GENERAL MODEL OF AN INFORMATION SYSTEM FOR CONTROLLING COMPLEX ORGANIZATIONS

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Introduction

Cybernetics, computing technique, theory of control, information theory, mathematical, symbolic modelling — these are disciplines which, on the base of the favourable experiences gained so far, have the right to call for organized ways of applications in developing the control of our existing systems. Apparently, the degrees and proportions of their applicability can be defined only within information systems of particular organizations. In simpler organizations this would not be problematic. In the case of a complex system, however, it becomes necessary to build up the model of its information system, and then, using this model, accomplish all the analyses and syntheses required for realizing an on-line, real-time, integrated system.

The railway organizations, displaying a high degree of complexity, are taking the lead in application of the up-to-date devices mentioned. This model appears to us, have been elaborated on such a level of abstraction that it would be applicable to any system. In order to illustrate the realistic bases of the model, the construction procedure remained in the form relating to the genuine railways organization.

1. The set of requirements, constituting the construction basis of the model

Before constructing a generally applicable model it will be reasonable to establish clearly the set of requirements to be satisfied by the model. Consequently, the most important conditions would be summarized in points as follows:

1. From the geometrical models it is apparent that even the most highly developed railways information system includes both human and machine constituents. Under such circumstances a model, built up on specialities of either human or machine system constituents exclusively, may not be considered as universally applicable. Consequently, the structure of the model should permit inclusion of any sub-system or element, appearing in the *man-*

machine system. To set up this requirement is generally acknowledged or desired both in the case of railway problems and in any other case.

2. An ever more commonly used method of the cybernetical way of reasoning is the *black box principle*, according to which, for lack of knowledge about internal structure and operation of a complex organization, operation of a particular delimited sub-system will be recorded with its output characteristics, produced by different so-called input characteristics. In respect of the railways information system this method is remarkable not only because during system analysis one must often take into account that internal structure and operation details of sub-systems could be recognized in proper depth only after longer time, but also because algorithms for automatic data processing as well as for solving mathematical models will be more and more commonly used by the railways management; then in many cases the control information required to be output would define the algorithm itself and the input informations as well. It follows from these premises that input informations should be separated from output ones when building up the model. In this way on the one hand one wishes to assure in advance the conditions for exact definition of the internal operation, on the other, one will be able to define the information transmission performances simultaneously, when turning over from information to carrier signals.

3. The present railways control system uses the *control circuit principle* in many respects. In other cases, however, the control circuit structure does not constitute a factor of the control processes. Consequently, one of the model construction principles should be its applicability in the case of control circuit as well as other control system structures. Although information system based on control circuit principle should be considered by all means as one of the criteria for up-to-dateness of a system, but to reorganize different extensive organizations according to the control circuit principle to a practicable extent would raise many problems and require longer time. Taking this in mind, we must endeavour to ensure this duality in the model construction. This is possible by distinguishing information flowing from every element to every element by separate alphanumeric symbols. This might result in distinctions also between non-existent information flows. Of course, in particular cases these terms become zeroed, that is, will be omitted. At the same time this construction principle allows to indicate all the flows (with a certain depth of breakdown) which is a considerable advantage if we admit to be now at the very beginning of recognition (analysing) of the railways information system, rather than to fully know the system.

4. Up-to-date organization of extensive systems much depends on the present advancement of information transmission devices. The information transmission gets even greater importance in respect of railways control, where the processes extend to the whole country and, in several cases, become international.

Consequently, the model will be more useful in practice, if it permits *to measure the information* to be transmitted among railway networks control organs. This condition is automatically fulfilled by the construction method used to satisfy the requirement 3 (separation of the information which flows everywhere), if the relative arrangement of the elements of the railways information system in space is known.

5. With a graphic model, converging sides of the figure parts, symbolizing railways information subsystems, attempted to visualize in advance the *pyramidal structure of the railways organization.*

The fundamental quality of this construction method has been mentioned in the literature dealing with problems of international and national non-railways organizations as well as in references discussing foreign and internal railways information systems. Littman states: "The degree of processing is correct if, the more condensed the numeric material the higher stands the recipient of this particular report in the management hierarchy".

It is commonly known that in the case of a railways information system, realized by automatic data processing and indirectly linked automatic information transmission apparatus, the number of superordinated control (or information processing) levels will decrease. Nevertheless, in the switch-over phase as well as in the period of analysing the railways information system it is absolutely necessary to emphasize the structure consisting of several control levels, but containing ever less components going upwards in the information system. Thus, $1-n$ control levels were distinguished during construction of the model. As it was emphasized by mathematical designations during detailed demonstration of the model, less and less elements have been taken into consideration going from 1 towards n. The model constructed this way — similarly to surveys at other organizations — allows more precise recognition of peculiarities in the railways control organization as well as numerical comparison of separate steps of the development pattern. Schmitz distinguishes four levels in the railways information system of the German Federal Republic. Note that the number of levels, performing processing of control information, is different in each special service within the railways, and is also a function of depth required in analysis and systems design. In the first studies it has seemed sufficient to distinguish 4 or 5 levels in the majority of special services. There are, however, railways control organizations where it is expedient to distinguish more levels from the very beginning. It is typical for the piramidal structure of the railways organization that under the General Superintendency there belong six Directorates, and then follow centres being defined by greater and greater numbers — shifting yards, locomotive shops, railway depots, junctions, store-houses, central stations etc, while the number of network points separable from the viewpoint of the information system (in its lowest plane) in most respects is of the order of magnitude of 1000 or even greater.

