

Theory of Transformations: Some Basic Representations of Practical Problems

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The Production transformation processes may be defined as a strictly determined sequence of actions, operations, and processing that guaranties a desirable result. They are divided, depending on the degree of their uncertainty, into three types. The main goal of the production process is to receive repetitive results. Yet, the final results are never strictly identical. It means that the full identity of different objects is principally impossible. It is possible to detect a set of properties, features or actions which are the same for similar objects or processes. If a set of these features (properties, actions) is complete and does not include any excessive ones, it is defined as Fundamental Properties. Two objects with the same Fundamental Properties are not completely identical. The set of Fundamental Properties defines so called sameness objects and processes. As a result, one can say that production processes can produce only the sameness results or goods. Fundamental properties for any object or phenomena may be defined in different ways for different hierarchic levels. They can also be changed for different observers or measuring systems. It is shown the growth of diversity at the top level of a hierarchical organization is ensured by limiting diversity at the lower levels. At the same time, increasing diversity on the lower level destroys the top level of the system's organization. The necessary flexibility of production system and optimization problems in full flow charts are studied. It was find the stability of the whole production system is closely connected with its hierarchical structure. The more independent levels in the hierarchy of the production system are the more stable the system is as a whole. Some ways for further investigation of the detected problems are discussed. Some ways for further investigation of the detected problems are discussed.

Introduction: A Brief Historical Overview

The universe is inhomogeneous. Its existence is realized in continuous changes. The simplest representations suggest that these changes can be casual and natural. All of them are a result of the interactions. These interactions are realized with the help of different flows: flow of substance, flow of matters, and flow of information. These flows affect the objects. If the affect is strong enough, one can say that it is a transformation of an object. Yet, frequently one can have a situation where the main part of an object does not change. This case is traditionally called a reflection. The difference between transformation and reflection is frequently insignificant. The difference between animated and non-animated matter is connected with activity of a living matter. Moreover, the higher animals are able to set goals of their activity. The results of this activity can be denoted as transformation processes. Certainly, all general theoretical descriptions of transformation processes have a large cognitive interest.

Each transformation process has two actions, which affect both the objects that are the sources of actions, and the surrounding environment. In turn, the environment can have a secondary impact on the object source of an action. So, after the appearance of the first organisms, their first forms created an oxygen atmosphere. This, in turn, led to the emergence of the new forms of life. This is known as *The Great Oxidation Event*. Similar phenomena are systematically repeated throughout the history of our planet [1, 2]. These problems have attracted a lot of attention in recent decades. They represent the main interest for most of the general scientific and philosophical theories. Yet, at the same time, historically much more attention of researchers was focused only on the pragmatic side of the issue. In these studies, the transformation was studied only from the standpoint of achieving the desired results. Already in prehistoric times all humans used primitive stone tools and directed

transformation to prepare meals, clothes and weapons. These tools, in turn, affected people. As a result, the interactions between transformations and humanity were the driving force of the socium evolution [3, 4]. It is well known that during the Paleolithic Age people started to have an initial understanding that the use of transformation had permitted one to achieve certain goals. Ancient philosophers made the first steps in theoretical comprehension of transformation processes. However, the serious study of these processes started at the end of the Renaissance. Many neologisms were introduced in Latin at that time. A big part of them came from Greek words. The foundations of modern descriptions of the processes of transformation started to form at that time. The great contribution to the formation of these theoretical representations was made by the countries of the German language. The German scientists used the term *Nützliche Künste* [5] to denote a transformation that could achieve desirable results. It was well known in English as “useful arts”. The special new term “technology” was at first used by a famous German scientist Johann Beckmann. The best of his books were translated into many languages. The last of them were printed not long ago [6, 7]. After Beckmann, the new term “technology” became widespread. At the same time his basic ideas and definitions spread everywhere. For more than two centuries after Beckmann, all areas of the possible usage of directed transformation processes were studied actively. Over that period, many general problems of philosophy and especially interactions between transformations (technology), economics and political evolution were successfully investigated [8-10]. Over the last years one can see many significant achievements in the usage of transformation processes in different areas of human activity. Therefore, the general study of these processes was carried out [11-14]. To avoid inaccuracies it was necessary to give special definitions for a studied area. For this reason, a wider definition of the different determinations for the term “technology” was created. As a result, we frequently have to deal with different misunderstandings. This can affect the results. This problem is especially important for instructional strategies. Therefore, we made special refinements of the commonly used terminology [15, 16]. These refinements were based on the General system of the transformation processes classification. The proposed classification system is divided into two principal parts [14, 15]. The first part is called Generative classification, it covers the transformations which study the most General interactions in the Object and Environment system. The second part was named Specific classification. It covers description of the transformation processes from the standpoint of their practical use. The most interesting feature of this system is the possibility of independent study of both of its parts. All practical problems are tied to the transformations which are covered by the Specific classification. Therefore, in future analysis we shall focus only on the transformation processes covered by it. According to [15] we shall denote the transformations of this part as *Production transformations*, or *Production technologies*.

Various production transformations differ according to the degree of their uncertainty. They can be divided into three types: *receipts*, *recommendations* and *production* [16]. Each of them may be described by a single definition:

Main definition: Production technology is a strictly determined sequence of actions, operations and processes that guaranties the desirable results.

