. During rolling, individual pieces are rolled first singly, then doubly or quadruply, in the form of so-called "packets." Each packet thus goes through a series of alternating operations involving multiple heatings and rollings, along with a series of different additional activities such as loading into the furnaces, feeding into the rollers, arranging in packs, etc. The whole series of operations lasts from one-half to one-and-a-half hours, depending on the size and thickness of the sheets, and individual operations last from several seconds to half an hour. We have here a typical collective work of technical equipment and people.

On the graphs mentioned above, I arranged the individual main operations on the horizontal direction [x-axis], and the time scale in the vertical direction [y-axis]. The lines drawn along this scale under each operation indicated the beginning, duration, and end of the given operation.

Looking at such a graph, which in a sense is a cinematographic diagram of all activities, a lack of harmony was noticeable both in the vertical and horizontal directions. It was evident that for obtaining a high production rate, the speed of individual operations was of secondary importance, while it was starkly highlighted that the main reason for low production was the fact that individual activities rarely took place at the right time, which caused interruptions or overloads.

A similar phenomenon, albeit on a smaller scale, can be observed when several people carry a heavy load. If the movements of all these people are not mathematically consistent, according to a certain sequence, there will be an uneven distribution of the load, overloading individual people, and as a result, a lot of energy is expended with little useful outcome.

Having found this main cause of the low efficiency of the studied group of people and equipment, I naturally asked myself what production could be achieved if the lines were arranged in a strict order, consistent with the logic of the process. Since the idea of directing work according to a pre-arranged chart came to mind, like conducting an orchestra with individual instruments using sheet music, I believed that it would be better to start at a slower tempo, but harmoniously. To simplify the issue, I took the duration of each operation as a starting point, not the shortest possible, but, on the contrary, even slightly longer than average. After making several such test charts, I selected the one presented in Fig. 1.

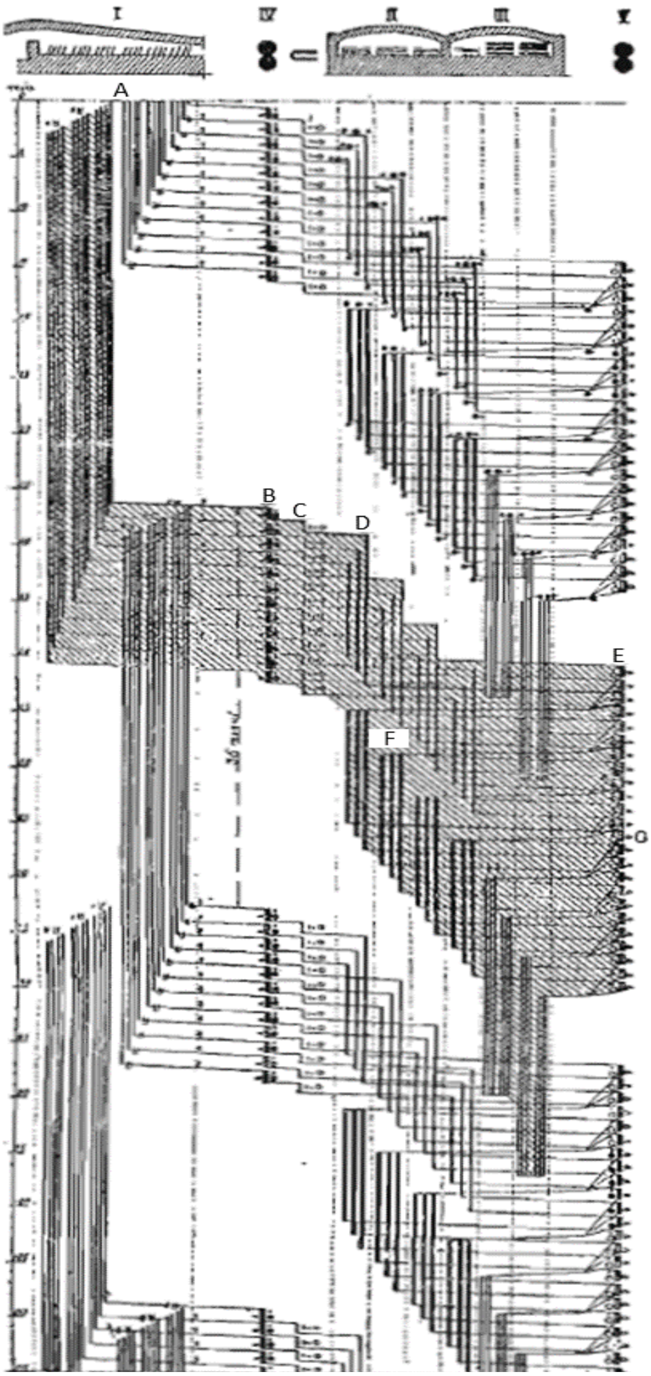


Figure 1 - Harmonograph characterizing the time consumed for individual activities

The A lines represent the time of the first heating of each packet (13 pieces) in furnace No. 1.

Line B shows the time of the first rolling on the first pair of rollers, No. IV.

Line C shows the time for bending double packs into quadruple packs.

Line D shows the time of the second heating in furnaces No. II and III.

Line E shows the time of the second rolling on the second pair of rollers, No. V.

Line F shows the duration of the third heating, and so on.

In this graph, we see the entire history of each finished pack, i.e., all the individual operations to which it is subjected during the entire process. The course of operations of one sequence is shown on the graph by slightly thicker lines. The shaded bars represent the history of a series of packs, which is referred to as a "batch." The vertical scale, in this case, is expressed in minutes. We can see, for example, that the total time for all processes for one pack is about 90 minutes. The rate of work could be called the time intervals between one batch, or series, and another; the rate, in this case, is 36 minutes.

Of course, the spaces between the lines represent stops in the work, that is, the idling of individual machines.

A casual glance at the chart shows that it is not a graph of the highest efficiency that could be achieved from the given devices - furnaces and rolling mills; we see that the waves after each series could still be brought closer together, but only to the limit of touching the lines of the IV-V rollers, which would reduce the work rate from 36 minutes to 30 minutes.

However, I decided not to do this because, having marked the work of people with corresponding symbols on the chart, I found that some of them would be overloaded and would not have the necessary breaks, which are essential even for the lightest work. Therefore, for this reason, I gave up on the first attempt to achieve maximum production that could be obtained with the given equipment and dimensions of rolled sheets. Even so, at a rate of 36 minutes, the efficiency expressed in kilograms exceeded the ordinary average production by several multiples, that is, the introduction of such organization promised an excellent result, namely: the usual daily efficiency was 2,500 to 2,800 kg; the foremen claimed that with other, better workers, it would be possible to achieve 5,000 kg; meanwhile, my reduced chart was calculated at 10,000 kg.

Finally, I decided to make an attempt. I won't describe here the resistance I initially encountered from the workers, who felt somewhat constrained in the freedom with which they usually operated. But already on the second day, this resistance completely disappeared. Instead there was noticeable satisfaction due to less fatigue, thanks to the balanced rhythm of work and breaks, and the increased production, which had risen to 8,500 kg. I even noticed among the workers a certain kind of satisfaction, which could be compared to the satisfaction of musicians in an orchestra when they manage to play a piece in harmony and with the appropriate enthusiasm.

As we mentioned earlier, the pace of a given task could be reduced to only 30 minutes, i.e., to the limit of full utilization of time for roller No. V. But, as can be seen, furnace No. I and roller No. IV will still be far from their benchmark production, hence the obvious conclusion that for the given task, individual devices were not properly matched. From the chart, it can be seen that roller No. V is not adequate to ensure the total production capacity of roller IV and the furnaces, particularly furnace No. I. The latter being at least twice as large as required.

We see, therefore, that the comparison of this kind of collective work charts not only facilitates the planning of the arrangement of the elements of such work, but also provides clear indications as to the relative sizes of individual devices.

III. Cost of time.

By examining the losses caused by low efficiency and then looking for the relationship between cost expenditures and the quantity of products produced in a given time, I concluded that all expenses of each production can be divided into the following three categories:

1. Expenses for which time has no significance and whose amount depends solely on the quantity of products produced;
2. Expenses which, on the contrary, are completely independent of the quantity of products, flow continuously and uniformly, and during a given time period are solely dependent on the length of that period, i.e. they are proportional to the length of the previous period of time;

3. Expenses having properties intermediate between the first and second, namely those which, although they fluctuate simultaneously with the fluctuation of production, this fluctuation is not completely proportional to it, since a certain portion of such expenditures flows steadily and semi-independently of production.

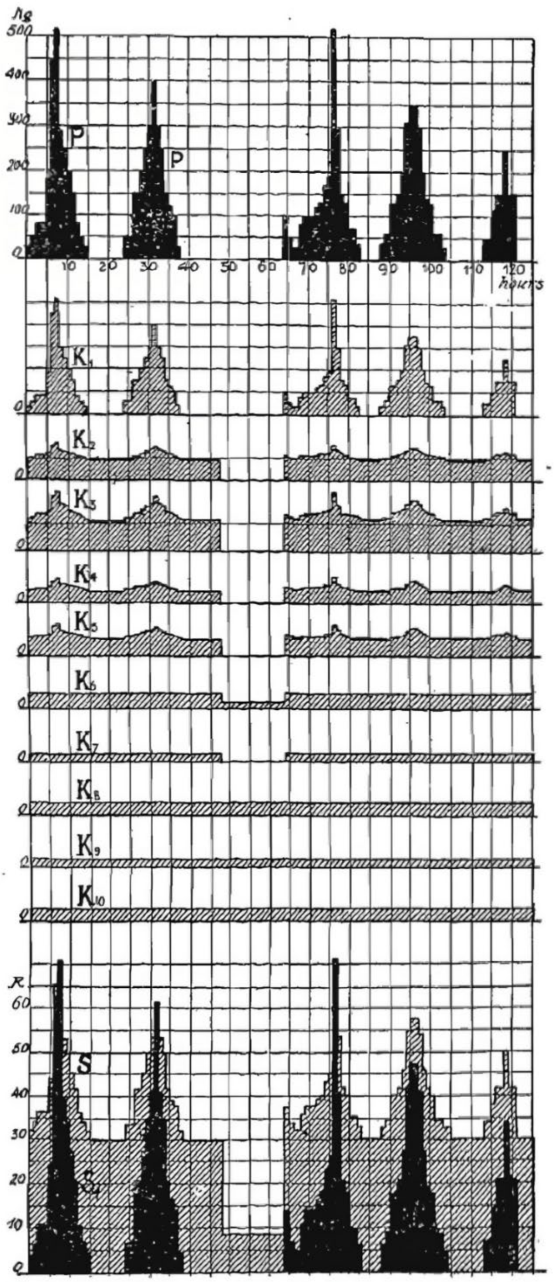


Figure 2
Production costs, reference cost, and cost of lost time.

I stated the above in a report presented at a meeting of the Association of Technicians in Warsaw in 1908 (see Technical Review [Przeglad Techniczny], from 1909).

I then cited the example of the hourly cost flow in a certain manufacturing process, graphically represented in Fig. 2. The vertical ordinates of the curve P express the actual fluctuations of production per hour, while the ordinates of the other curves K_1 to K_{10} express the individual positions of operating costs per hour as they fluctuated over time. The vertical coordinates of curve *S* represent the total costs per hour. It is obvious that each production becomes most economical when production per unit of time reaches its maximum, as then the cost of one unit of product is the cheapest, and this cost can be considered as the standard. Therefore, if production per unit of time is lower than the possible maximum, its cost will be relatively higher, and the difference between it and the standard cost will be the cost of lost time. The area covered by the cost curve *S* expresses the total actual cost for a given period; the area under the curves S_1 expresses the standard cost, and the difference between these areas expresses the cost of lost time during that period.

The presented graph of the flow of operating costs only confirms the most general theorem concerning the relationship between operating cost and productivity per unit of time, namely:

1. If productivity drops to 0, i.e. a given production workshop is idle, the cost per unit of time never drops to 0
2. If productivity per unit of time increases, the cost also increases.

Analyzing their operating costs, [accountants] express this relationship simply in the form of a graph shown in Fig. 3, i.e. they consider the total cost as if it were made up of two parts - a fixed K_0 independent of production, and a variable K_1 proportional to production; that is, they assume that the cost line per unit of time is a straight line *AB*.

However, this assumption is incorrect. The cost line is not a straight line, as shown in Fig. 3, but a curve gradually tilting upwards. I have arrived at this conclusion by a simple observation of facts. Analyzing the costs of all manufacturing plants, we can easily see that the more a given plant produces, the lower the cost per unit of production will be, but for each plant there is always a certain well-defined limit of productivity at which the cost per unit is the lowest; if this limit is exceeded, the cost per unit begins to rise again, i.e. productivity becomes less economical. In other words, there is always a certain limit of productivity beyond which overburden occurs.