6. The analysis and development of the railways information system is so much at its beginning that the exact number of elements to be assumed with respect to the organization as a whole as well as to its parts chosen by other subsystems (e.g. special services) is predictable. It may occur that today it would not be possible to indicate at a 100% security neither the order of magnitude of the number of elements to be taken up in the lowest information organization range. After these preliminaries, when constructing the model, it was attempted *to make, according to the requirements, all the components distinctible* (vertically n, horizontally m). The model, built up this way, is suitable for determining also the organizational structure, increasing or decreasing according to the transport demands.

7. In developing the railways information systems, one requirement is *to meet the so-called "real-time" condition*. In this respect as well as in order to define the required dimensions of the technical data transfer system, *systematization of flowing information in the order of the flow period time* also has proved to be necessary (see Ch. 3. with Roman numerals as indices). This way the urgent informations can be separated from the non-urgent ones and a basis arises for choosing the method of transmission (telephone, telegraph, post etc.). Besides, a model construction permitting such grouping, is necessary also in order to demonstrate — and subsequently to eliminate — duplicated input, transfer, processing of information (see the chapter dealing with integration).

8. In developing information systems of both railway and non-railway organizations, a frequent aim is *to realize an integrated information system*. Although integration of the railways information system can only be reached as the result of long-time work — regarding its size and complexity — it would be incorrect if the model were not suitable to formulate exactly the most important requirements preparing the purposeful accomplishment of an integrated information system.

9. The model, symbolizing the railways information system, *should display* the character of a *framework system*, which would ensure the preliminary definition of the extension, depth and area of systems analysis and design detailing work requiring to all probability, several decades of preparation. During this work no one organizational sub-system should be left out of the range of analysis and development, and on the other hand, the indicated work should not involve fields of useless directions, sizes, maybe with overlaps.

10. Relevant studies on the development of information systems in both railways and other organizations, supply a great number of ideas and methods in addition to those enumerated above. Considering that the mere listing of all the aspects would lead us too far, so, having mentioned the points likely to be of importance with regard to building up the railways model, we only refer to sources, apt to supply some additional (e.g. economical, methodological etc.) aspects, not mentioned before, without striving for completeness.

2. Grouping principle, employed for information processing elements of the railways organization and for information, flowing within railways organization. Symbols

It is reasonable to define further sorting principles for building up the model.

Neither analysis, nor integration of the information system is feasible at once for the railways control system as a whole is considered. *Development of the information system should be envisaged as analysis and subsequent improvement of properly separated sub-systems, then superposition of the improved sub-systems.* For these reasons, both for information processing and information transmission systems, the model should permit recording of information functions of the smallest components. To reach this goal we always depart from one element when creating the model.

SCHULZE gives an important principial basis for creating this structure of the model by considering elements of the information system as those of a dynamic system (displaying changes in time). Elements of the railways information system are also numerous and they can change states. It is evident that elements of the railways information system also may be characterized by the set of variables functionally linked in a certain way and changing in a given range of values.

SCHULZE expresses the above mathematically as follows:

$$S_{(x,y,z)} = \sum_{i=1}^{n} x_i(t), y_i(t), z_i(t)$$

where:

S	=	designation of the system (e.g. an office)
x, y, z	=	designation of the system elements (e.g. department, place of service etc.)
$x_1, x_2, \ldots x_n$ $y_1, y_2, \ldots y_n$ $z_1, z_2, \ldots z_n$	=	different states of each system element
$x_i(t), y_i(t), z_i(t)$	=	designation of state changes in time

As it will be seen, the railways information system model to be demonstrated describes changes in time by cycle analyses. Notation of the railways information system elements is of similar form, with the following special distinctions.

Regarding that for ease of treatment the railways information pyramid was transposed into planar system, (see p. 11) so it is *sufficient to denote the element by the symbol Sxy*, where x and y are sufficient to exactly locate the element.

With an information system, problem of the control level is often raised, in respect of either locating the processing function, or information transfer. That is why it was necessary to split the information processing system by control levels within the model. *Levels as system components are designated by Sy*, where a particular control level may be marked by adding a numeral to y. (The index x is fit to detach by serial numbers the elements occurring on each level).

Finally, in many respects — for example, in respect of the external and the material energy systems — it is necessary to develop a model for the whole railways information processing system. As it is not required to provide coordinates *for the railways information processing system as a whole*, so it will be denoted symply by S.

As to the enumerated processing systems Sxy, Sy, S and to grouping of information, flowing from these systems, the classification, outlined in the following has been considered as necessary.