This means that the base of technology is an algorithm of the sequence of operations, actions and processes that can predict a final result. It is possible to say that such a process produces or transforms some initial things or goods into desirable objects. Consequently, the principal behaviour of production technology or production transformation, in the simplest case, may be presented in the form of a triad (fig. 1). This triad consists of an initial object (input) and a final one (output). These objects can be of a very different nature. For instance, in the case of educational systems, the input and output parts of a triad are students. The middle part is traditionally defined as method.



Figure 1. The triad form of representation of Production processes (transformations or technologies).

The transformation or production process (technology) includes a schedule of actions and operations. It includes different technical systems, such as engines, apparatus, machines, tools, and instruments [17-20].

The study of production transformations, which is briefly discussed above, gives many interesting and useful results [13, 21]. As usual, the reference to these results raises new problems. One of the most important is connected with clarification and specifications of the meanings of the terms that were used in the main definition of Production technologies. This problem will be discussed in the next section.

Ideal and Real Production Processes

Despite the complexity of the universe, its perception by humans is possible as a result of a simplified analysis. One defines

a simplified analysis as modelling. In the process of modelling, one takes into account only some valid properties of objects and their environment. It means that simplification causes a loss of several important properties of a studied situation. It is a necessary cost for analysis simplification. A prerequisite for successful modelling is the ability to identify its main factors. The most simplified model, which captures the main properties of the object or phenomenon, is frequently called an ideal model. A good example of an ideal model is a triad form of the presentation of the transformation process given in Fig. 1. The ideal model can be very useful. However, it can never fully reflect all details of the case. Nevertheless, the ideal models bring huge benefits. This is due to the fact that thanks to these models we can see the most important features of the studied objects and phenomena. Further specification usually requires improvement of the used models. Such models are usually called the real ones.

The ideal model of the triad form identifies the basic properties of any transformation. This point enables us to introduce a very convenient form of description of the processes and machines [11, 15, 17, 19, 20]. Study of this ideal model permits us to give the main definition of Production Transformation or Production Technologies given above [15, 20]. In most cases, in this definition, one pays attention to the very important fact of the strict sequence of different transformations (actions, procedures, operations, processes). This is surely a fundamental fact. Therefore, the additional important assumption is frequently omitted from analysis. The requirement is that the ideal Production Transformation (technology) should guarantee desirable results. It is usually assumed that it is sufficient to consider all saleable results as desired. Unfortunately, the more detailed concept of the desirable results is not discussed very often. Therefore, we have to analyze it in detail.

A desirable result of any transformation is a highly subjective quality. One can say this about an individual desirability and average desirability or expectations of a group of customers. Many different circumstances can affect its definition. This very definition is based on the enumeration of a number of desired properties of an object or process. To put it simple, this is about customers' specifications. These properties may be both quantitative and qualitative. For simplicity let us suggest that each property can be expressed numerically. The standard analysis involves the use of one of the four types of measurement scales: nominal, ordinal, interval or ratio. The standard methods of their measurement will be the way of receiving the necessary values. The values attributed to the properties can be normalized to a standard interval [0 -1]. In each real situation, not all the properties of an object or process are interesting for practice [15]. It means that the desirable results do not give a full description of an object. As a result, we can say that the assumption that desirable properties can unambiguously describe Production transformation, is a typical idealization.

Clarification one: The notion of an ideal Production transformation or Production technology is based on three independent simplifications. The first is the ability of building a simple structure of sequence of actions, operations and processes. The second is the ability to clearly express the wishes of different groups of possible users. The third is the ability to strictly define the objects, goods or processes by incomplete enumeration of their properties.

It follows three independent conditions which define the concept of an ideal product transformation. The last one is usually not discussed despite its importance. At the same time, this simplification is closely related to some basic problems of Natural Philosophy. These authors decided to study this problem in a separate section.

Production Transformations and the Problem of Identity

From the point of abstract studies the ideal Production transformations create goods, materials, services etc. which fully and precisely satisfy the expected specifications. In a more detailed form this means that if one has the same kits of goods and machines, and performs the same sequence of different actions, operations, or processes, then he (she) obtains the same result. Moreover, it is implicitly assumed these results may be checked. To put it simple, we can suppose that if all conditions of Production transformation process and input materials are the same, all the results will be strictly repeated. In a simple routine understanding, this means that if all conditions of transformation are the same, the results will also be the same. This is a simple and natural statement. However, it requires updating.

Let us take, as an illustrative example, several objects which are the result of a production transformation process. In a standard situation all different objects must have the same values of customers' specifications. We define such objects as *Sameness objects*. The term "sameness" can be extended to resulting processes and services too. What does it mean to receive two sameness objects in reality? Let it be A and B. From the Ancient Greek Philosophers we say: if $A = B$, all properties of both objects are the same. In this case the philosophy says: it is a *strict* or *numerical identity*. More exactly this was said in Leibniz's Law [22, 23]:

If A is one and the same thing as B (that is, A is numerically identical to B) then: every property that A has, B also has to have, and vice versa.