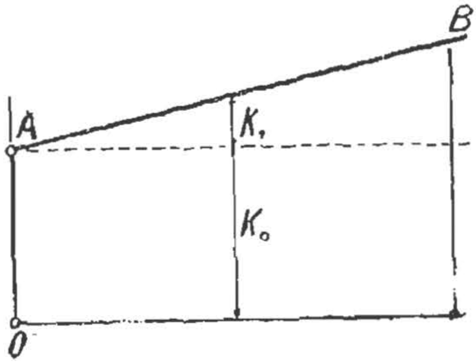


Figure 3
The relationship between operating costs and efficiency

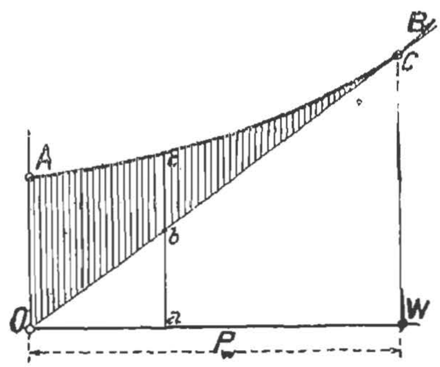


Figure 4
The proper picture of the relationship between operating costs and efficiency

If we consider expenses as the expenditure of energy and resources, we will realize that every machine, every working cell, every process, small or large, and finally every human being has this property. It is a principle of nature and we cannot imagine that such a limit does not exist for each production unit. This limit is one of the most important characteristics of each production unit.

This allows us to claim that the cost per unit of time is expressed by the upward-sloping curve *AB*. And if we draw line *OC* to this curve, starting from the origin of the coordinates, we will find the boundary point *W* beyond which the ratio of costs to production deteriorates.

Therefore, we can consider production P_W as the benchmark for a given workshop, organization, or other production unit.

Line *OC* divides total costs into two parts: *ab* and *bc*. Cost *ab* is a useful cost, while cost *bc* is the cost of wasted time.

The graph in Figure 4 is the most general characteristic of economics. Each working unit, whether consisting of a single cell, collective, living being, or machine, has its own unique characteristic. In other words, each unit has its own time price, which never drops to zero, and each has its own benchmark production, at which it operates most economically. This is an extremely important conclusion that provides us with fundamental guidelines regarding organization. (d. c. n.).

Part II

Technical Review [*Przeglad Techniczny*], 1924, Vol. 62, No. 52, pp. 579-583

IV. Harmony in the selection of cells and harmony in action.

If we consider the organization of the above-mentioned mill and its action plan, presented in Figure 1, in light of this conclusion, i.e. if we draw graphs characterizing each of the individual cells, we can easily calculate the losses resulting from faulty selection. A comparison of such graphs is shown in Figure 5.

We can clearly see here the inappropriate selection of individual apparatuses, i.e. when producing 10,000 kg, according to the given schedule, furnaces II and III and rollers V are close to their target production, while the remaining apparatuses are still largely underutilized, and the total daily loss due to this amounts to the sum of lines *a+b+c+d*. In normal unharmonized work (at a production of 2,500 kg), losses due to wasted time are expressed as the sum of lines *e+f+g+h*. By analyzing our workshop in this way, we see that losses due to wasted time may result from two reasons:

1. when individual cells are not properly selected, i.e. their target productions are not equal
2. when the action of these cells is not properly harmonized.

Therefore, the conclusion is that the best harmonization of action is only possible when the individual cells are best suited to each other, i.e. when there is harmony in the selection itself.

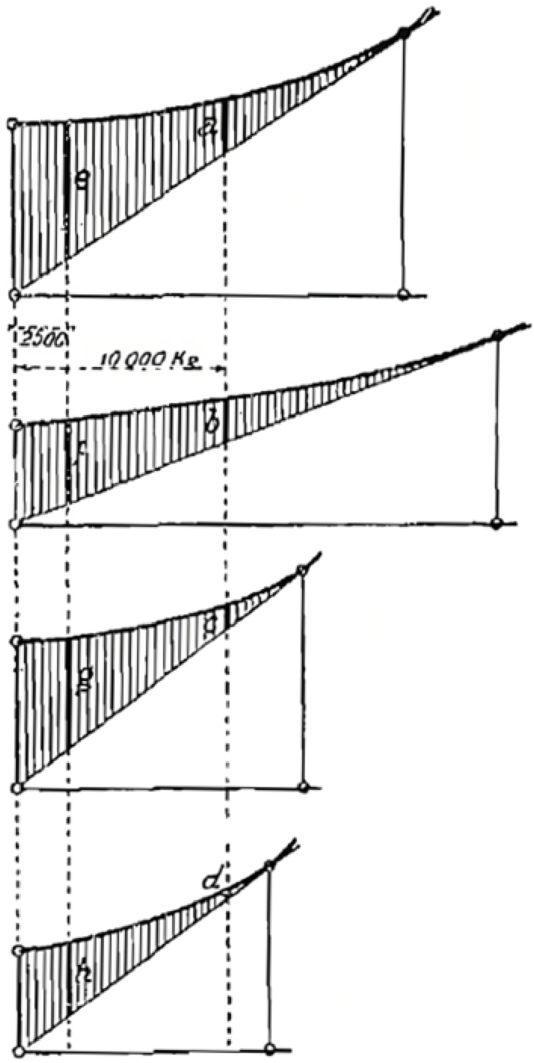


Figure 5
Graphs of own costs and losses

Since every cell of a given productive organism can always be expressed by a precise characteristic curve that shows the dependence of its costs on production (its price in time), the concept of harmony of selection ceases to be indefinite and becomes a very concrete thing. We can call a selection harmonious if the characteristic curves of all the cells are in agreement with each other, both in terms of their exemplary productions and when the sum of the verticals of all these curves is the smallest for given technical means, in other words, when each cell is economically the most perfect.

To express this idea more precisely, we can say that a given cell can be considered the most perfect if, among all the cells or devices serving the same purpose, its cost curve is the lowest, i.e., the least money flows through it per unit of time, and if this curve is as steep as possible, i.e., the cost of the last unit produced is the smallest. For example, of three cells A, B, and C that we have to choose from, C will be the most perfect, as shown in Fig. 6.

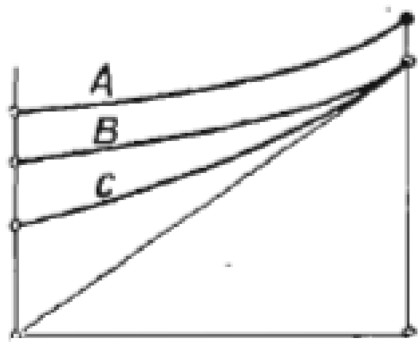


Figure 6
Comparison of several activities in terms of their efficiencies. The most perfect of them brings us closer to a straight line starting from the zero point.

Considering every workshop as an organism consisting of individual cells that work together as a collective whole, we can regard each individual cell, regardless of whether it is a machine, apparatus, tool, or person, as a kind of tap through which a certain amount of money flows per unit of time. The thickness of this stream is generally variable depending on production, and this dependence is expressed by the appropriate characteristic curve for each tap. The steepness of these curves varies and approaches straight line drawn from the zero point. The tap regulates itself more perfectly as the slope of the cost curve increases, and conversely, the closer the cost curve approaches a horizontal line, the less sensitive the tap is and the less it regulates production. Finally, we also encounter cells similar to taps, through which a constant amount of money flows per unit of time, regardless of whether the cell produces anything or not.

After all the cost items for each production unit are determined, there is only one cost item that is completely regulated automatically, and that is the cost of raw materials. However, when considering the entire workshop as a collective entity, which is like a cash register that processes money, it is noticed that it processes a stream of money whose thickness is regulated by production quantity, as shown in the cumulative chart. Therefore, when producing, the stream of money does not stop; when production increases, the stream expands gradually, but in such a way that there is always a certain ideal production limit at which the ratio of the thickness of the money stream to production is the smallest.

The ideas mentioned above include the essence of harmonizing collective work. We see that the inclusion of harmonization consists of two parts:

1. harmonizing the characteristics of the flow of costs of individual cells, and
2. harmonizing all their activities.

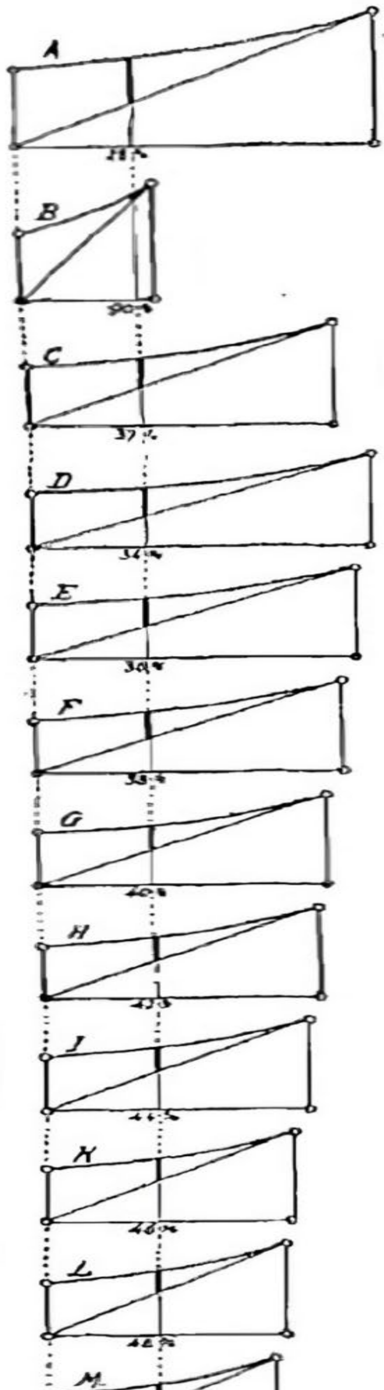


Fig. 7
Wire rolling harmonogram

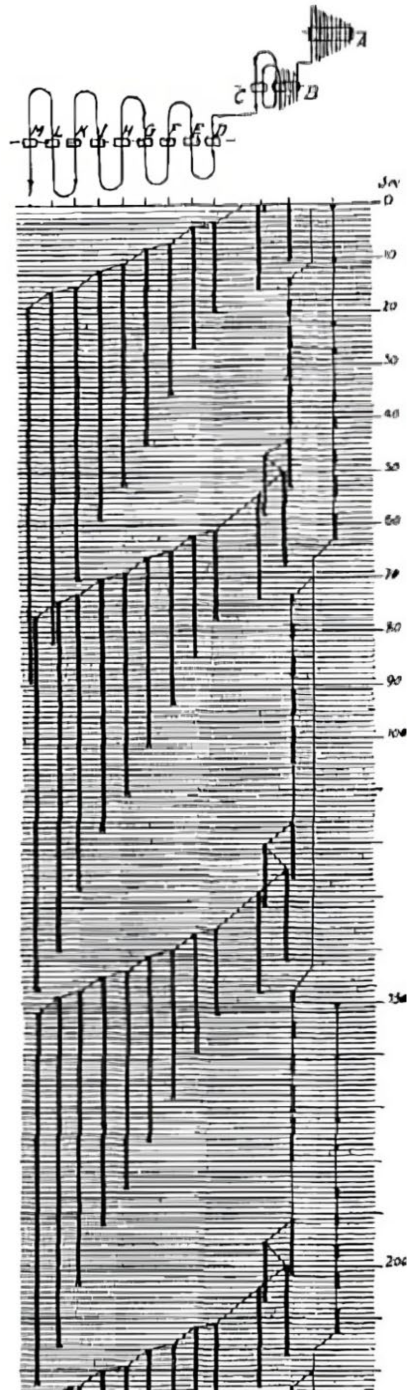


Fig. 8
Characteristic charts of rolling mills

To solve the first problem, the main criterion is to compare the characteristics of the flow of costs, which can be expressed using the presented charts. The guiding idea for solving the second problem is the coordination of the timing of the individual activities, which can be effectively implemented using graphical methods, as shown in the example.

It should be noted that both these methods can be applied in two cases. Firstly, they can serve to examine each manufacturing workshop, investigating to what extent its processes deviate from harmony in selection and operation. Secondly, they can be used to pre-design the most perfect assembly, both in terms of selection and operation. In other words, we can compose a standard plan for the set of work cells or machines and a standard plan for their operation.

V. Analysis of collective work using graphical methods.

Using these methods to analyze various production workshops and organizations allowed me to see that most workshops, even among the most recent ones, are very far from perfection, both in terms of harmony in selection of cells and in terms of harmony in operation. The losses resulting from this are very easy to calculate.