Before all, one must separate *input* information from *output* one. Within both of these information types it is necessary to isolate *information, flowing within the railways system* from those *coming from outside* or *going outwards the railways*. In the class of information, flowing within the railways there was further separated the *informations, circulating between the railways material energy system from those in the railways information system*. Finally, *informations, flowing within the railways information system* were separated according to whether they flow either between some control level and *higher levels*, some control level and *lower levels*, or *within one control level*. This method of grouping can be surveyed by the following numeration:

1. *Input information*
   11. *External information*
   12. *Internal information*
      121. Information between material energy system and information system
      122. Information within railways information system
         122.1. Information between a level and lower levels
         122.2 Information between a level and higher levels
         122.3. Information within one level

2. *Output information*
   21. *External information*
   22. *Internal information*
      221. Information between material energy system and information system

222. Information within railways information system
  222.1. Information between a level and lower levels
  222.2. Information between a level and higher levels
  222.3. Information within one level

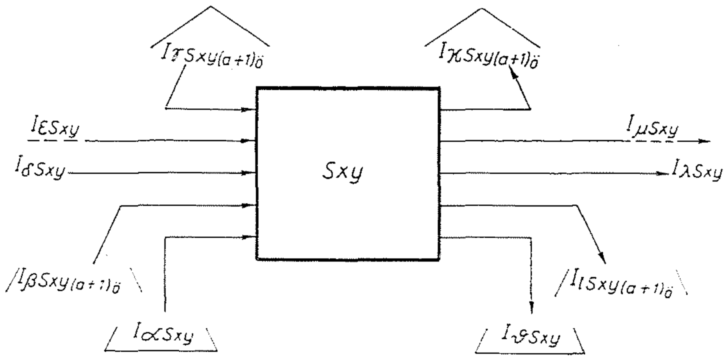

Fig. 1

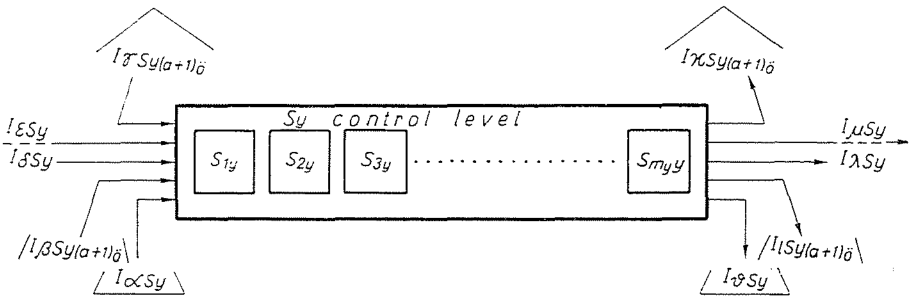

Fig. 2

Figure 1 shows information system flowing to a processing element *Sxy*
Figure 2 shows information system flowing to a processing level *Sy*
Figure 3 shows information system flowing to the whole processing system *S* or the system of information, flowing from *Sxy*, *Sy*, *S*. On the referred figures it is possible to distinguish input information from output one with the help of arrows showing the flow direction. Relations between the information groups defined by the above decimal classification and the set of alphanumeric symbols, marking these groups and used in the model — in the case of dissection of depth *Sxy*, *Sy*, *S* — can be indicated by Greek letter indices, to be interpreted subsequently.

After this, before turning to the actual construction of the alphanumeric railways information system model, let us summarize all the notations, employed in the model:

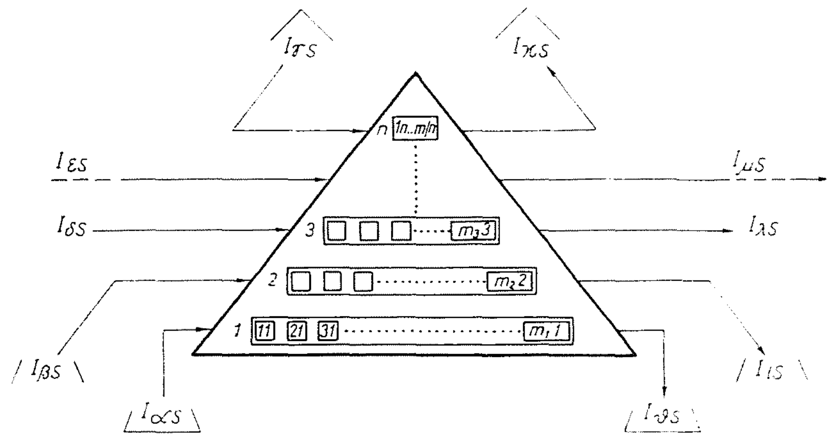

Fig. 3

Meaning of notations, used throughout in the model. Main symbols:

I = informations flowing between information processing elements of the information system

T = information stored

A = processing algorithms in the information processing elements

1,2,3, . . .n serial numbers, denoting control levels in the information system, going level by level, upwards from below

1,2,3, . . . a = serial numbers, denoting (lower) control levels, below one control level

1,2,3, . . . m = serial numbers of elements, expediently distinguished on each level

1,2,3, . . . g = serial numbers, denoting control levels in external information organizations.

y = a symbol, marking some control level in general

x = a general symbol, marking an information processing element, located on any control level