The detailed additional study of this problem was done by the famous philosopher McTaggart [24]. The main conclusion from many reviews of this problem [23] is summarized in the following statement: *There are never in nature two beings which are perfectly alike*. It can be also said in a little more detail: *Everything is identical to itself; nothing is ever identical to anything else except itself*. Finally this means: *Two objects (things, goods and even the set of actions) can never be fully identical* [25]. Moreover, each object changes in time. Yet, the ordinary needs of a human never require strict identity of objects and situations associated with his (her) life. Therefore, since their birth, all people subconsciously divide all objects and events on the basis of less stringent requirements than full identity. The brains of the higher animals, such as the humans, selectively pick up all features or properties of objects and events and divide them into two main parts. The properties of one of these parts remain constant or invariant over time, in size and through several transformations of the object (process). The second part of the features (properties) may vary within wide limits. It is hardly possible to predict in advance how to divide all features (properties) into these two independent parts. The result of this procedure depends on several factors. One of them is strongly tied to the senses of biological species [26]. The other is connected with the environmental situation or, more general, from the context in which the object or set of actions are perceived.

The group of invariant features (properties) is obviously less than the full list of these items. As a result of its incompleteness, the list of invariant properties can be the same for various objects. The difference between these objects is tied to a set of non variant properties. All objects or processes with the same set of invariant features (properties) in a certain range of requirements can be considered as being similar. One can say: *The full identity of different objects (processes) is only an ideal situation*. It may be also said: *The groups of identical objects (processes) are always single*. In real life, the requirements for matching the properties are less stringent. Therefore, in reality, the groups of objects (goods, materials, processes), which a user of consumers treat as similar can be large. For practical purposes all these objects and processes are usually treated as similar. All objects or processes which are gathered in such groups are defined as *sameness*. Sameness objects are the real replacement of ideal representation of identities' objects. They are the targets of human activity. It is clear that the sameness objects are the desirable results of production transformations (technologies) in the main definition written above.

To illustrate these General considerations let us take a simple example. For preparing a set of transistors an engineer needs to have a piece of germanium single crystal with a given value of conductivity σ . It is well known that as the first approximation one can say: σ depends on carrier concentration n . This is a difference between concentrations of negative and positive carriers (electrons and holes). This value may be the same, as for example, at this time the concentration of electrons can be different. Moreover, concentration of electrons is set by the concentration of donor impurities. Usually the donors are the atoms (ions) of the fifth group of the periodical system. It may be P, As, Sb. The value of σ or n can be the same in several pieces of Ge, yet, some other properties of these samples can be noticeably different. One can say, if someone compares such samples of germanium from the point of conductivity the other properties of these samples are not the same. So, these samples are sameness objects, yet, not identical ones. It is not difficult to give some other examples of this type.

It is necessary to pay attention to another important fact. Traditionally, all general philosophical studies of this problem never analyse the structure of the object's properties. In many cases, this is enough. Yet, for the problems connected with the analysis of the Production transformations it is necessary to take into account some other circumstances. A quick look at the above example with germanium samples draws attention to the fact that such properties, as conductivity and concentration of impurities and their enumeration belong to the different levels of the hierarchy of the sample features.

Some words about hierarchical structure of the Universe. At first the idea of the universal structure of the world was expressed in 1761 by J.H. Lambert in his *Cosmologisches Briefen über die Einrichtung des Weltbaues*. It was printed in Augsburg [27]. After this time a lot of books and articles were printed across all countries [28]. The main idea of this principle of the iUniversal hierarchy can be expressed as *the structure of the World is intrinsically complex, with variation of different objects at all detected scales*. As a result *the hierarchy theory considers that any complex system is at the same time a component of the other system at a large scale and is itself comprised of self subsystems*. Some decades ago the idea of the universal hierarchy was supplemented in 1967 by Arthur Köstler who introduced the concept of *holons* [29]. Each holon has its border. They may be both visible and invisible. It is valid to take into account that holon levels and their borders effectively act as filters of holon's features. This, in turn, allows us, if it is necessary, to consider the properties of holons, regardless of the properties of the whole system. This approach gives huge advantages in the analysis of many problems. Hierarchies are already the models in a decomposed form. The different control and communication channels between the holons constitute the coupling system of the decomposition. The hierarchy with holons, as its components, is frequently named *Holoarchy*. Holoarchy constitutes generally a very desirable decomposition of the overall system (Fig. 2). In short, the overall model is decomposed into different levels, where each level models the real system in discussion from a certain domain specific and abstract point of view. Within a domain specific view of modeling, the model, represented by a multi-strata hierarchy at a certain level, is a refinement of the models of the levels above. Very often this refinement is realized by an accompanying decomposition. Therefore, any component of a level model consists of several components on the next lower level [29].

According to the holoarchy concept, one says: *The horizontal structure of hierarchical systems (each of its level) appears as several subsystems named holons.* Holons have a dual nature. On the one hand, they represent a holistic alien structure of the whole system. On the other hand, they are almost independent systems of the lower level. It means, they can be divided into some smaller items. One can say: each holon is a complex aggregate of holons of a lower level range, and at the same time it is an element or holon of a level of a higher range.