I could provide hundreds of examples from my practice confirming the above statement, but I will only mention one example from the steel industry, in which these errors are particularly evident.

Figure 7 shows the schedule for rolling a 5 mm wire. It is an accurate average of the action of the rolling mill, which consists of a series of separate rolling machines. The image was obtained using a stopwatch. This schedule corresponds to an hourly production of 3650 units. This production was considered insufficient since the rolling mill was designed for simultaneous rolling of two wires, which could only be achieved in rare moments and only for a few seconds. The craftsmen and supplier of this rolling mill explained it as a lack of skill among the workers. However, the above schedule clearly highlights that the low production was not due to this reason, but rather due to fundamental errors in the design of the entire rolling mill and improper distribution of work between the individual rolling machines.

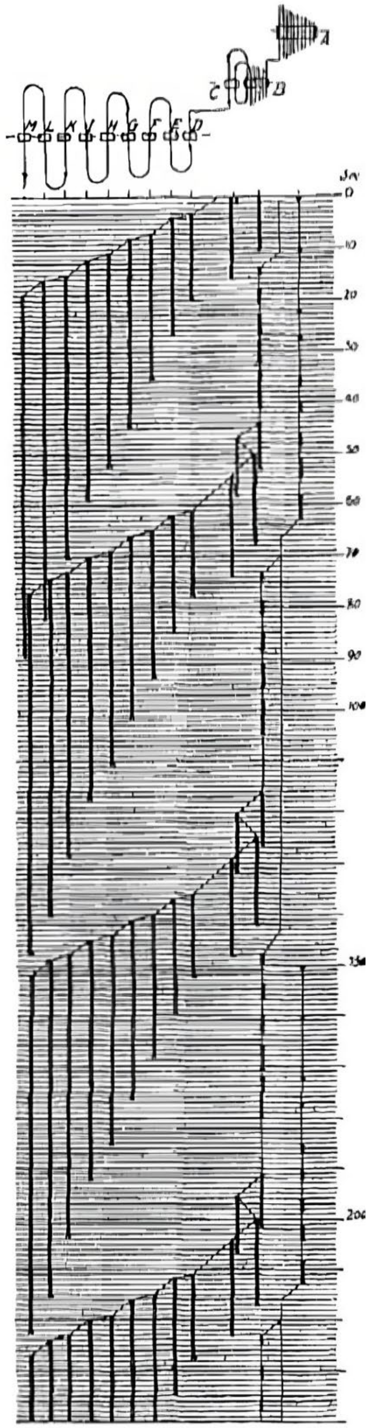


Fig. 8
Characteristic charts of rolling mills

First and foremost, it is evident that a closer approximation of the individual waves is impossible since the operating time of the B rolling machine has already been fully utilized, and the remaining breaks could not be reduced further, even with the most highly skilled rolling machine operators. At the same time, we can see how poorly all the remaining rolling machines are utilized, especially the A rolling machine, on which the actual working time is only 28%, while the rest is idle time.

Figure 8 shows the characteristic graphs of all the individual rolling machines, produced according to the above schedule. This graph clearly shows the losses in costs resulting from time losses and the dependent relationship of these losses on the lack of harmony in the selection of individual parts and the improper division of work between them.

Of course, completely eliminating losses due to idle time would be impossible without a radical change in the entire workshop's construction. This could be achieved only through the introduction of a better distribution of work but on condition of changing the raw material to wire rods of 75 kg from the blocks of 150 kg as originally intended by the rolling mill designer.

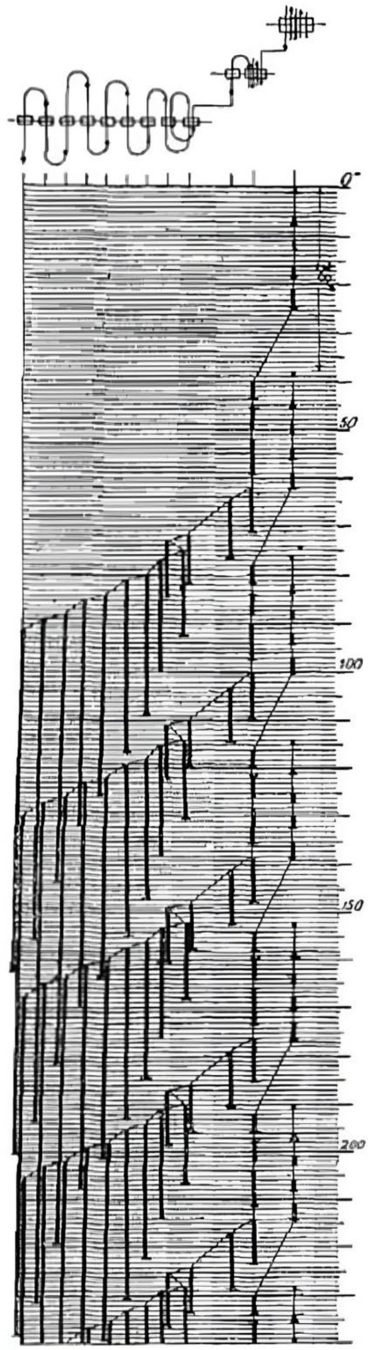


Fig. 9
Harmonogram of the new selection of rolling mills

Therefore, a new schedule, presented in Figure 9, was designed, which, of course, is not perfect, but the individual rolling machines were utilized far better, achieving a production rate of 6350 units per hour.

VI. Great losses due to lack of harmony.

In my personal experience with various types of collective work - including rolling mills, large-scale production, mechanical workshops, textile factories, ceramics, paper mills, and construction sites - I've encountered hundreds of examples of this kind. Such fundamental errors are frequently found, which is not surprising. Until now, in the construction and operation of manufacturing workshops, we've barely scratched the surface of harmonizing the work of individual parts. When constructing new building installations, technical knowledge was applied, yet it was often overlooked that each work cell would essentially act as a conduit for the flow of money during operation. The dependency of this flow on production per unit of time was not clearly understood. Consequently, once any factory line was installed, the organization was largely left to chance. At best, it depended on the managerial talents and routines of those in charge.

Such a situation is accurately and intelligently presented by Mr. Harrington Emerson in his *12 Principles of Efficiency*. His claim is completely valid that if in the past era we occasionally encountered extraordinary efficiency in harmonizing collective work, it was rather exceptional and only when special conditions simply forced perfect harmony, or when the intended result was impossible without perfect harmony. As a few of the rare exceptions of this kind, he cites, for example, the course of American trains called "chronometry" or shooting cannons on American warships.

In contrast to these ideas of harmony, I quote a conversation with the chief of the repair workshops, who looks at Emerson with a smile of pity, claiming that all activities in a mechanical workshop are equal and should be carried out according to plans as precise as the schedule of "chronometry" trains.

In the era of extraordinary technological development, the majority of technicians and engineers belonged to the type of the aforementioned workshop chief, while pioneers of organization such as F.W. Taylor, H. Emerson, [Frank and Lillian] Gilbreth, Gantt, and others, were exceptional. In this era, we improved details but did not cover the whole picture. We focused primarily on the design and operation of individual devices and mechanisms but did not pay sufficient attention to the proper coordination of these devices, their adaptation to working conditions, and the cost of their operation. Therefore, we often encounter workshops consisting of a whole range of devices, often themselves perfectly improved but not mutually corresponding and acting in a way analogous to hitching both racing horses and oxen to the same cart, i.e., animals of different power and character.

VII. Planning collective work - graphical method:

Everything said above leads us to the following conclusion:

The arrangement of an organizational plan for each manufacturing process has the same importance as making a drawing for the construction of some mechanism, device, or structure. If in every mechanism or structure, all parts must correspond precisely to each other, then similarly, in carrying out the joint collective work of the mechanism, device, and employees, the work of each of them must correspond strictly to one another. Not only should each of them demonstrate exemplary efficiency, but the action of each of them must be so connected that the whole team also shows exemplary efficiency.

Having a clear understanding of what should be understood as the harmony of selection and operation of productive cells, the simplest logic also leads us to the conclusion that in order for a productive workshop, whether small or large, to give the highest economic result, i.e., to be able to work with the highest production at the lowest cost of labor and resources, the project of general organization should be prepared before the project of the installation itself. Only such a plan will give us strict guidelines for the equipment, the size of individual cells, the conditions of their cooperation, and their model efficiency.

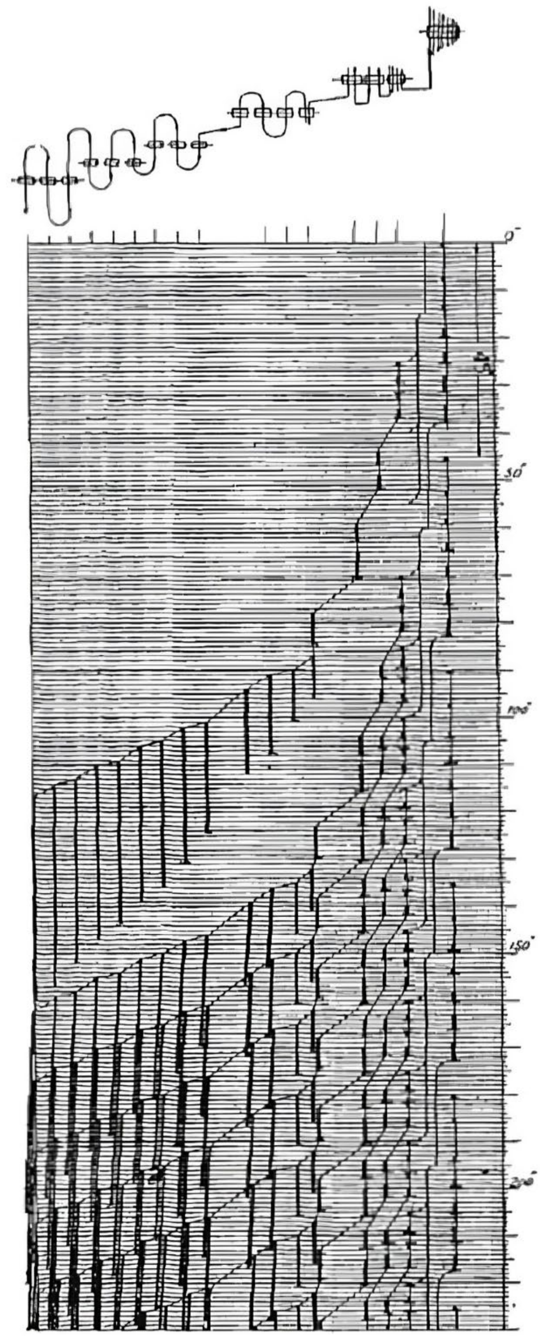


Fig. 10
Harmonogram as the basis for designing a factory

However, it must be stated that if in the field of construction technology, such progress has been made that no sane engineer would ever think of starting construction without first creating a general project, specific drawings, and precise calculations, then in the field of work organization and planned operation, we are only taking the first steps when we proceed to set up productive workshops without having a detailed plan for the individual cells and the whole team. We must also carry out strict research and calculations regarding the probable costs of each cell's time and their model efficiency.

The science of organization fundamentally changes such a state of affairs, advancing as one of the most important postulates that each job should be carried out according to a plan prepared in advance and based on a thorough analysis of all work elements.

The graphic method of work harmonization presented above enables the comparison of such a plan in advance. The charts presented provide us with the main guidelines not only on how cooperating cells should be arranged to achieve the highest efficiency, but also on how such devices and cells should be selected according to their economic characteristics.

Yes, as an example of the perfect result of such a procedure, it can be noted that the wire rolling mill of one of the largest ironworks in southern Russia was designed based on a work schedule developed from the beginning. The mill was built in 1910 according to this project. Figure 10 shows this schedule and the general diagram of the mill. When compiling the schedule, simultaneous rolling of three wires was assumed. It was said several years later that the result completely confirmed this assumption - the mill produced an average of 14,800 kg per hour. The engineers who led the mill told me that they could not imagine this device working so efficiently without a properly prepared action plan, which provided many first-rate indications regarding the entire equipment, and the importance of which would not be suspected even if there was no such a clear drawing in front of their eyes showing the entire work plan of all the cells.

The examples given relate only to one area of technology, namely rolling, but of course, this method of harmonizing operations can be applied to any collective work, as the most important condition for collective work - whether it is simple or complex - to be performed most efficiently is for each activity to be carried out at its proper time, neither earlier nor later. If the movements of three blacksmiths who forge a piece of iron must be coordinated in time with an accuracy of a hundredth of a second so that the work can be done with the greatest efficiency, this principle is equally important for even the most complex work consisting of thousands of work elements and thousands of cells performing these works, regardless of the type of cooperating cells, and whether the duration of individual work and movements is measured in seconds, minutes, hours, days, weeks, or months.