S = a symbol, denoting the whole of the system, or its part if in subscript

Sy = a control level as sub-system

Sxy = an information processing unit

Notations to simplify indices

α = IBAE	ϑ = OBAE
β = IBA	ι = OBA
γ = IBF	$\varkappa$ = OBF
δ = IBH	λ = OBH
ε = IKI	μ = OKI

Within these:

I = input information
O = output information
B = information, flowing within the information system
K = information, linked with an external information system
AE = material energy system
A = lower
F = higher
H = horizontal

For denoting interpretation ranges:

i, j, k, l
$I, II, III, \ldots : X$ = for notation of information system elements in cycle time orders of magnitude
Θ = empty set
$\neq$ = not equal
$\cap$ = common part

3. Model of flowing informations

31. *System of input informations*

a. *Input informations, flowing between the railways material energy system and the information system*

aa. *Informations flowing to one element*

Input informations, coming from every element of the railways material energy system to *one information processing element* (Sxy) of the railways information system is the following:

$$\mathbf{I}_{IBAESxy} = \mathbf{I}_{IBAE_1} + \mathbf{I}_{IBAE_2} + \mathbf{I}_{IBAE_3} + \ldots + \mathbf{I}_{IBAEm_{AE}} = \sum_{i=1}^{m_{AE}} \mathbf{I}_{IBAE_i} \qquad (1)$$

where the symbols denote:

I = information
I = input
B = within railways system
AE = material energy system
S = system
xy = coordinates, determining a processing component of the railways information system in the case of planar (triangular) representation (y = number of control levels, x = serial number of an element of a particular control level)

$1, 2, 3, \ldots m_{AE} =$ serial number of an element of the material energy system, producing the input information.

For lucidity of the subsequent description let us introduce these simplified designations:

$$IBAE = \alpha$$

Transcribing the initial relationship with this designation, the equation

$$\mathbf{I}_{\alpha Sxy} = \mathbf{I}_{\alpha 1} + \mathbf{I}_{\alpha 2} + \mathbf{I}_{\alpha 3} + \ldots + \mathbf{I}_{\alpha m_{AE}} = \sum_{i=1}^{m_{AE}} \mathbf{I}_{\alpha i} \tag{2}$$

defines information, coming from the railways material energy system to an arbitrary information processing element of the railways control organization (see figure 1).

ab. *Informations flowing to a control level*

Of course, from the viewpoint of the railways information system, in addition to the information, coming from the railways material energy system to an element of a certain control level, it is also important to know the information, flowing from the railways material energy system *to all the information processing element being on the same railways control level* (e.g. level of marshalling yards, of directorates etc.). Knowing the relationship 1 and taking into consideration the line diagram, Fig. 2, this can be computed by summing all the information flowing in all possible links between every element on a control level and every element of the material energy system. That is, the full range of input information, flowing from the railways material energy system to an arbitrary control level is composed of the undermentioned elements.

$$\begin{matrix} \mathbf{I}_{\alpha 11}, & \mathbf{I}_{\alpha 12}, & \mathbf{I}_{\alpha 13}, & \ldots, & \mathbf{I}_{\alpha 1 m_{AE}} \\ \mathbf{I}_{\alpha 21}, & \mathbf{I}_{\alpha 22}, & \mathbf{I}_{\alpha 23}, & \ldots, & \mathbf{I}_{\alpha 2 m_{AE}} \\ \mathbf{I}_{\alpha 31}, & \mathbf{I}_{\alpha 32}, & \mathbf{I}_{\alpha 33}, & \ldots, & \mathbf{I}_{\alpha 3 m_{AE}} \\ \vdots & \vdots & \vdots & & \vdots \\ \mathbf{I}_{\alpha m_y 1}, & \mathbf{I}_{\alpha m_y 2}, & \mathbf{I}_{\alpha m_y 3}, & \ldots, & \mathbf{I}_{\alpha m_y m_{AE}} \end{matrix}$$

If we look for elements in Fig. 2, corresponding to each row, one after another, we shall see that these denote informations going from all the elements of the railway material energy system to each information processing element on a particular control level. The information, flowing from the mentioned system to each element is given by the sum of elements in one row, or essentially each row corresponds to Equ. 2 excepted that in order to make information processing elements on the same level distinctible, it was necessary to employ another index (the first) for each term (first index: serial number of elements being on the same level, second index: serial number of the elements of the material energy system). By reason of the above, one may write:

$$
\begin{array}{l}
\mathbf{I}_{\alpha 11} \;\; \mathbf{I}_{\alpha 12} \;\; \mathbf{I}_{\alpha 13} + \ldots + \mathbf{I}_{\alpha 1 m_{AE}} = \mathbf{I}_{\alpha S1y} \\
\mathbf{I}_{\alpha 21} \;\; \mathbf{I}_{\alpha 22} \;\; \mathbf{I}_{\alpha 23} + \ldots + \mathbf{I}_{\alpha 2 m_{AE}} = \mathbf{I}_{\alpha S2y} \\
\mathbf{I}_{\alpha 31} \;\; \mathbf{I}_{\alpha 32} \;\; \mathbf{I}_{\alpha 33} + \ldots + \mathbf{I}_{\alpha 3 m_{AE}} = \mathbf{I}_{S3y} \\
\vdots \qquad \vdots \qquad \vdots \qquad\qquad\quad \vdots \qquad\quad \vdots \\
\mathbf{I}_{\alpha m_y 1} \mathbf{I}_{\alpha m_y 2} \mathbf{I}_{\alpha m_y 3} + \ldots + \mathbf{I}_{\alpha m_y m_{AE}} = \mathbf{I}_{\alpha S m_y y}
\end{array}
$$