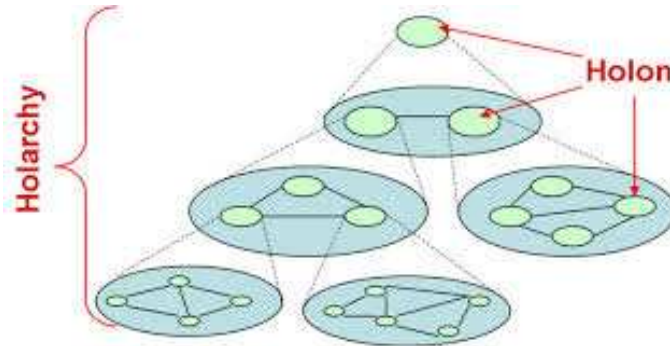


Figure 2. The principal sketch of horizontal and vertical interactions in the part of hierarchical system or holoarchy.

For study of this issue, it is important to pay attention to the nature of the interaction between elements of the system. These interactions exist between the elements of each holon. We call them *Internal interactions*. In addition, there are interactions between elements of different holons, or external ones. If the interactions occur on the same level a hierarchical system we call them *Horizontal interactions*. The emergence in the system of the substructure in the form of a holon is a consequence of the fact that on the same hierarchical level the power of internal horizontal interactions are much stronger than external. In many practical situations this permits one to study different holons on the same system level as independent entities. *Vertical interactions* in many systems can occur between adjacent levels, and between levels spaced away from each other. There are also known systems in which vertical interactions simultaneously occur between holons at different levels and between their internal elements. The interaction between the elements of the holons at different levels can be quite strong.

It is clear that General idea of holoarchies provides important refinements to the concept of identity. In relation to the issue of Production transformations, we will discuss this matter further.

Identity and Sameness on Different Levels of Hierarchy

We have investigated above the situation with the properties of a sample of germanium single crystal. Let us return again to this problem and discuss a similar situation in more detail. Let us suppose that someone is interested in studying the main properties of a liquid, for example, water. The properties of water depend on external features, such as surrounded temperature, atmospheric pressure, contaminations of vessel and others. Yet, the basic behaviour of the studied amount of water depends on the structure of the water molecules. If one knows that the molecules of the liquid are described as H_2O , all features of studied liquid are known. Let somebody study several vessels with such molecules. If all external factors are the same, he (she) can say that the features (properties) of liquid in these vessels are practically the same. From this comes a natural desire to proclaim all these samples of water as practically identical. This term is too complex and it is much better to treat all these samples as sameness. It does not make sense to speak about the full identity of these samples. Each person who finished college perfectly knows that two H_2O molecules at each moment of time have different structures of their electronic clouds. Moreover, the quark status of all nuclei of atoms in water molecules change continually. Nuclei in a billion water molecules in water samples have different internal status. Nobody can detect simultaneously all individual properties in the full set of nuclei under observation. Therefore, it does not make sense to pose a question of identity of two or more water samples. It is useful to note that these considerations resonate with one of explanations of the famous *Gibbs' Paradox* [30].

The above reasoning suggests a discussion devoted to the problem of identity, without taking into account the hierarchical structure of the Universe, is useful only as an ideal speculation of idealized objects and processes. It gives many interesting results, yet, in the cases of practical human activity one needs to use the concept of sameness. Its definition depends on the level where the practical interest of investigation is. We denote this level as the *Level of Sameness*. The position of this level in the whole structure of the hierarchy is not constant because it is connected with delicate behaviours of the studied problem. For instance, in case with germanium samples which was discussed earlier, in one situation, the level of sameness is tied with the level on which an investigator measures the electrical conductivity of a material. In more sophistic studies this level may be connected with the level, which describes the content of impurities in this sample. It is possible to detect some other positions of this level.

Clarification two: Real position of Level of Sameness is not strictly determined. Its position depends on the nature of a studied problem.

It is evident that the position of Level of Sameness also depends on the methods of measuring or estimations of the *Fundamental properties* studied in the analysis. These properties include only the full list of properties which describe the object in order to distinguish it from the whole set of objects. It is necessary to understand that the possibility of detection of any property frequently depends on context. For instance, it is simple to observe and measure the size of a green box on a blue background. Yet, it is more difficult to measure the same properties of this box with the given precision on a light yellow background. It is clear that the results of the detection depend on the used type of instruments. They also depend on the nature of animal or different humans which make observations [26].

Definition one: It is possible to detect a set of properties, features or actions which are the same for the similar objects or processes. If the set of these features, properties, or actions is complete and does not include any excess it is defined as Fundamental properties.

Clarification three: Fundamental properties for any phenomena may be detected in different ways for different hierarchic levels. They can also be different for different observers or measuring systems.

The closer the different observers are, the easier it is to detect sameness in different sets of phenomena connected with individual perceptions. At the same time, the noticeable difference of real perceptions allows the observers to get a more complete description of phenomena.

Approval one: The proximity of different observers improves their understanding yet loses the completeness of the description.

Practically, this means that frequently a good rapport reduces the completeness of the description.