Therefore, any collective work can be presented in the form of a chart, with the elements of the work of each cell arranged in a single row, for example, horizontally, and the duration of each work element indicated by lines plotted vertically on the time scale.

If we draw such a picture from nature with the help of a chronometer, we will obtain an extremely clear means for analyzing collective work. We can precisely measure the degree of opposition, time losses, flaws in the harmony of operations, and flaws in the harmony of selecting individual cells.

Of course, this same method provides us with a means of proper harmonization. So, if we know all the elements of collective work in advance, if we know the time required to perform each task and their mutual ratio, we can use the above graphical method to design a schedule that corresponds to the model of operating efficiency. Such a schedule, along with characteristic charts, provides guidelines for the harmonious selection of cells and subsequently for the method of organizing work processes.

The main goal in creating a musical piece is to make sure that each sound is played at the right time, neither earlier nor later. In this regard, the role of the composer is similar to the role of the manager: both aim for harmony, the musician in terms of the harmony of the sounds, the manager in terms of the harmony of the work elements.

As for the selection of sounds, the science of acoustics provides numerical, mathematically precise indications regarding the choice of sounds. As for the selection of the cells performing the divided work elements, we have fundamental guidelines in the form of characteristic graphs mentioned earlier, in terms of the relationship between time, cost, and useful result for each cell.

The graphical method of harmonization that we present here does not necessarily require the collective work to belong to so-called mass production, consisting of constantly repeating actions. It can be applied equally successfully to all kinds of work, to analyze and plan the layout of the standard plan for execution.

I personally used this method many times, as I mentioned, for various construction works, including iron-concrete works. I used it in 1916 during the construction of a large iron-concrete factory building. The work was analyzed in detail beforehand, with a half-hour time interval. Due to this detailed approach, the whole construction went so fast that, for example, in carpentry work (mounting forms), some tasks were completed in half an hour, while they would have taken several hours under normal circumstances. In addition, all carpentry work was done with the help of six carpenters, instead of the 34 that were preliminarily estimated by the building specialist for iron-concrete works.

In 1915, in one of the train wagon factories, my method was used to reorganize the forging of connector hooks for wagons, and the following results were obtained: before the reorganization, a brigade of workers produced 15 hooks per day, using 2.011 kg of coke per hook. After the reorganization and the use of new furnaces whose dimensions were determined according to the schedule, the same brigade of workers was able to produce 70 hooks per day, using only 0.78 kg of coal per hook instead of coke.

I will not present many examples from my practice here, but I want to mention that a similar method was used in 1913 and 1914 to repair wagons in one of the South Russian railways. The result was a multiple increase in production in a very short time. The method was also applied in 1911 and 1912 during the construction of a complete set of equipment for a large furnace in one of the largest ironworks in southern Russia.

Considering myself, to some extent, to be the inventor of this method of analyzing collective work and planning it in advance, I must admit that it has long been used as a graphical method for determining train schedules.

Because the topic of my presentation concerns the importance of harmonization in the scientific organization of work, what I have said will be sufficient evidence that the organization in terms of the selection of personnel and their actions is one of the most important areas of this science, which, however, has been insufficiently taken into account by modern managers. (unknown date).

Part III

Technical Review [*Przeglad Techniczny*], 1924, Vol. 62, No. 53, pp. 594-595

VIII. Three laws of economics as the basis of the science of organization.

While I'm on the subject, I must address another fundamental issue, namely concerning the criticisms of many skeptics when American pioneers called their organizational methods "scientific." Many of them argue that these methods could be considered at best as an art, but not as science, because we usually consider science to be knowledge based on certain thematic axioms or laws of nature. In Europe, professor le Chatelier first defended this issue, arguing that Taylor's system and other American pioneers of organization deserve the name of science because they use scientific methods. For a long time, I found this explanation insufficient, even though I was always deeply convinced that the science of organization deserves this name, believing that it has the right to it for other important reasons. After long reflection on this matter, I eventually arrived at what I believe to be the correct conclusion, which I would like to present to this Honorable Assembly.

Not content with le Chatelier's defense, I posed the question: what precisely causes the methods employed by scientific organization to result in the economy of energy and resources, that is, why is the same desired outcome achieved with less effort and greater efficiency? If we always achieve better economic results by following the suggested organizational methods, it stands to reason that this occurs because these methods align with certain natural laws. These laws guide the economical use of energy and resources spontaneously, irrespective of our intention or consciousness.

Looking at the methods of what is called "scientific" organization from this perspective, I concluded that they are indeed based on such fundamental laws.

One of them is already indicated in the *report of the Committee for Administration* presented in 1912 [p 1131] at the American Society of Mechanical Engineers, of which James Mapes Dodge was president, namely the law of division of labor. This law was seen as the primary reason for the economy obtained by far-reaching division of labor into execution and management, which is most prominent in the methods of Taylor and other pioneers of scientific organization.

The law of division of labor, finally defined by Adam Smith, is the law that guides the whole living nature towards economy, and in an incredibly perfect way.

But there is another law of nature, namely the law that could be called the law of concentration or integration. Nature is also guided by this law, constantly striving for economy. Cells in performing their life functions, divide and specialize, thereby reducing the overall cost and waste of energy and resources. However, we also see that at the same time, another process takes place, namely, cells performing identical, or similar, functions, join together for common action, creating cooperation, whole organs serving a specific purpose, and thus achieving economy again.

These two laws - the division of labor and concentration - complement each other, they are closely related, so that by observing the manifestations of living nature, we see that differentiation into various functions occurs, as if in order to enable the integration of identical functions to be fully manifested, and the result of these two processes is ultimately energy and resource savings.

The English philosopher, Herbert Spencer, calls these two inseparable phenomena of living nature the general law of evolution.

Recognizing the law of concentration as the second fundamental principle of economics, associated with the law of division, we can now ask whether this law is also taken into account in the methods of scientific organization. In Taylor's system, this is quite clear, namely: by separating the executive work from the managerial thinking work, the office organizing the work combines the latter into one body. The same is true for Emerson, who proposes the creation of a staff specifically encompassing the entire organizational thinking work.

So the methods of organization also take into account the second great law of economics.

But there is also a third law of economics, namely the law of harmony, which living nature spontaneously uses in an extremely perfect way to save energy and resources. The ancient Greeks deeply felt this law, for whom both rhythm and harmony were a kind of religious cult.

Although we frequently use the word "harmony" today, we usually refer to a rather vague concept by this term, and we underestimate the importance of harmony in terms of economics. Perhaps this is because we have not yet tried to define precisely what we mean by harmony in productive work.

As far as the purely material aspect of productive work is concerned, I believe that a precise definition of the law of harmony is not difficult. Everything I have said above about harmonization explains it all too well.

Therefore, in order to achieve exemplary efficiency from an economic standpoint, we have seen that it is necessary to choose organs, or work cells, according to their complementary functions, and then these organs or cells must work together in close connection so that each action takes place in its own time.

In this definition, I see the entire economic content of the law of harmony. Understanding harmony in this way, as a fundamental law, we can easily see that this law is closely related to the first two laws of division and concentration.

If nature spontaneously and constantly tends towards division and concentration, achieving higher economic efficiency, then it is easy to see that despite this, the highest economy could not be achieved if the individual parts of the collective organism that perform divided and concentrated work were not properly matched and did not cooperate in time according to a strict plan or order.

At every step, living nature offers us vivid examples of its adherence to these three laws. It becomes easy to realize that it is precisely by obeying these laws that nature constructs its works with such astounding efficiency, to the point where we often say that nature has the ability to create something from nothing.

If we now ask ourselves whether this third law of harmony is taken into account in the methods of scientific work organization, we can certainly answer in the affirmative, because in the methods proposed by all pioneers of this new knowledge, selection and cooperation are considered the primary factors for achieving exemplary efficiency.

By putting these three laws as the main foundations on which the science of work organization is based, I do not want to be accused of trying to discover America for the second time. Undoubtedly, these laws have been widely known for a long time and are manifested in all the works and activities of modern progress, and precisely thanks to them, civilized man increasingly saves his own energy and the energy of nature. However, we must state that so far, we have been guided by these laws rather unconsciously, intuitively, and without proper understanding of their great significance, more often sporadically and chaotically, and sometimes even with some reluctance, considering the division of labor as a human misfortune.

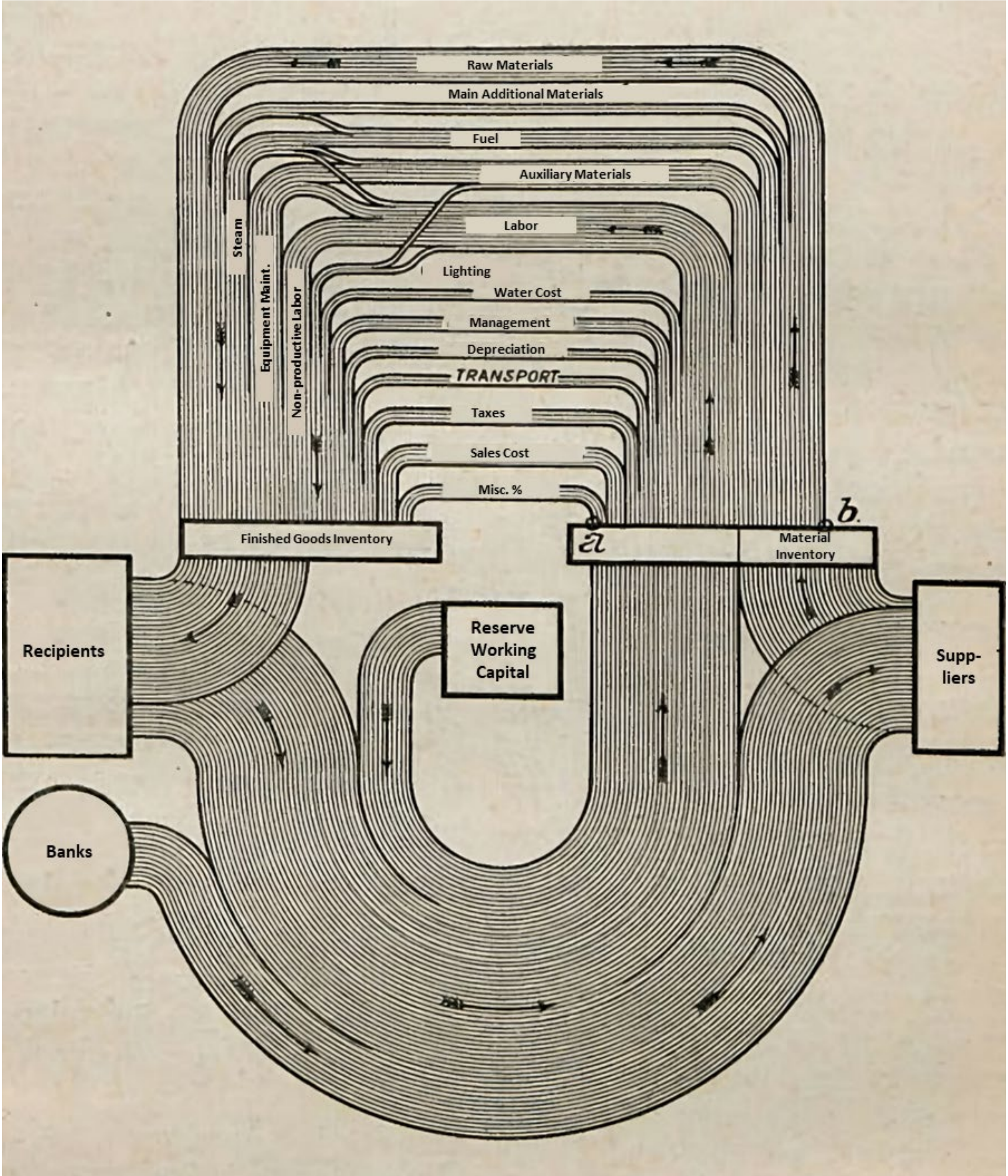
Considering the colossal losses of time, energy, and resources that we see at every step in production work, despite the extraordinary progress of technology, and which losses Harrington Emerson so truly and glaringly highlighted in his *12 Principles of Efficiency*, we can easily convince ourselves that the main cause of this is precisely that we have not sufficiently appreciated the above three economic laws and have sinned against them at every step.

Having come to these conclusions and emphasizing the importance of the three fundamental laws of the economy of nature: division, concentration, and harmony, I dare to claim that the science of work organization has the right to be called a science not only because it uses scientific methods, as Professor le Chatelier claims, but above all because these methods are based on these three natural laws and therefore have the right to the name of science in the highest sense of the word.