where the 1, 2, 3, . . . m_y appearing in the first place of the index is the sequence number of information processing units on the same control level; the other designations are the same as those mentioned in connection with relationships 1, 2. Subsequently, the information, flowing from the railways material energy system to the input of all the elements of a control level is given by the sum of the row sums.

$$
\mathbf{I}_{\alpha Sy} = \mathbf{I}_{\alpha S1y} + \mathbf{I}_{\alpha S2y} + \mathbf{I}_{\alpha S3y} + \ldots + \mathbf{I}_{\alpha S m_y y} = \sum_{j=1}^{m_y} \mathbf{I}_{\alpha Sjy} = \sum_{i=1}^{m_{AE}} \sum_{j=1}^{m_y} \mathbf{I}_{\alpha ij} \qquad (3)
$$

Flow of information $\mathbf{I}_{\alpha Sy}$ onto a control level is shown in figure 3.

ac. *Information flowing to the entire railways control system*

In respect of the railways control it is important to know the proportion of railways material energy system information received by all the information processing elements on all the control levels of the entire railways control system. The goal is to assure the most effective control with the least information intake possible. The word "least" in the previous sentence involves the necessity of quantity determination of the information mentioned, what is possible only if the totality of information to be measured is known by its components.

In the alphanumeric model creation steps, reviewed till now, the information, flowing from the railways material energy system to one information processing element and to all the elements on a control level has been defined. If information, flowing from the indicated system to all the elements of the entire control information system is to be determined, then sum by elements or by levels. Doing this, the classification displayed on figure 3 should be considered.

In the case of summing by elements, the addends are given by elements of a spatial matrix. This spatial matrix can be derived from repeating the planar structure preceding the relationship 3 parallelly with itself as many times, as many control levels in the railways control organization exist. Transformability of the system elements requires introduction of a third index, placed before the first two.

Form of the spatial matrix is clear from the following sums (First index: serial number of control levels, second: serial number of elements within level, the third: serial number of the material energy system elements):

On the first control level:

$$\begin{array}{l}
\mathbf{I}_{\alpha 111} + \mathbf{I}_{\alpha 112} + \mathbf{I}_{\alpha 113} + \ldots + \mathbf{I}_{\alpha 11 m_{AE}} = \mathbf{I}_{\alpha S_{11}} \\
\mathbf{I}_{\alpha 121} + \mathbf{I}_{\alpha 122} + \mathbf{I}_{\alpha 123} + \ldots + \mathbf{I}_{\alpha 12 m_{AE}} = \mathbf{I}_{\alpha S_{21}} \\
\mathbf{I}_{\alpha 131} + \mathbf{I}_{\alpha 132} + \mathbf{I}_{\alpha 133} + \ldots + \mathbf{I}_{\alpha 13 m_{AE}} = \mathbf{I}_{\alpha S_{31}} \\
\vdots \\
\mathbf{I}_{\alpha 1 m_1 1} + \mathbf{I}_{\alpha 1 m_1 2} + \mathbf{I}_{\alpha 1 m_1 3} + \ldots + \mathbf{I}_{\alpha 1 m_1 m_{AE}} = \mathbf{I}_{\alpha S m_1 1}
\end{array}$$

On the second control level:

$$\begin{array}{l}
\mathbf{I}_{\alpha 211} + \mathbf{I}_{\alpha 212} + \mathbf{I}_{\alpha 213} + \ldots + \mathbf{I}_{\alpha 21 m_{AE}} = \mathbf{I}_{\alpha S_{12}} \\
\mathbf{I}_{\alpha 221} + \mathbf{I}_{\alpha 222} + \mathbf{I}_{\alpha 223} + \ldots + \mathbf{I}_{\alpha 22 m_{AE}} = \mathbf{I}_{\alpha S_{22}} \\
\mathbf{I}_{\alpha 231} + \mathbf{I}_{\alpha 232} + \mathbf{I}_{\alpha 333} + \ldots + \mathbf{I}_{\alpha 23 m_{AE}} = \mathbf{I}_{\alpha S_{32}} \\
\vdots \\
\mathbf{I}_{\alpha 2 m_2 1} + \mathbf{I}_{\alpha 2 m_2 2} + \mathbf{I}_{\alpha 2 m_2 3} + \ldots + \mathbf{I}_{\alpha 2 m_2 m_{AE}} = \mathbf{I}_{\alpha S m_2 2}
\end{array}$$