From the given approval one could understand the major role of the observer's behaviour in the process of comparison and classification of different phenomena. In other words, the comparison of several phenomena and determination of different objects and processes should take into account the role and behaviours of a real observer or measuring instruments. To put it in brief:

Approval two: Comparison of two phenomena in reality requires an independent object observer.

Briefly it means:

Clarification four: Each taxonomy is possible only if we have no less than two phenomena (objects) and the third independent object for comparative action.

The role of diversity in perceptions of different observers can be explained with the effect of stereovision. Two human eyes see different objects from two close points. Their reflections are not entirely similar. As a result, our brains can build a better partial image and estimate the distance between the object and observer. All these considerations clearly show the important role of the observer for comparison of the behaviours of different phenomena.

The level of sameness depends on the studied problem. In this process all principal actions and transformations take place on this level. The neighbouring upper and lower levels are also essential. More distant levels usually do not have any significant role in the studied situation. Therefore, only the three mentioned levels have practical interest. All diverse processes and changes of phenomena happen in the active part of the whole hierarchical system. This does not mean that there is no diversity on the other levels of hierarchy. In fact, weak vertical interactions in the hierarchical system permit us to neglect diversification effects on the levels which are distant from the sameness level for the studied problem. In many cases it permits us to forget about this "Closed Diversity". Then, in the simplified formulation we can say:

Approval three: The growth of diversity at the top level of hierarchical organization is ensured by limiting diversity on the previous levels, and increased diversity on the lower level destroys the top level of the organization.

This statement is frequently called: *The law of hierarchical compensation*, or *The Sedov's Theorem*. Its justification was made in the set of articles by Professor E.A. Sedov. We do not know about any translation of any of these articles into English. The brief content of this problem one can find in [31]. The diversity on the distance levels of hierarchy is not taken into account and discussed in these articles. Such simplification does not affect the principal content of Sedov's statement.

Clarification five: The holoarchic approach says: Diversity really exists, yet the interactions between the subsystems on distant levels are very weak.

Therefore, the approach of closed diversity well describes the actual situations. It means that allE-m conclusions based on Sedov's theorem are valid.

Our analysis indicates that the solution of the problems of identity and sameness is closely connected with the character of interactions between different subsystems. The power of horizontal interactions, as it was written above, separates holons of any level from each other. All of them are inside the same level. In the vertical direction, the situation is more complex. In this case, the interactions between the levels may be of two different types. In one of them the elements of any holon on any level interact with the single elements of the holon on the other level. In the second case, the interactions affect the holons as something whole. Moreover, the single holon of one level can interact with the whole holon of another level. All these diverse interactions can be strong or weak. There are many more possible situations than in the horizontal interactions.

To study Product transformations it is necessary to detect processes which are more complex than moving, rotations, mechanical treatments, and other actions which are not associated with the creation of fundamentally new properties. The theory of the systems [32] investigates the phenomena which are observed on a level of the system which is usually called *an integrative level*. This phenomenon does not represent a simple sum or difference of behaviours of pre-existing phenomena of a lower level. The emergence of a principal new phenomenon is a typical system effect tied with self-organization. This new effect, named *Emergency*, has attracted attention since ancient time [4].

Definition two: Emergency is denoted as a process where larger entities, patterns, and regularities come up through interactions among smaller or more simple entities, that do not exhibit such properties themselves.

Clarification six: As a result of Emergency, the new entities with radical novelty have emerged.

There are many different examples of Emergency known [33]. Production transformation is a set of actions to create entities with new features. Principal novelty, as a result of Emergency, is of a practical interest. Therefore, it is useful to allocate a special group of interactions and transformations which are the basis of creation of entities which properties are the result of Emergency. We shall denote them as *Emergence interactions*, and *Emergence production transformations (Emergence production technologies)*. A typical simple example of Emergence production transformation is the creation of new taste sensations when cooking soup.

Production Transformations: Refinement of the Main Definition

The main goal of Production transformations and Production technologies is to satisfy the specific needs and desires of potential customers or offered services. The customers' goal is a set of requirements and indication of their basic features. The preceding discussion has shown that real requirements do not include the full list of product or service properties. Therefore, the repeated sequence of given actions has to create only a set of sameness entities. They have the list of properties, which determine only the desired properties on the sameness level of hierarchy.

Depending on external circumstances, manufacturing systems use different types of Production processes. The main of ones are: Job, Batch, Intermittent, Continuous, Quasi continuous. The principal difference between them is connected with the volume of products, the number of employees, and the nature of demand. All these factors actively affect the requirements for the products and services. Let us cite an example with tailoring a suit. Not long ago the suit was made by a personal tailor. He (she) was a qualified artisan. The sizes, look and fabric were very individual. Therefore, the final product was rather something unique. One can say that it was a production of a single copy. Therefore, many valid properties of this product are never repeated for various customers. The sequence of tailor's operations was not very hard. It means, the properties of each suit in many ways were very individual. At the same time, the style and several other properties of the suits were unchanged. Such a process was a *Recommendation transformation*, not a production one [15]. In modern times, the vast majority of suits are made in factories. These products are manufactured as several groups of standardized properties. A lot of workers of average skills are involved in such manufacturing. Many operations are automated. The properties of each group of suits are practically the same. This means, the deviations of given norms changes little. This is a typical Production technology (Transformation). Customer demand requires creation of some variety of products. The fashion is usually constant, yet, the colour and accessories may be different. So, on the one level of hierarchy of consumer preferences the suits of one style can be considered sameness. In case someone decides to include the colours in the list of necessary properties, to have one style fashion, this assessment of sameness is not enough.