In addressing the issue of work harmonization in this presentation, I tried to draw special attention only to economic, purely material moments. I pointed out two types of harmony, namely harmony in the organization of the organism, or the harmony of selection, and harmony in action. These two types of harmony relate to all factors of collective work, i.e. machines, equipment, and people. But there is still a third type of harmony that concerns only the human factor and unfortunately cannot be captured in diagrams that facilitate harmonization. This is the harmony of the spirit, which should unite all human beings cooperating in a single collective organism, such as every production plant.

Despite the fact that the principles of spiritual harmony cannot be expressed in mathematical functions, the principles on which it is based can be precisely formulated, and the science of work organization assumes that the highest economic efficiency cannot be achieved if the principles of spiritual harmony are not fully applied.

The issue of spiritual harmony is a topic that goes beyond the scope of my presentation, so I will say only a few words about it in conclusion. When the principles of spiritual harmony are applied to the organization of human labor - for the ultimate benefit of the worker and all of humanity - the impact is profound. By striving towards the highest ideals, invoking enlightened judgment, instituting discipline rooted in superior moral motivations, and acting justly, we apply Harrington Emerson's foundational principles of efficiency to every civilized individual. In short, if we fully engage with these principles of spiritual harmony, there's no doubt that the science of work organization will become one of the most significant cultural factors in the coming era. It will ensure that work becomes a source of the greatest wealth, encompassing not just material gain but moral wealth as well.



Raw Materials
Main Additional Materials
Fuel
Auxiliary Materials
Labor
Lighting
Water Cost
Management
Depreciation
TRANSPORT
Taxes
Sales Cost
Misc. %
Steam
Equipment Maint.
Non-productive Labor
Finished Goods Inventory
a
b.
Material Inventory
Recipients
Reserve Working Capital
Supp-liers
Banks

Fig. 7.

The position of an Engineer as a Manager of Manufacturing Plants (1924)

Scientific Organization of Work [*Naukowa organizacja pracy*], Warsaw, 1925, pp. 47-72

Forward to the English edition:
In this report, Karol Adamiecki addresses the role of engineers as managers in manufacturing plants, emphasizing waste reduction, proper management of resources, and achieving the greatest useful output with the least input. He presents one of the earliest examples of a Value Stream Map, which compares production costs and sales values as a visual representation of the manufacturing process.

The article cites the Waste in Industry report findings that seventy-five percent of waste is due to management's poor understanding of the system. However, it also offers solutions to these underlying issues. It describes the qualifications necessary for the role of a manager, as well as the role, position, and responsibilities of technicians when acting as managers. Adamiecki advocates for an individual who possesses extensive knowledge, experience, analytical skills, and the ability to harmonize all factors of production to achieve the greatest economic benefit for society, employees, and invested capital. He highlights the importance of the manager's intellectual and moral level, strength of character, and fair and honest behavior.

Report

In order to take a closer look at the role of an engineer and technician in managing a manufacturing plant, it is necessary to first consider the main outlines of the progress made so far in manufacturing processes from the point of view of the relationship between the input of production resources and the useful output. Then, we need to consider the main issues that arise from this for a manager.

Waste alongside the progress of manufacturing work.

The rapid development of material culture that has taken place over the past 150 years, thanks to the natural sciences and the engineering art based on them, is simply astonishing. Humans, who for many hundreds and thousands of years relied solely on the work of their muscles and the power of domestic animals, harnessed incredible amounts of natural energy during this short period. Physical work was delegated to machines, and as a result, humans ceased to be draft animals.

Small artisan workshops employing a few or several workers gave way to large industrial facilities filled with a multitude of diverse devices and machines, operated by hundreds and thousands of workers. These facilities produce enormous quantities of products that are distributed all over the world.

Thanks to technology, we have entered a new era where machines, driven by the forces of inanimate nature, have become the slaves of humans, thereby finally bringing an end to the epoch of human slavery. The amount of harnessed energy is already so great that it far exceeds human physical work. If we express this energy in units equal to the work of a single individual, we calculate, using the United States as an example, 22 such units allocated to each adult male. In other words, we can say that each adult male has the help of 22 "mechanical slaves" who assist him in his work.

Today, we use engineering and technology that our ancestors could not have dreamed of 150 years ago: we travel by railways, fly in the air, talk through radio telephones with people on the other side of the world, and so on.

All these incredible achievements are our pride. And indeed, we have much to be proud of when we look at these magnificent works of human genius.

However, unfortunately, the same methods of thinking and research that led us to these results also force us to look at things from another perspective.

There is a fundamental law of economy - the law of least effort, which governs all of nature, every living being, striving to achieve the greatest result with the least amount of effort and resources. This law also applies to humans and is the main guideline for all our technical sciences. The ultimate goal of technology is to obtain the greatest useful output with the least amount of work, energy, and all production resources. Its unattainable ideal is to convert the entire input into a useful output.

Therefore, to properly assess our magnificent achievements, which we admire so much, we need to compare them with the amount of energy and resources invested in their achievement: we need to compare the useful output with the input.

If we take even a cursory glance at things from this point of view, our excitement will cool down significantly when it turns out that the magnificent achievements are still surprisingly small compared to the input of energy and resources, and upon closer examination of this issue, we will find that in modern manufacturing processes, we encounter such waste that we have not yet come far from barbaric times in this respect.

Indeed, we have transferred our physical work to the forces of inanimate nature, taking advantage of its wealth to a degree that our ancestors could not have dreamed of. However, we squander it ruthlessly. American engineer Harrington Emerson is absolutely correct when he says that we treat the wealth of nature no less extravagantly than a young half-wit who unexpectedly received a huge inheritance. This engineer-philosopher is also not wrong in pointing out that the firefly is 15,000 times less wasteful of energy in producing its light than a human is today converting coal energy into electric light.

When the first pioneers of scientific organization pointed to the extremely low coefficient of useful efficiency in various modern branches of manufacturing work and proved that the amount of useful output could be increased several times with the same input of work and resources, they were met with great disbelief, and the belief prevailed among interested circles that waste only occurred in certain individual cases. However, recent studies by the American Engineering Council collected in the work *Waste in Industry* confirm on a large scale that waste is not an exceptional phenomenon but a widespread one. The figures obtained in such studies are striking.

The American Engineering Council has done a great job in bringing to light the fact that even in such a magnificent industry as the American one, only 35% to 50% of the total input of work and production resources is converted into useful output, and the rest goes to waste.

If in American industry, which uses machines and rational organization to such an extent as no other industry in the world, we encounter such great waste, then what can we say about our manufacturing work?

The studies by the American Engineering Council, demonstrating this state of affairs, would give rise to sad reflections and doubts about modern progress if they did not also indicate ways to remedy the situation. Thus, we see first and foremost that the research commission, summing up the losses and deriving the coefficient of useful efficiency, compared it not with an unattainable ideal standard but with a standard already achieved at the current state of technology and organization science. This gives hope that, although the losses are enormous, they can be eliminated if existing and effective measures are applied.

The second significant advantage of the work *Waste in Industry*, which elevates it to the rank of the most outstanding engineering works in recent times, is the identification of factors upon which the elimination of waste depends and the indication of the importance of these factors. The statement that nearly three-quarters of waste elimination depends on administration and organization is somewhat sensational news, especially for those who focus solely on technology or routine and underestimate the importance of these factors.

Upon closer examination of the causes of the large losses we encounter in all areas of manufacturing work, it is easy to see that the main source of this state of affairs stems from the fact that, in the past, when we had powerful means and achievements of technology at our disposal, we paid too little attention to the most important principle: "the greatest useful output with the least input." We were on the path to the greatest output without regard to the means by which we would achieve it. Having the ease of obtaining great results, we did not pay attention to the input of production resources.

I do not deny that in some branches, we tried to achieve the highest coefficient of useful efficiency: the entire history of engine development, for example, shows how meticulously we studied energy flow balances and made various inventions to save even one-tenth of a percent of the energy input. Similar efforts in improvements can also be observed in many technological processes and in the work of individual machines or devices. However, we must admit that most often this was an improvement in technical details, without encompassing the entirety of production processes. So far, we have predominantly been technicians-specialists with little or almost no orientation in the phenomena of manufacturing from an economic perspective; we have not even been able to accurately measure the values that flow through a manufacturing plant and compare the total useful output with the input.

Another important cause of the wastefulness so far was that, in the past, the matter of organization was not based on strict knowledge and scientific principles, but was almost exclusively left to the innate talents and routines of managers. Until recently, it was even believed that organization was an art that could not be captured by general principles that everyone could follow. This belief was quite similar to the view that prevailed widely about 150 years ago regarding technology; at that time, technology was also considered an art that could not be captured by scientific principles and that only innate talent and tradition passed from father to son could achieve anything.

Today, however, we already see clearly that basing technical methods on scientific principles has brought about the astonishing progress that we are witnessing. Now, organization is also at a similar turning point. Over the past twenty years, organizational methods have been based on scientific principles, and the results already achieved open up new, distant horizons for progress in eliminating the enormous losses in human labor, natural energy, and other means of production.

If we consider the low coefficient of useful efficiency of the past epoch as an era of plundering exploitation of natural resources to some extent, we are now entering a new period in which rational use of these resources will be the main indicator of progress, thanks to technology and organization based on scientific principles.

Main management issues and guidelines for solving them.

If we now look at the technical and economic issues encountered in all areas of manufacturing work and consider that all these issues must be resolved in accordance with the most important economic principle mentioned above, we will see that the engineer's task as a manager of manufacturing workshops covers a much broader scope than before. To perform this task, we must move beyond the narrow confines of pure technology and take control of all economic and social processes that take place in such a complex organism as every modern manufacturing plant.

From an economic point of view, all these processes, expressed in monetary units, ultimately boil down to two main streams, namely

1. expenditure, or the costs of producing a certain quantity of product, and
2. income, as the sum obtained from the sale of this product.

Regulating these two basic flows is the main task of a manufacturing plant manager, and the main guideline in this regulation is the principle of obtaining the greatest useful output with the least input of production resources. This task is not easy when we have to deal with a highly complex network of phenomena that are interdependent and dependent on various external influences.

However, thanks to modern research, we already know the main laws that govern the two streams mentioned above and that provide us with clear points of support for solving the most important economic issues concerning the management of the production process.

1. One of these laws expresses the relationship between the quantity of the product produced, its operating cost (expenditure), and time;
2. the second expresses the relationship between the quantity of the product, its sales value (income), and time.

As for the first relationship, it can be represented by the graph in Fig. 1, if we plot production (*p*) performed in a unit of time on the horizontal axis (*OX*), and the cost (*K*) of that production on the vertical axis. In this way, we obtain a very characteristic cost curve (*AB*) in a unit of time:

1) it is a curve that continuously rises upwards as production in a unit of time increases,
2) the starting point (*A*) always lies above point (*O*), which means the cost in a unit of time never falls to zero when the plant does not produce anything,
3) the curve (*AB*) is concave upwards, as for each production unit, there is only one optimal production (*pw*) at which the ratio, i.e., the cost per unit of product, is the lowest.