On the third control level:

$$\begin{array}{l}
\mathbf{I}_{\alpha 311} + \mathbf{I}_{\alpha 312} + \mathbf{I}_{\alpha 313} + \ldots + \mathbf{I}_{\alpha 31 m_{AE}} = \mathbf{I}_{\alpha S_{13}} \\
\mathbf{I}_{\alpha 321} + \mathbf{I}_{\alpha 322} + \mathbf{I}_{\alpha 323} + \ldots + \mathbf{I}_{\alpha 32 m_{AE}} = \mathbf{I}_{\alpha S_{23}} \\
\mathbf{I}_{\alpha 331} + \mathbf{I}_{\alpha 332} + \mathbf{I}_{\alpha 333} + \ldots + \mathbf{I}_{\alpha 33 m_{AE}} = \mathbf{I}_{\alpha S_{33}} \\
\vdots \\
\mathbf{I}_{\alpha 3 m_3 1} + \mathbf{I}_{\alpha 3 m_3 2} + \mathbf{I}_{\alpha 3 m_3 3} + \ldots + \mathbf{I}_{\alpha 3 m_3 m_{AE}} = \mathbf{I}_{\alpha S m_3 3}
\end{array}$$

On the "n" th control level:

$$\begin{array}{l}
\mathbf{I}_{\alpha n11} + \mathbf{I}_{\alpha n12} + \mathbf{I}_{\alpha n13} + \ldots + \mathbf{I}_{\alpha n1 m_{AE}} = \mathbf{I}_{\alpha S_{1n}} \\
\mathbf{I}_{\alpha n21} + \mathbf{I}_{\alpha n22} + \mathbf{I}_{\alpha n23} + \ldots + \mathbf{I}_{\alpha n2 m_{AE}} = \mathbf{I}_{\alpha S_{2n}}
\end{array}$$

$$
\begin{array}{llllll}
\mathbf{I}_{\alpha n31} & + \mathbf{I}_{\alpha n32} & + \mathbf{I}_{\alpha n33} & + \ldots & + \mathbf{I}_{\alpha n3m_{AE}} & = \mathbf{I}_{\alpha S_{3n}} \\
\vdots & \vdots & \vdots & & \vdots & \vdots \\
\mathbf{I}_{\alpha n m_n 1} & + \mathbf{I}_{\alpha n m_n 2} & + \mathbf{I}_{\alpha n m_n 3} & + \ldots & + \mathbf{I}_{\alpha n m_n m_{AE}} & = \mathbf{I}_{\alpha S m_n n}
\end{array}
$$

To the effect of point 5 ch. 1 the relationship $m_1 > m_2 > m_3 > \ldots > m_n$ is true. Because of this, in comparison to the element set, belonging to the first, lowest control level, the further levels consist of ever less rows. It is the matrix belonging to the n-th (highest) control level which has the least number of rows, because on this level there are the fewest information processing elements. In the case of the most general system, number of columns may be the same in the planar matrices belonging to all the levels as it is theoretically possible for every level to receive input information from every element of the material energy system. But in a practical system it should be assumed that elements of the higher control level receive concise input information about material energy system from elements of lower levels (see point 5, ch. 1.), consequently, elements of rows in many places may be reduced to zero, so on the upper levels the number of columns decreases too.

Sum of information of type AE input to elements of each control level can be formed by analogy to equation 3.

On the first control level

$$\mathbf{I}_{\alpha S_{11}} + \mathbf{I}_{\alpha S_{21}} + \mathbf{I}_{\alpha S_{31}} + \ldots + \mathbf{I}_{\alpha S_{m_1 1}} = \mathbf{I}_{\alpha S_1}$$

On the second control level:

$$\mathbf{I}_{\alpha S_{12}} + \mathbf{I}_{\alpha S_{22}} + \mathbf{I}_{\alpha S_{32}} + \ldots + \mathbf{I}_{\alpha S_{m_2 2}} = \mathbf{I}_{\alpha S_2}$$

On the third control level:

$$\mathbf{I}_{\alpha S_{13}} + \mathbf{I}_{\alpha S_{23}} + \mathbf{I}_{\alpha S_{33}} + \ldots + \mathbf{I}_{\alpha S_{m_3 3}} = \mathbf{I}_{\alpha S_3}$$

On the n-th control level:

$$\mathbf{I}_{\alpha S1n} + \mathbf{I}_{\alpha S2n} + \mathbf{I}_{\alpha S3n} + \ldots + \mathbf{I}_{\alpha S m_n n} = \mathbf{I}_{\alpha S_n}$$

Evidently, sum of information input from railways material energy system to every information processing element on all the control levels of the railways information organization is obtained by adding sums for each level.

$$\mathbf{I}_{\alpha S} = \mathbf{I}_{\alpha S_1} + \mathbf{I}_{\alpha S_2} + \mathbf{I}_{\alpha S_3} + \ldots + \mathbf{I}_{\alpha S_n} = \sum_{i=1}^{n} \mathbf{I}_{\alpha S_k} \qquad (4)$$