This situation would be clearer if one studied conveyer assembling of vehicles. In this case several levels of customer preferences may be taken into account. It may be a demand to buy a simple passenger car, or any specific model, or a car with a given colour and additional electronic devices on its dashboard and so on. It is evident that the sequence of actions of the

manufacturing process are variable depending on each customer demands. As a result, we come to the following conclusion:

Refinement one: The concept of specified Production technology is strongly tied to the level of sameness for a given product or service. This relationship should be considered as the most important clarification we have added to the main definition of Production technologies.

The Levels of Production Processes System

There are known to be important areas of developing theory and practice of production processes [21]. Our point is that the most important of them are *Generative* and *Specific Classifications* [15] and the study of Process optimisation actions. Classification is the basis of automation of various practices. These problems are actively studied in several related fields of engineering [19, 20]. Many useful results are known in this field. The problem of optimisation is closely tied with the problem of classification. Yet, it is more complex. Both of these problems are based on hierarchical structure of transformation processes. To create a single map of all actions for any production is an incredibly complex and cumbersome task. For example, someone decides to create a sketch for printing a book. So he (she) must draw the basic operation line. In a simplified form of an element, this line would look as (Fig. 3):

This short line is only a small part of a full one for the given level of the hierarchical description of printing process. Further development of the description generates the simple line branches and turns them into a network. The elements of this network are analogous simple lines, such as for producing letters for printing a matrix, preparation several sheets of paper of a given quality, manufacturing of coversheets and so on. Each line consists of a sequence of operations on lower levels to unite the lines of the described type in a more complex process mapping. From the standpoint of abstracted analysis, the whole network must cover all the spheres of humankind activity on Earth. It is easy to understand that such a process map cannot really be drawn. Moreover, such an idea has no sense because of its excessive complexity. No one can even imagine the humans or computer can estimate the main properties of such a huge problem. Therefore, everyday practice has developed specialized methods of analysis of the system based on the study of its parts. Historically, the study of these parts is produced independently from each other. As a result, the problem of creating a single theoretical information system is not definitively solved.

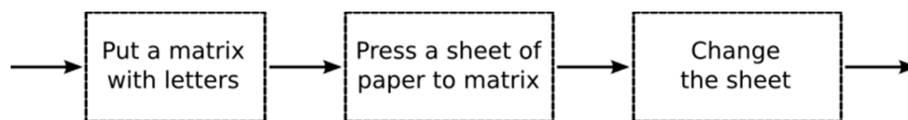


Figure 3. A small part of full line description of printing process.

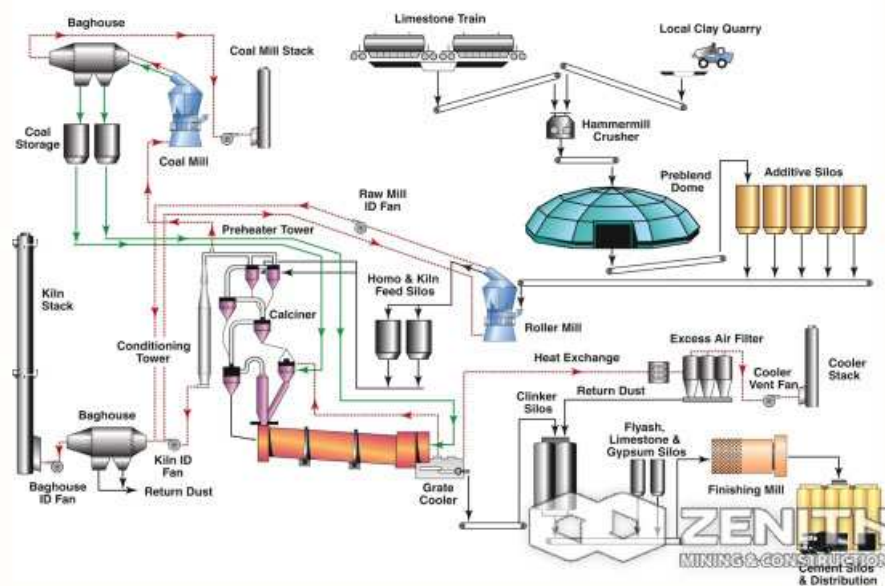
Huge descriptive systems have to take into account many contradictory requirements. As a result, a set of adaptive compromises [15] is necessary for such systems operation. It is possible to write a general equation to find mathematical equations to search for the appropriate conditions. Unfortunately, these equations would be so complex that it is possible to find only its numerical solutions. They are usually not clear enough. Because of this, searches for compromise conditions are carried out separately for each line of production operation networks. This raises certain issues which we will explain with a few specific examples.