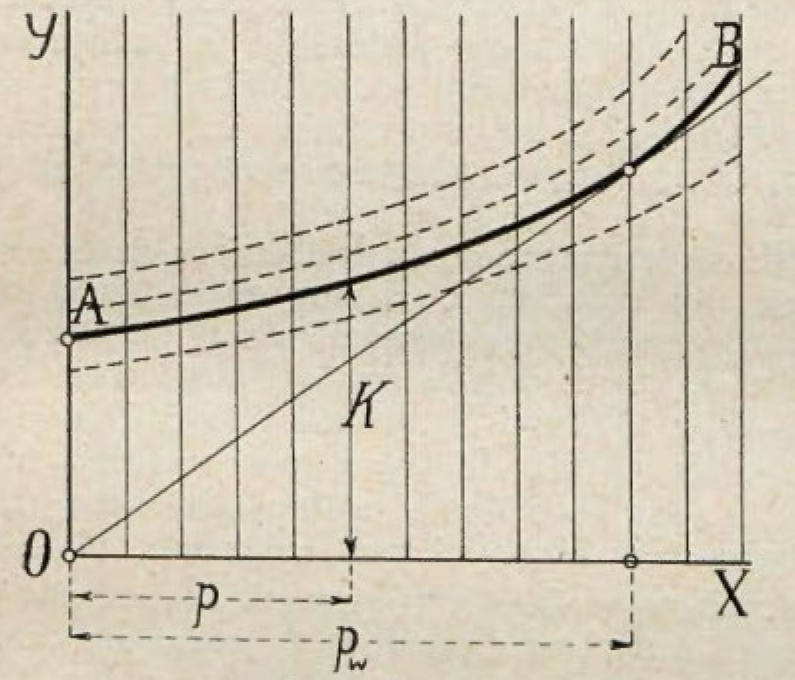


Fig. 1

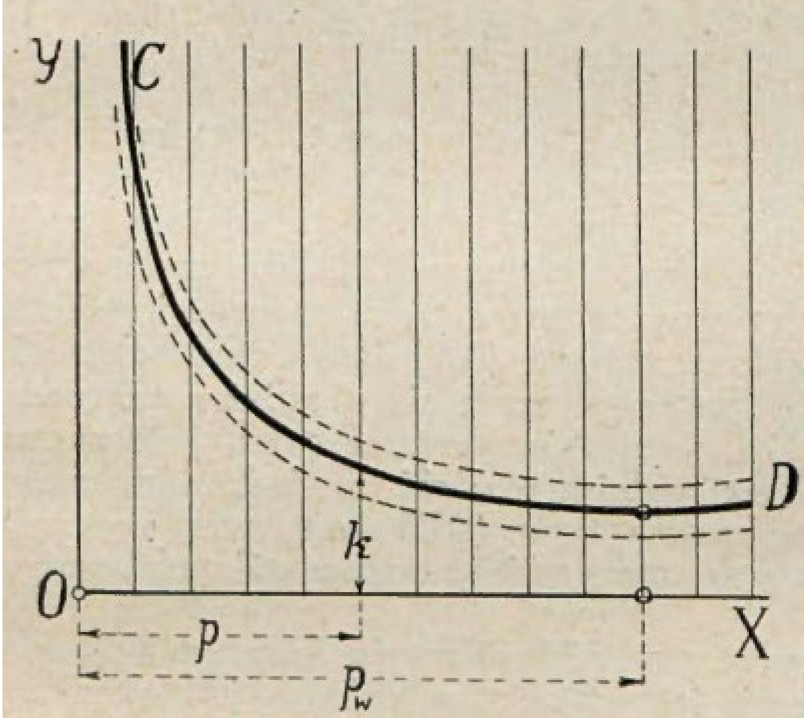


Fig. 2

The above graph is a fundamental characteristic of every production unit, in other words, it is the price of its time, assuming that when production (*p*) fluctuates, all other factors and conditions on which expenditure (*K*) also depends, such as the prices of materials, their quality, working conditions, the condition of equipment, machines, etc., remain the same.

If all these factors and conditions start to change, the cost curve in a unit of time (*AB*) changes its position, inclination, and curvature accordingly, but given equal conditions, it never loses the three previously indicated characteristic properties and has a strictly defined position and curvature.

The graph shown in Fig. 2 results from the previous graph, namely: the ordinates $k = K/P$ of the curve (*CD*) express the cost per unit of the product at different productions in a unit of time. The curve (*CD*) is somewhat distorted hyperbola and shows that the cost per unit of product decreases rapidly as production in a unit of time increases and reaches its minimum at the optimal production *Pw*.

With changing conditions, i.e., the change in the position of the curve (*AB*), the curve (*CD*) also lowers or raises.

For a more detailed explanation of the relationship between production, its costs, and time, as well as the many significant conclusions that can be derived from this relationship, I direct the reader to my articles in Przegląd Techniczny (No. 41-44 from 1923 and No. 49, 52, and 53 from 1924). At present, I must limit myself to the above remarks, especially since I am only concerned with providing a general characterization of the issues related to managing a production facility.

However, for further argumentation, it is necessary to emphasize that the law of cost flow in a unit of time, expressed by the curve *AB*, applies not only to the total sum of costs flowing through the entire production complex but also to all the constituent cost streams flowing through each work cell, which make up the entire workshop as a collective organism. Thus, each individual cell of the factory has its operating cost curve similar to curve (*AB*), meaning that a certain cost stream flows through each of them in a unit of time, which is also influenced by changes in material prices, working conditions of the cell, its condition, and so on. The total cost of the entire factory in a unit of time, expressed by a curve of type (*AB*), is the sum of the characteristic graphs of all individual cells of the factory.

Considering all cost items of production from the point of view of their type, we encounter only one item whose stream flows proportionally to production, regardless of the organ through which it flows, namely the cost of raw material. This cost is therefore expressed in our system by a straight line (*OB*) starting from point (*O*) in Fig. 3. All other cost items either flow constantly, independent of production volume, or grow not entirely proportionally to it and do not drop to zero when production in a unit of time is equal to zero. In any case, the sum of all cost items, whether flowing through the entire production organism or its individual organs in a unit of time, always varies according to a certain characteristic curve (*AB*), as indicated earlier.

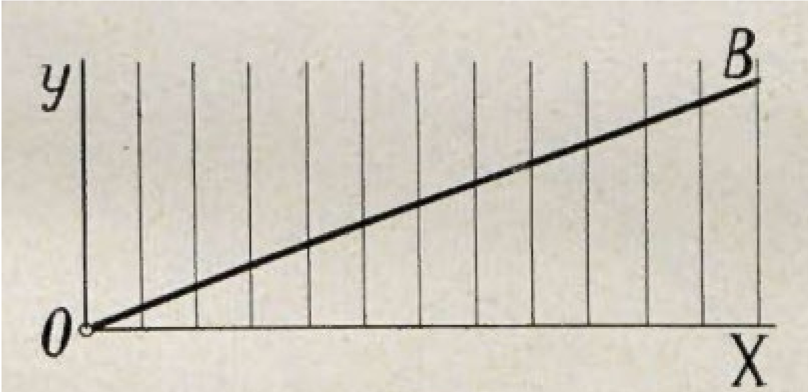


Fig 3.

As for the relationship between production, its sales value, and time, this relationship can also be expressed graphically in a similar way as we expressed the relationship between production, its manufacturing cost, and time. In Figs. 4 and 5, this relationship is presented. The curve of the product's sales value, contrary to the cost curve, always starts from point (*0*) because if we do not produce anything, the sales value is obviously equal to zero. If the price (*c*) of the product unit is constant (Fig. 5), the total sales value (Fig. 4) is expressed by the ordinates of the straight line (OS_1). However, this is usually an exceptional case and occurs only when there is a constant balance between supply and demand, regardless of whether we release a small or large quantity of the product to the market.

Most often, however, as we release an increasing quantity of the product for sale in a unit of time, or as the market becomes saturated, the price of the product unit gradually decreases (see Fig. 5), and the curve of the total sales value, bending downward, takes the form of (*OS*), and at a certain production level (*OG*), the value reaches its maximum [Σg] (limit value).

We will not delve further into the value curve here, as for the purposes of this report, we only need a few remarks concerning this curve. The reader will find more details on this subject in the extremely valuable book "Zarys ekonomji politycznej" (Outline of Political Economy) by Prof. Z. Straszewicz.

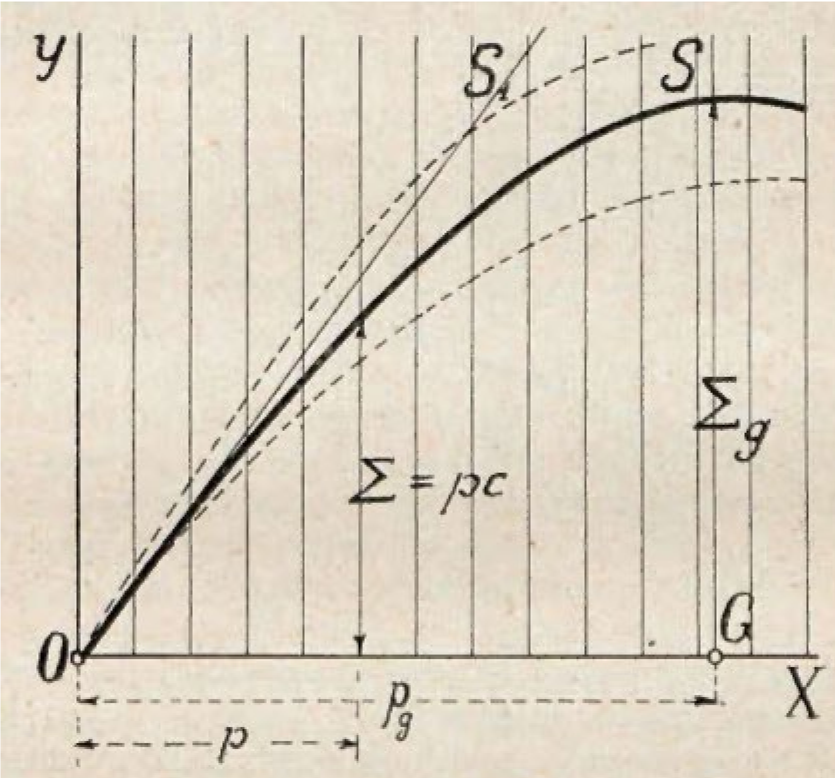


Fig. 4.

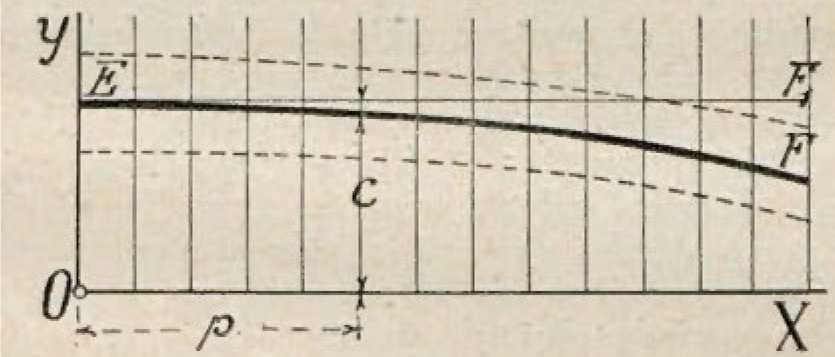


Fig. 5.

We have just mentioned that the law of supply and demand is the reason for the gradual decrease in the price of a product unit when increasing production, but due to the same law and varying levels of competition, the price of a product unit can increase or decrease even with the same production level of a given production facility. This means that the price curve (*EF*) can rise or fall, as shown by the dotted lines in Fig. 5. The total sales value curve (*OS*) can deviate in one direction or the other, pivoting around point (O*).* (At the same time, the curvature of this curve and the limit value may change).

With normal economic development, we most often encounter a decline in product prices, and for this reason, we can say that the sales value curve of the product generally has a tendency to tilt downwards.

If we draw the manufacturing cost curve and the sales value curve on the same scale, we can superimpose one onto the other, thereby obtaining a single general graph of expenditure and income, which gives us a clear understanding of the flows of various values that take place in a production facility. Fig. 6.

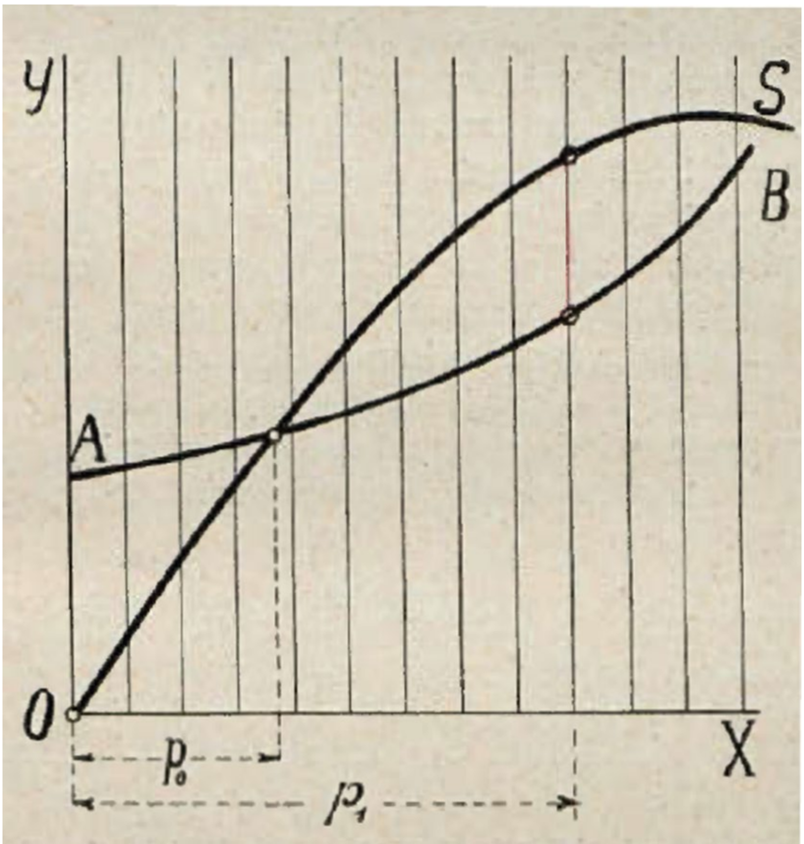


Fig 6.

A closer examination of this graph leads us to a series of extremely important conclusions related to the issues that a manager of a production facility encounters.

The scope of this report does not allow for a detailed consideration of all these conclusions. However, we must point out a few of them to at least present an outline of the general technical and organizational tasks.