Considering that

$$\mathbf{I}_{\alpha S_1} = \sum_{j=1}^{m_1} \mathbf{I}_{\alpha S_{1j}} = \sum_{i=1}^{m_{AE}} \sum_{j=1}^{m_1} \mathbf{I}_{\alpha ij}$$

$$\mathbf{I}_{\alpha S_2} = \sum_{j=1}^{m_2} \mathbf{I}_{\alpha S_{2j}} = \sum_{i=1}^{m_{AE}} \sum_{j=1}^{m_2} \mathbf{I}_{\alpha ij}$$

$$\mathbf{I}_{\alpha S_3} = \sum_{j=1}^{m_3} \mathbf{I}_{\alpha S_{3j}} = \sum_{i=1}^{m_{AE}} \sum_{j=1}^{m_3} \mathbf{I}_{\alpha ij}$$

$$\vdots \qquad \vdots \qquad \vdots$$

$$\mathbf{I}_{\alpha S_n} = \sum_{j=1}^{m_n} \mathbf{I}_{\alpha S_{3j}} = \sum_{i=1}^{m_{AE}} \sum_{j=1}^{m_n} \mathbf{I}_{\alpha ij}$$

relationship 4, departing from individual components, can be expressed also as:

$$\mathbf{I}_{\alpha S} = \mathbf{I}_{\alpha S_1} + \mathbf{I}_{\alpha S_2} + \mathbf{I}_{\alpha S_3} + \ldots + \mathbf{I}_{\alpha S_n} = \sum_{k=1}^{n} \mathbf{I}_{\alpha S_k} = \sum_{i=1}^{m_{AE}} \sum_{j=1}^{m_n} \sum_{k=1}^{n} \mathbf{I}_{\alpha ijk} \qquad (5)$$

Expressed in words: totality of information of type *AE* flowing to the input of the entire railways information system may be produced by summing information, transferred from every element $1 \ldots m_{AE}$ of the material energy system to every information processing component on every level $1 \ldots n$ of the control organization.

b. *Set of input information, flowing within the railways information system, between its component elements*

ba. *Information, flowing from lower levels towards a given control level*

In the railways information system the following information flows to a single *information processing element*, on a certain control level, *from all the processing components on another lower control level*:

$$\mathbf{I}_{IBASxy(a+1)} = \mathbf{I}_{IBAy_1} + \mathbf{I}_{IBAy_2} + \mathbf{I}_{IBAy_3} + \ldots + \mathbf{I}_{IBAy_{my}} = \sum_{i=1}^{m_y} \mathbf{I}_{IBAyi}$$

where

A = lower control levels
a = number of lower control levels
Ay = y th of the lower control levels

$$1 \leq y \leq a$$

$y(a+1)$ = level above the lower control levels, corresponding to the element examined for information input

$1, 2, 3 \ldots m_y$ = serial number of information processing elements on the control level y

For sake of convenience let us introduce the following index designation: Using the new notation, the previous sum function can be rewritten as:

$$\mathbf{I}_{\beta Sxy_{(a+1)}} = \mathbf{I}_{\beta y_1} + \mathbf{I}_{\beta y_2} + \mathbf{I}_{\beta y_3} + \ldots + \mathbf{I}_{\beta y m_y} = \sum_{i=1}^{m_y} \mathbf{I}_{\beta y i} \tag{6}$$

Equ. 6 defines the information flowing from a single lower level to an element of the control system.

In order, however, dimension the data transmission equipment, it may be required to know also the information flowing from all the lower control level information processing elements to one element. Their totality is obviously provided by summing informations flowing to that element for each lower control level in turn, below the control level corresponding to this element, according to relationship 6. The so derived level totals would be summed again. If serial numbers of the levels under the control level containing the element in question are 1, 2, 3, . . . α, *the information, flowing from all the elements of all the lower control levels to the input of a higher information processing element is defined by the relationship*

$$\begin{aligned} \mathbf{I}_{\beta Sxy_{(a+1)_{\Sigma}}} &= \mathbf{I}_{\beta Sxy_1} + \mathbf{I}_{\beta Sxy_2} + \mathbf{I}_{\beta Sxy_3} + \ldots + \mathbf{I}_{\beta Sxy_a} = \\ &= \sum_{l=1}^{a} \mathbf{I}_{\beta Sxyl} = \sum_{i=1}^{m_y} \sum_{l=1}^{a} \mathbf{I}_{\beta Sxyil} \end{aligned} \tag{7}$$

where: Sxy · element, examined for input; $1 \ldots a$ the lower levels with all their elements $/m_y/$.

The information to be summed in this total may be considered as elements of a matrix, in which each row represents one lower control level $/1 \ldots a/$, and row elements the number of processing elements on each lower level $/1 \ldots m_y/$.