Let us find the optimal solidification rate for manufacturing semiconductor crystals. It is well known that the quality of grown material depends on a growth rate. Within certain limits the greater the growth rate is, the worse the quality of the ingot is. Therefore, small growth rates are desirable. At the same time, the higher this rate is, the better the performance of the process is. To achieve good economic performance, the pre-study of the relationship between material quality and growth rate should be carried out. Then it is necessary to determine the maximum allowable deterioration of providing acceptable economic performance. It is the simplest compromise for the pair of quality vs performance. This is a typical compromise on a lower operational level. The next higher level takes into account more than the modes of processes. Optimisation on this level engages the equipment (machine) design.

For example, a designer has to optimise sizes and other parts of the equipment. For definitiveness we assume that it will be the equipment for the Czochralsky crystal growth process [34]. Many technical parameters of this equipment are valid. They are temperature of the furnace, speed of pulling, speed of crucible rotation, volume of crucible, the maximum length of the mechanical rod, automatic systems, and some others. Let us suppose it is necessary to design the equipment for germanium single crystals growth. If these crystals have to be doped with indium, the optimal growth rate and other parameters will be different than in the case with antimony dopant. Moreover, the set of parameters for growing germanium with indium impurity depends on impurity concentrations, the desired crystal weight, and sizes. Without going into detail, one can say the optimal

parameters of a pulling machine for manufacturing germanium single crystals depend on the required properties of the final product [35, 36]. The real plant for manufacturing semiconductor single crystals produces several final product categories. The demand of each category varies. It depends on external economic conditions. On the analysis of such conditions, the management of the plant or company has to find the set of the optimal designs of used single crystal producing machines. In any case, the universal machines are more desirable. Yet, in other cases the sequence of machines, which are oriented on producing a narrow range of specialized production categories, may be preferred. We can say it is the next more complex solution of the optimization problem. One can say that this is a typical feasibility problem. In this way one can get a number of interesting and useful solutions [37].

The problems considered above analyze only the simplest practical problems. Real manufacturing systems are much more complex. This is due to the fact, that they are created on the basis of a combination of simple manufacturing processes which we have just discussed. In Fig. 4, the authors present the flow chart of a manufacturing process.



(From Internet. The owner of information is specified in the lower right corner of figure at the right bottom of this figure)

Figure 4. Process flow sketch for manufacturing of cement.

The arrows in this figure indicate the flows of a different nature, such as materials, energy, information, details and so on. Let us take a look at the upper left part of this diagram. One can see three flows of various nature enter Reactor number 1. Information flow (action) enters this reactor from the right. Only one flow with the new features leaves this reactor after processing. One can see that several various flows enter in each active part of the whole system. The number of output flows is also various. So we can say:

Refinement two: All processing systems consist of different active parts, such as engines, reactors, computing systems and so on, and input and output flows of a different nature. These flows are combined and separated. The points at which the flows get connected or get separated, forming branches, are denoted as Nodes.

So, the most simplified scheme of a *Production transformation process* or a *Production technology process* is the diagram with symbols of active processing parts and sketch of flows of a different nature and their nodes. All flows described with the help of their principal behaviours, intensity, time dependence, velocity, and their allowed variations. If one decides to review the origin of the flows, the flowchart should be engaged. The result is a very complex net of active parts, flows, and nodes. This net covers different hierarchical levels of Production processes system. It is a typical *Cross functional map*.

On each level of processing hierarchy it is often possible to simplify this net and make it lie on the single hierarchical level. This means the simplified net unilevel chain has a plane form (Fig. 5). The full number of hierarchical levels which covered all Earth zone of humankind production activity is very high. One of the upper of them is the zone which describes the distribution of urban settlements based on landscape and flows of production [38]. Theoretically speaking, it may be possible to build full flow charts in the volume of the entire earth's technosphere. However, it is not difficult to understand that practically this task is not solved due to its complexity. As we know no one makes any attempt to carefully study this problem. For this reason, it does not make sense to consider the task of full optimization of transformation processes in this field.

However, the optimization of individual parts of the complete network of Production processes is widely used in practice.