First and foremost, the issue of profits stands out. We can see from the graph above that profits can be discussed only when the manufacturing cost curve and the sales value curve intersect, and if the production per unit of time exceeds a certain minimum (*p0*). Otherwise, the enterprise incurs losses.

This minimum production could be called the "first critical production."

Curves (*AB*) and (*OS*) are independent of each other, and they can also fall and rise independently. With such fluctuations, it is very easy for an enterprise that generates profits at a certain level of production to turn into one that incurs losses, and vice versa.

If we look at the curves expressing the law of expenditure and income for each production facility and consider that these curves continuously change their curvatures, positions, and inclinations depending on the changes in internal and external conditions of the company, and that we arrive at the discovery of these curves and their understanding through simple observation of facts and logic, then the whole theory of Marx about surplus value, or profit, and all his conclusions, appear before our eyes as one big folly. It is hard to believe that such a concept could have arisen in the human mind, and even more so that so many people subscribed to it. I would argue that in the history of human intellectual development, it is a kind of stain, darker than the worst superstitions, because it has fueled conflict under the guise of progress.

If we look at a production facility from the perspective of the highest return on investment, the expenditure and income chart (Fig. 6) clearly shows the paths to follow to achieve the highest profit. Since the sales value curve, as we have already mentioned, usually has a tendency to tilt downwards, and this phenomenon does not depend on our will, there are only two ways left for us to achieve the highest profits: lowering our operating costs, i.e., lowering curve (*AB*), and increasing production to the limit (*p1*), at which the difference between the ordinates of curve (*OS*) and curve (*AB*) is the greatest.

From the chart, we can easily notice that such a policy of the plant manager also leads to satisfying the most important interests of the buyer of the manufactured product, as the low unit cost allows for a reduction in the selling price, and the increase in production, i.e., supply, allows it to be purchased by more people.

So, we see that there is no fundamental contradiction between the interests of capital invested in the manufacturing plant and the interests of the consumer, as long as the manager properly understands the laws governing the flow of expenses and revenues and follows the above-mentioned paths to achieve the highest profits (reducing production costs and increasing production).

But looking at the chart, we notice that increasing profits by increasing production has its limit at the point when curves (*AB*) and (*OS*) are farthest apart.

We could call the production (p_1) corresponding to this second point the "second critical production." If we exceed this last point, the total profit will begin to decrease - the price per unit of production will fall faster and faster, and after exceeding the marginal value (market saturation), demand may decrease so much that a crisis eventually occurs - when further increasing production begins to bring losses. We will always reach such a crisis if we increase production too quickly without taking into account the pace of market purchasing power development and not exploiting all possibilities of reducing cost curves. However, if we gradually increase production and simultaneously lower our operating cost curves and influence the expansion of the sales market with appropriate sales price reduction policies, then despite the decrease in the sales value curve, the point of the greatest distance between both of these curves will move to the right; in other words, such an increase in production will no longer cause a decrease in profits or a crisis resulting from excess production compared to demand.

Someone could object here that such a conclusion is a theoretical assumption that could fail in practice - however, whoever has carefully read [Henry] Ford's insights will be convinced that he adheres to precisely such a policy in managing his plants and has practically proven on a large scale that it is the right policy that can always reconcile the highest profit with the greatest interest of the consumer.

But analyzing production costs as a function of production and time leads us to a third extremely important conclusion concerning the remuneration and interests of workers. Since the total cost (*K*) consists of a whole series of items, including labor, i.e., the amount paid to workers employed in the enterprise, one might superficially conclude that reducing production costs directly leads to the necessity of lowering wages; however, a deeper examination of the dependencies between the individual cost streams and production leads us to the opposite conclusion, namely, that increasing wages, reducing working hours, and generally improving working conditions can be fully reconciled with lowering the total sum of production costs and increasing production per unit of time, as long as various technical and organizational improvements aimed at saving energy, materials, and time are applied appropriately. Although progress in the field of technology is already significant, we do not yet see an end, and technical sciences continue to open up new fields for progress; organizational science is only taking its first steps and opens up immense horizons for us in the field of eliminating waste. Therefore, when looking for ways to reduce costs and increase production, we will always find inexhaustible means in technology and organization, and we do not need to resort to lowering wages or worsening working conditions. On the contrary, even rational wage increases and improvements in working conditions can, in many cases, directly contribute to lowering operating costs and increasing production.

Due to lack of time, we cannot go into a more detailed analysis of this issue here; we will only say that a detailed consideration of all the factors on which the cost flows depend - strict engineering accounting with a pencil in hand, without resorting to various humanitarian considerations - ultimately leads us to the assertion that there is no contradiction between the interests of workers, high return on capital, and the interests of consumers, as long as we know the whole mechanics of expense flow and can rationally regulate these flows.

The chart in Fig. 6 shows the general law governing these flows. If we wanted to graphically represent the total balance of flow at a given production per unit of time, we could present it in the form of a chart shown in Fig. 7, namely, if we draw production costs and sales values in the form of streams, the width of which we will take equal to the ordinates obtained from the chart in Fig. 6 at a given production. Thus, in the example provided in figure 7, the width of the total cost stream (*ab*) is equal to cost (*K*) at a given production (*p*).

The width of the streams in the upper half of the chart consists of a whole series of streams and rivulets representing different cost values.

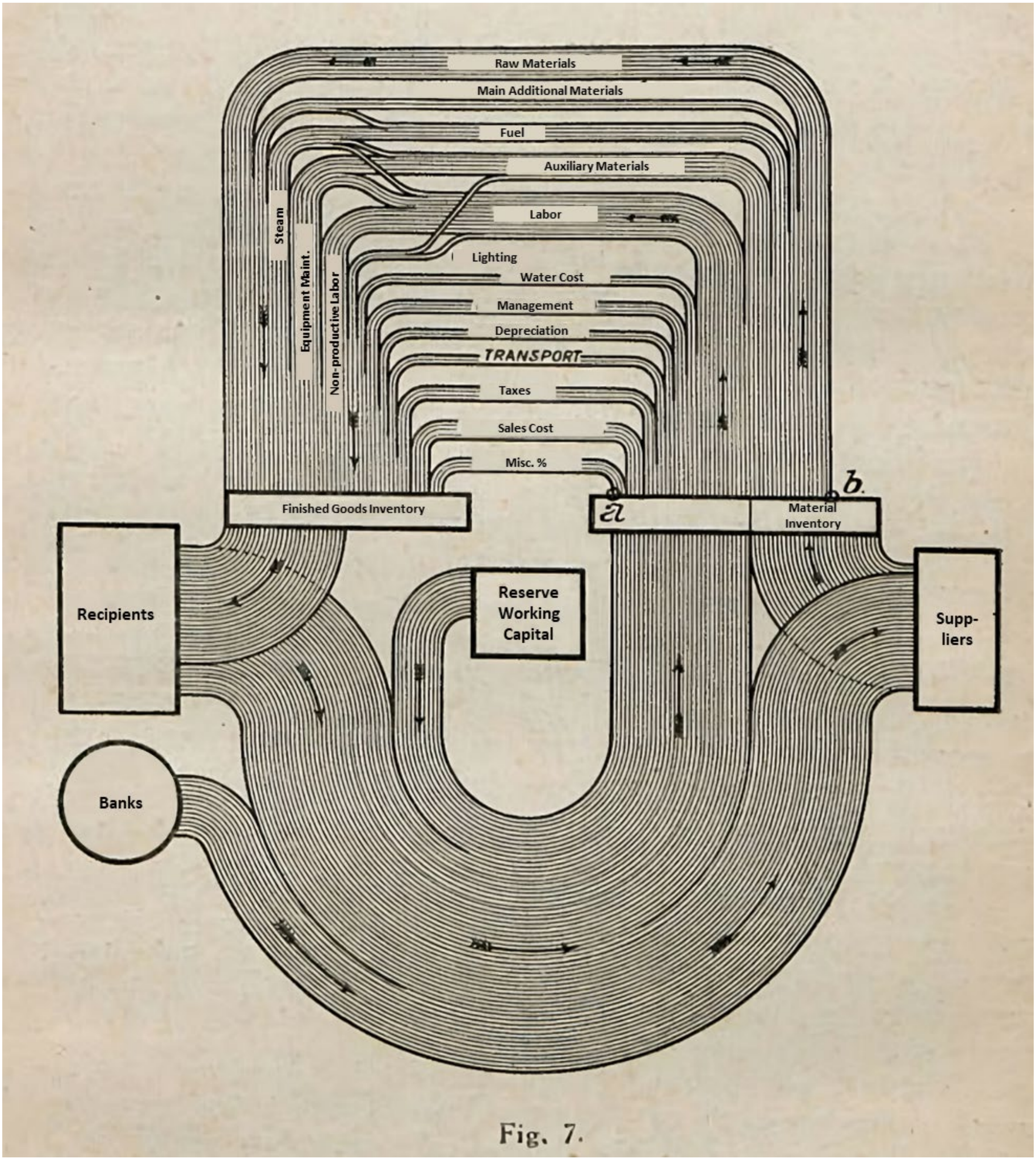


Fig. 7 [“Value Stream Map”]

The lower half of the chart represents revenue. But the inflow of money for the sold product does not go synchronously with the expenditure on production in a given unit of time. In a given month, for example, not all the products produced may be sent to buyers (with a portion stored temporarily in the warehouse). Payments from recipients may also arrive for products sent in previous months. The same can be true for deliveries: in a given month, a greater or lesser amount of materials may arrive than were used in that same month for manufacturing, and the payment for the supplied materials may relate to previous deliveries. In other words, we can encounter the most diverse thicknesses of inflows and outflows on the chart.

But the expenditure needed for production cannot wait – the thickness of the cost stream must be covered in a given month, otherwise it would result in a halt in manufacturing. This lack of synchronicity in flows applies not only to the main outflow and inflow streams of money. We can easily notice this in almost all the individual streams throughout the entire cycle. Therefore, we must have some additional accumulators that would take on the excess inflow or cover the deficit in case of a decrease in inflow. Such accumulators are:

- stocks of finished goods and materials,
- reserve working capital, or
- various credit institutions such as banks, etc.

The chart in Fig. 7 presents a general picture of expenditure and income processes taking place in every manufacturing establishment and is a graphical balance of the entire circulation of value in a certain unit of time, e.g., a month, and at a given production (p) executed during that month and the various exchanges the establishment had with outside parties during that time.

If we express the streams in general sums, we will get a fairly simple picture indicating that we are dealing with a circulatory process. However, the more we delve into the details of this process, the more we will realize that it is highly complex.

Each of the main streams consists of numerous smaller ones, expressing either the flows through various individual organs that make up the entire productive organism, or expressing individual expenditure or income positions, e.g., material costs, sales values of individual products, acquisition costs of various means of production, inflows and outflows of money from buyers and to suppliers, etc.

All these streams and rivulets generally do not flow synchronously among themselves and not synchronously with production, although each of them is more or less dependent on it and flows according to its own characteristic chart (*AB*).

This circulatory process reminds us of blood circulation in a living organism. All the more so because the width of the streams is not constant, but variable, they depend on one another and on various internal and external influences.

All these streams and rivulets constantly pulsate, and they are interconnected in an incredibly subtle way. If we start to influence any of them, it will affect the entire flow. Some streams have a property that if we start to expand them, other streams will also expand automatically in various proportions or, conversely, narrow down automatically, and so on.

In a word, we are dealing with an organism in which highly complex and subtle economic processes take place, and which a manager must direct. Of course, this task is not easy. It requires extensive knowledge and experience to not only orient oneself in such an immensely complex web of technical, commercial, financial, and economic issues, but also to be able to regulate the flows with the thousands of knobs and faucets from all the streams to achieve the highest useful efficiency coefficient.

If we compare this circulatory flow (balance) with other similar processes we have thoroughly scientifically studied and can manage efficiently, e.g., if we compare it with energy balances in converting fuel heat into mechanical and electrical energy, or cycles of various technological processes, we come to realize the intricate complexity of the entire manufacturing process expressed in monetary terms, and its comparative lack of extensive study.

We must admit that while we have made significant progress in some technical aspects of this process, in others related to the economic side and coordinating everything into a perfectly functioning whole, we are only taking the first steps. Undoubtedly, we will only be able to manage a manufacturing plant effectively when we scrutinize all its processes with the same precision that we've applied to studying energy transformations in engines or various reactions in technological processes.

Our current position in dealing with the immense complexity of economic phenomena in today's manufacturing plants is analogous to that of an engineer operating a steam engine, but to whom the complex energy transformations occurring within it are a complete mystery.

So, the task is not easy, but there is no doubt that we are quickly approaching rational solutions. We have already found the two aforementioned laws governing the flows of expenditure and income, expressing their dependence on production and time, and the science of organization is expanding ever wider, starting from the organization of sequential tasks for a single worker and now applying scientific methods to the organization of all production and economic processes in industrial facilities.

Qualifications necessary to perform the role of a manager.

From this brief overview, we can see how extensive knowledge and experience a manager should have in order to meet the challenge. The operation of the entire organism depends not only on its internal structure but also on many variable external conditions – commercial, financial, economic – necessitating a thorough understanding and ability to navigate these conditions to find the optimal solution for each unique situation.

If we then consider that this entire manufacturing organism is composed not only of machinery and devices, but also of people, who form a kind of collective nervous system that directs the entire organism, and who are incredibly subtle machines with not only physical but also a vast array of spiritual properties and interests, we will understand how challenging and responsible the task of a manager is, whether directing the entire industrial plant or its individual parts.

Who can meet such a challenge?

To this question, we can answer that only someone who:

1. has sufficient knowledge and experience, and is able to:
2. analyze in the finest detail the entire intricate web of phenomena,
3. discover the laws governing them, and properly utilize these laws,
4. apply scientific methods to eliminate all unnecessary waste,
5. consider the properties and needs of employees, and
6. coordinate all factors towards the three most important goals, namely:
    a. the greatest economic benefit for the whole society,
    b. the greatest benefit for the employees, and
    c. the highest profit from the invested capital.

Today, there is a widespread belief that the person who has the right to be the overall manager of an industrial plant is primarily the person who invested money in it, the owner. However, owning a property does not imply the ability to manage it, especially an industrial enterprise. If it were only about the interests of the owner, about receiving personal profits from the invested capital, then obviously nobody would need to worry about whether the owner-manager has the necessary qualifications or not, even if they were completely illiterate. But every manufacturing plant is essentially a specialized organ fulfilling some economic functions of the entire nation. This is a point that all industrialists acknowledge, particularly when they're advocating for their interests or seeking privileges or assistance from the government and society.

Therefore, society cannot afford to be indifferent as to whether the owner of a manufacturing plant is qualified as a manager. Incompetent management can lead to significant harm, not only to the enterprise's employees, but also to society as a whole. Today, many people who still believe in the omnipotence of capital find it challenging to accept the idea that capital is not the primary driving force. They struggle with the concept that mere ownership does not automatically entitle them to independently manage the enterprise.

It is worth quoting the following statement by [Henry] Ford:

> *"The employer is just a person, just like his workers. He has the right to maintain his position only as much as he can fulfill it. If he can steer his enterprise, then he fits his position, otherwise, he has no more qualifications than a newborn baby."*

So, if we look at things impartially, we must answer our question that the mere title of ownership is not a sufficient qualification to manage an industrial plant. And if we start examining the existing relationships, we can easily see that a significant number of owners of manufacturing plants do not have sufficient knowledge, experience, or other qualifications for management.

Engineer as a manager of manufacturing plants

For some time now, there have been claims for workers to take managerial positions in industrial plants, primarily from some leaders of the labor movement who have turned the workers' cause into a tool of politics. The average worker, possessing a fair amount of common sense, would typically hesitate to take charge of such complex affairs that require knowledge they do not possess. Of course, some of them might aspire to the position of a director or workshop manager, but mere desire cannot replace the necessary qualifications, and such experiments can only lead to the ruin of manufacturing plants, as has been broadly tested in Bolshevik Russia. There is no doubt that among workers, there are occasionally talents so outstanding that they could successfully hold official positions. However, this should not be generalized to all.

Merchants and financiers often claim to be best suited to manage manufacturing plants. But this only proves that people who meddle in affairs they don't fully understand can be found everywhere. While a deep understanding of commercial and financial matters is essential, it only constitutes one part of the necessary qualifications. Among merchants and financiers, of course, there are individuals capable of embracing the entirety of the required qualifications, but these are rare exceptions, and generally, outdated prejudices still dominate these spheres, such as among merchants—the belief that the whole art of trade lies in buying as cheaply as possible and selling as expensively as possible—and among financiers—the belief that money is the entire economic power and that manufacturing plants exist solely to extract money, before which all other considerations and objectives must yield. Members of these two groups hold a deep conviction that industry and commerce cannot be guided by social or national considerations because they weaken their economic power. They have equated these considerations with the always devastating effect of charity, a legend many people unfortunately believe.

Since management positions in manufacturing plants are most often occupied by people with technical education of various levels, the question arises whether technicians and engineers have sufficient qualifications to solve all the above-mentioned management-related issues. To this question, we must also answer negatively and state that among today's technicians and engineers, there is still a small percentage of people who can cope with such a great task. Generally, we have more than enough preparation for solving technical problems; but our knowledge in the commercial, financial, and economic fields is insufficient, and above all, we do not have training in organization itself.

Despite this, we can confidently assert that the methods of rigorous mathematical and realistic thinking in which technicians are best trained, and which have already produced such great results, provide a guarantee that it is technicians, rather than anyone else, who will best solve the tasks related to managing manufacturing plants after expanding their knowledge in other fields.

However, analyzing the issues related to production processes, we see that among them there are many issues of another category, which cannot be solved by knowledge and professional experience alone, and for which we can find the key only in individual and social ethics.

Therefore, the manager of a manufacturing plant should possess outstanding virtues in this category.

If we want to apply for a production managerial role, we must understand that the widest professional knowledge will be greatly flawed if it is not accompanied by an equally high socialization of the manager. A person lacking these virtues should not take on managerial roles, because instead of contributing to progress, they can easily become a social pest.

Role, position, and responsibilities of a technician as a manager.

We must finally get rid of certain prejudices that have also penetrated some technical minds, particularly that there is a fundamental contradiction between the interests of workers and the interests of capital, as this prejudice obscures the mind and eliminates any basis for the logical thinking required in solving every economic issue.

If this fallacy of conflicting interests were true, then we technicians would have no choice but to roll up our sleeves and join the fight on one side or the other, using all our technical knowledge as a means of combating the other side. It would be more logical than putting our creative work between two fiercely fighting sides, watching helplessly as it is destroyed, and constantly receiving painful blows from both sides.

Today, knowing that there is no such contradiction and having reached this conclusion not only through theoretical analysis but also through practical experience, as Ford has done for example, we must abandon our passive and narrow position and, having expanded our knowledge, take on higher positions in production management. We must occupy an unoccupied position and roll up our sleeves, not to fight opponents, but to harmonize all pertinent factors and forces and, in this way, eliminate incredible waste, converting it into wealth for everyone.

Harrington Emerson's statement that if we could only turn a fraction of our current losses in energy, human labor, materials, and time into useful results, all humanity would be living in prosperity, is the most realistic truth, and not merely an impossible idealistic dream. Proof of the realization of this claim is not only Ford's activity but also the striking fact that all those nations that currently work better and more effectively, eliminate losses in the use of labor, natural resources, and live in greater prosperity than nations that cannot.

Harrington Emerson also puts forward another claim, that one of the most important principles of efficiency is fair and honest behavior. An truth as old as the world, but we has so forgotten about it that those who remind us of it are often called eccentrics. Such an eccentric is Ford and many of those American activists who have made the greatest fortunes. It seems that the time is coming when man, having tried all means to avoid this truth, will have to return to it as one of the most important foundations of modern economy.

It seems to me that everything said above is enough to define qualifications and shed light on the position a manager of production facilities should occupy. But for his work to be effective, he must rely on some higher moral authority, which would be respected. Such authority can only be created by associations dedicated to a more altruistic vision. American engineers have already started this by uniting in one federation with the motto of serving society and all humanity. They are currently planning to create such a federation of engineers from all over the world.

This level of focus is essential not only because it fosters authority, which is needed to override various detrimental biases and narrow views that lead to wastage of labor and productive resources. It is also needed to cultivate a sense of higher civic responsibilities among its members, which primarily lie on the person directing the manufacturing work.

Our main organizational task is to harmonize all factors of production for cooperation, not for struggle. This task would not be so difficult if today's employers and workers stood at a higher level of culture and if the deeply rooted prejudice that their interests are contradictory and that only through extreme selfishness, without considering general social interests and the interests of the other party, can they achieve the highest results for themselves.

To achieve the desired results under such conditions, the manager-engineer must develop not only purely professional but also general cultural activities - he must therefore support all legitimate demands of both sides, while also opposing demands that would hinder cooperation or impede the application of technical and organizational achievements aimed at eliminating waste and increasing efficiency.

For effective development of such activities, it is necessary to create a third force that both sides of the conflict would have to reckon with - we must therefore have a sense that in our efforts to remove these obstacles, the opinion of an altruistic association, as a representative of the interests of the whole society, stands behind us.

When we take such a position, we will be able to effectively counteract the encountered obstacles, for example, if an employee makes a demand contrary to the proper functioning of the production organism, hindering its development and limiting technical and organizational improvements. If an employee seeks to improve their well-being by demanding higher wages and better working conditions, while supporting these legitimate demands, we will have to veto them if they want to achieve them immediately, without considering all other conditions and economic possibilities, as we are not miracle workers who can instantly implement technical and organizational improvements and change the streams of income and expenditure to cover the increased labor costs without causing a rise in the cost of production, which is always dangerous for the workers themselves.

We must energetically oppose the false ideology of workers that they can raise their own well-being through increasing wages without increasing productivity and wasting time in all its forms.

We must energetically oppose the factors destroying the discipline of collective work, as it is one of the most important foundations of organization and cooperation.

We must also actively intervene and veto any obstructions that may arise from the business owner. For instance, should the owner view their enterprise solely through the lens of personal and immediate gains - intending to boost profits by reducing worker wages or worsening working conditions, or prioritizing short-term earnings over long-term sustainability by neglecting equipment maintenance, technical enhancements, and ongoing organizational progress. It's problematic if a considerable portion of the profits isn't reinvested in the enterprise for improvements and financial fortification against potential crises.

We must also intervene if the business owner views the manufacturing plant as a platform for various speculative activities and aims to introduce policies that encourage such speculation. We must oppose their intentions if they believe that the optimal strategy to boost profits involves increasing the selling price and forming cartels to achieve this objective.

We will have to intervene if the entrepreneur sets up production plants for purely speculative purposes or without having a clear idea of the sales market, thus contributing to the triggering of crises and so on.

Finally, understanding our managerial position in the economic life of the entire nation, we will have to veto if the government or legislative bodies, interfering in industrial or workers' affairs, wanted to introduce regulations even in the best faith, but not in accordance with economic laws or that could hinder the development of technology and organization in industrial bodies. We must veto if the government, for political reasons, will adhere to the policy of "taking into account the current mood" and thus unwittingly help the harmful violation of fundamental economic rights or the reduction of work efficiency, of which we have numerous examples since the beginning of the rebirth of our statehood.

But pointing to the numerous duties that arise from the position we must take as plant managers; I would not like to be misunderstood. Saying that mainly among technicians and engineers, there may be people who can best solve issues related to the management of manufacturing work, I do not claim that this should be a reason for giving them special rights or privileges in this regard. Giving such privileges would distort the whole matter and would lead to the harmful path of caste and regulation of activity, which cannot be regulated.

The position of managerial manufacturing work, requiring great knowledge, experience, and highly developed sense of citizenship, as well as outstanding personal qualities, cannot be achieved through any privileges. Such a position is achieved only through the actual possession of all personal qualifications and demonstrating proficiency through action.

If I claim that there is also a need for a certain collective force, it is not at all for the defense of the material interests of the members of the association or for taking a militant position, as is the case today in all professional associations, but to raise the civic culture of its members and create a higher authority that would stand guard over the interests of the entire society and fulfill its functions with the help of its impartial opinion.

Lastly, when I argue that the managers of manufacturing operations must counteract and eliminate hurdles that impede the harmonization of all forces and factors of production, undermine work efficiency, and contribute to waste, it's important to clarify what this entails. This does not involve meddling in economic affairs via various commands, prohibitions, rules, privileges, or similar forms of top-down regulation. Rather, it involves actions and adaptations of existing economic relationships that prevent such obstacles from arising in the first place. However, we must acknowledge that these hurdles and resistances cannot be eradicated immediately, as they primarily stem from deeply entrenched aspects of our general cultural state and cannot be removed simply through artificial regulation or forceful methods. Elevating our cultural level is key. One of the most effective ways a manager can influence and counter these obstacles is by maintaining a high intellectual and moral standard and demonstrating strong character. It's undeniable that these qualities in a manager exert a positive and remedial effect on the entire environment.

In conclusion, the advent of organizational science—a field that pervades all sectors of the economy and conducts an all-encompassing analysis of its phenomena—unveils a substantial civilizational task for technicians and engineers eyeing managerial roles. This endeavor may pose challenges, but the immense honor and prestige it offers is undeniable.