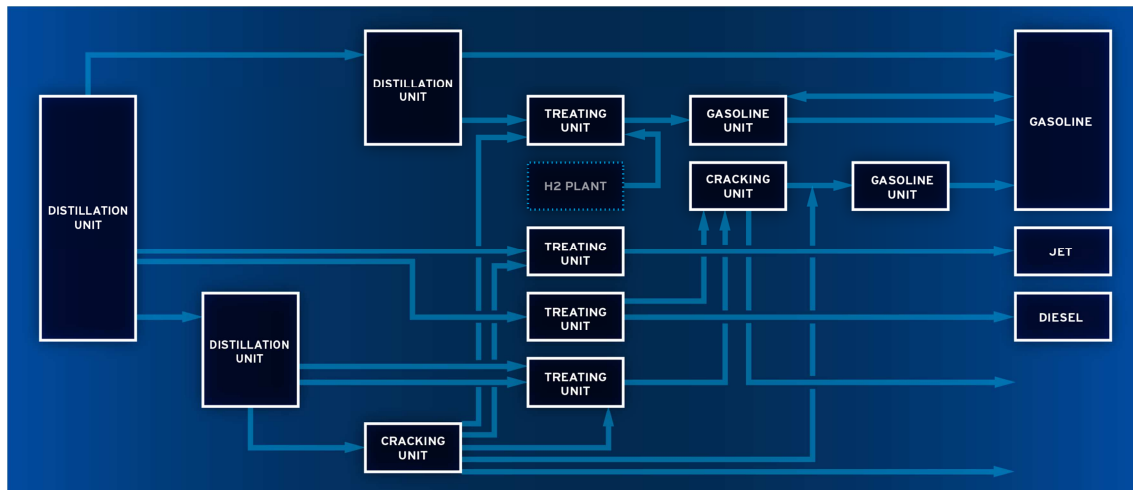


Figure 5. Example of plane flow map after creating new abstract entities. (From: Robert Creek Process Planning Manager Technology Solutions. Chevron. <https://www.filepicker.io/api/file/QeBlUFrqQs2hTZvkAT3i>).

To investigate this issue, one needs to study three groups of problems. All of them should make three types of knowledge transparent. The first has to explain how the properties of a final product or activities interact with other entities in the transformation process and its environment. The second knowledge, as we have written in the previous sections, should find the main relationship between the quality and performance of products involved in the investigation. The last group of knowledge has to study how it is possible to make all products, details, activities, and services better and cheaper. All these studies finally transform into entities which better meet the demands of end users and society needs. The last group is the basis of optimization activities of manufacturing staff.

There are several problems tied with the effective optimisation. The simplest to understand, but still not solved, is the problem of unification of the used terms. Various parts of the General production chart are studied by different sciences. Practically all of them are developed independently. Therefore, a lot of basic concepts and related terms differ. Great efforts must be made to put all these materials into a unified form. Another important, but not very difficult task, is the creation of a unified system of graphic symbols necessary for representation of the processing maps. These problems can be considered as auxiliary. As a result, the most important optimization problems are harmonization of the mode flows and ensuring the stable operation of the entire network. Their solutions are closely related.

Let us take as an example the cross functional map for car assembly. The plant producing the final product assembles cars from such parts as its frames, engines, wheels, bodies, and other. All of them arrive at the plant from different places. It means the conditional entrance to the plant is a node where all these part flows meet. The plant management has to organize the levelling of the production schedule of the variety of car parts and different flows. To ensure uniform operation of the plant the management must agree on the rate of supply of parts for all the flows. As a result, the flow of engines depends not only on the conditions of optimization of their production at the previous stage. The intensity of this flow must be in accordance with the flows of frames, wheels, etc. One should also consider the optimization processes for the final step at the manufacturing plant. The result is a new level of optimization. It is the third level in the discussed chain. The first level was optimization of the single process according to the ratio: quality vs performance. The second level is tied with optimization of the production map for manufacturing of each engine part. Finally, the last level is tied with the conditions of accordance of the speed of production in all parts of the previous level flow maps.

The accordance of various flows provides only an ideal production chart. In real conditions, there are numerous factors that violate the synchronous operation of large flow chart maps. Transportation problems like unexpected traffic jams, and repairing works, fluctuations of demand are the simplest examples of them. It follows that the heavy, strict coherent scheme is workable only for relatively small production systems. As a result,

Approval four: To ensure stable operation of a large scheme, it should be divided into parts.

These parts must be connected with flexible elements.

The simplest flexible element is storage of spare parts and goods. The flexible parts of flow charts usually coincide with the nodes of a full flow chart map. We can denote these nodes as *Active nodes*. Consequently, we denote the other nodes as

Passive nodes. Therefore, the problem arises about the optimal partitioning of the full flows chart map to the rigid areas. It is not convenient to solve this problem in general. It is much better to study it separately for each specific situation. This is a new optimization problem which arises as an emergency effect.

Approval five: Optimization problems in full flow charts have hierarchical structure. The upper levels in this hierarchy are tied with demographic, educational, and social processes.

Optimization effects are associated with the presence of Active nodes in the flow chart map. These nodes frequently interact with the lower hierarchical levels. Therefore, one can say:

Approval six: The stability of the whole Production system is closely connected with its hierarchical structure.

Clarification seven: The number of independent levels in the hierarchy of Production system hardly affects its stability. More independent levels usually provide the more stable system as a whole.

All these results are equally inherent to information systems and the systems of retail chains. In these systems the focus is on sending the final products to customers. It is known that the last operation of transportation goods or information to customers, which are spread across big areas, creates a special problem named *the problem of the last mile* [39].

Definition three: The last mile denotes communication and logistic technologies and processes which connect the last customer or warehouse of final products or services with the end customer, user or vendor.

Clarification eight: The interest in the last mile problem in optimization solutions is a consequence of its high price. This price is related to the specific location of an end customer. This in turn, requires personal service that creates its cost.

The hierarchical structure of Production systems generates specific problems of optimization. One can say:

Approval seven: The optimization process has a hierarchical structure. It is convenient to solve optimization processes separately for each level, if it is possible.

Conclusions

There are common ways to describe a huge variety of production transformations. The first attempts on this way permitted the authors to detect some new problems which require a special detailed study. The most important of them are the problems of sameness of the final production and optimization of big manufacturing systems. The main principal results obtained in this article permit us to clarify the problems and identify the main ways of their further study.

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