In order to design a railways information system — particularly when calculating the performances required from information transfer routes to be inserted between remote control levels — it is essential to know, in addition to the information flowing to an element of a control level, also the information going to all control information processing elements belonging to all the identical levels, accommodated often in the same place (e.g. in the building of Directorate). If on the control level in question $|m_{(a+1)}|$ there are information processing elements, then information, flowing from all the elements of one lower level to the input of all the elements of a higher level may be calculated on the base of information given by the relationship 6.

$$\mathbf{I}_{\beta S y_{(a+1)}} = \mathbf{I}_{\beta S_1 y_{(a+1)}} + \mathbf{I}_{\beta S_2 y_{(a+1)}} + \mathbf{I}_{\beta S_3 y_{(a+1)}} + \ldots + \mathbf{I}_{\beta S m_{(a+1)} y_{(a+1)}} = = \sum_{j=1}^{m_{(a+1)}} \mathbf{I}_{\beta S j y_{(a+1)}} = \sum_{i=1}^{m_y} \sum_{j=1}^{m_{(a+1)}} \mathbf{I}_{\beta ij} \tag{8}$$

In this sum the information to be added forms a matrix of as many rows. as many elements there are in the control level examined for input $|m_{(a+1)}|$ and of as many columns, as many elements $|my|$ there are in the one lower control level from where the input informations rise.

If the information flowing from all the elements on all the lower control levels to the input of all the elements of a control level are sought for, then information delivered by relationship 7 for the input of one element should be considered as many times, as many elements there are on the control level with the input sought for. So we get:

$$\mathbf{I}_{\beta S y_{(a+1)\delta}} = \mathbf{I}_{\beta S_1 y_{(a+1)\delta}} + \mathbf{I}_{\beta S_2 y_{(a+1)\delta}} + \mathbf{I}_{\beta S_3 y_{(a+1)\delta}} + \ldots + \mathbf{I}_{\beta S m_{(a+1)} y_{(a+1)\delta}} = = \sum_{j=1}^{m_{(a+1)}} \mathbf{I}_{\beta S j y_{(a+1)\delta}} = \sum_{i=1}^{m_y} \sum_{j=1}^{m_{(a+1)}} \sum_{l=1}^{a} \mathbf{I}_{\beta y ijl} \tag{9}$$

The information to be summed in this relationship may be understood as elements of a spatial array. As many planes may be defined in the spatial matrix as many elements there are in the examined control level $(a + 1)$. Elements of each plane may be formed by rows and columns the same way as for the matrix mentioned in respect to 7.

If in order to form a reference ratio, the *information, flowing from all the elements of all the control levels* had to be calculated, then the spatial matrix formed by elements in relationship 9 would be considered as many times, as many such control levels might be assigned in the railways information organization which may receive input information from beneath $|n + 1|$, that is:

$$\mathbf{I}_{\beta S} = \sum_{i=1}^{m_y} \sum_{j=1}^{m_{(a+1)}} \sum_{k=1}^{n} \sum_{l=1}^{a} \mathbf{I}_{\beta ijkl} \tag{10}$$

Relationship 10 defines summing of an information set, similar to that for relationship 9. Since however, the summation should be accomplished for all levels, the quadruple sum appearing in 10 means that the spatial matrix mentioned before — with elements formed according to the meaning of course — should be taken into account as many times, as many control levels exist in the railways information system.

bb. ***Information flowing to a given control level from upper levels***

In the railways information system the undermentioned information flows to a single information processing element on a control level from all the processing components, above this particular control level:

$$\mathbf{I}_{IBFSxy_{(a+1)}} = \mathbf{I}_{IBFy_1} + \mathbf{I}_{IBFy_2} + \mathbf{I}_{IBFy_3} + \ldots + \mathbf{I}_{IBFymy} = \sum_{i=1}^{m_y} \mathbf{I}_{IBFyi}$$

where:

$y_{(a+1)}$ = control level corresponding to the element considered for information input

F = upper control levels

Fy = y th of the upper control levels

and $$(a+2) \leqq Fy \leqq n$$

To simplify indices let us introduce the following notation:

$$IBF = \gamma$$

Now the equation may be brought to simpler form:

$$\mathbf{I}_{\gamma Sxy_{(a+1)}} = \mathbf{I}_{\gamma y_1} + \mathbf{I}_{\gamma y_2} + \mathbf{I}_{\gamma y_3} + \ldots + \mathbf{I}_{\gamma y m_y} = \sum_{i=1}^{m_y} \mathbf{I}_{\gamma y_i} \qquad (11)$$

So the equation 11 defines information, flowing to the input of a single information processing element on a certain control level, from all the elements on an upper control level.

It is also necessary to know the amount of information flowing from elements of all the upper control levels to a given control level or to one of its elements. Information coming to the input of an element, is supplied by the following summation:

$$\mathbf{I}_{\gamma Sxy_{(a+1)\Sigma}} = \mathbf{I}_{\gamma Sxy_{(a+2)}} + \mathbf{I}_{\gamma Sxy_{(a+3)}} + \mathbf{I}_{\gamma Sxy_{(a+4)}} + \ldots + \mathbf{I}_{\gamma Sxy_n} =$$
$$= \sum_{l=(a+2)}^{n} \mathbf{I}_{\gamma Sxyl} = \sum_{i=1}^{m_y} \sum_{l=(a+2)}^{n} \mathbf{I}_{\gamma Sxy_{il}} \qquad (12)$$

where: Sxy element examined for input,

$(a+2) \ldots n$ levels above the element examined with all their elements which may supply an input.

The information being twice summed may be considered as elements of an array, each row of which corresponds to a control level above the level

of the element having the input in question. $(a + 2), (a + 3), (a + 4), \ldots n)$ and these rows consist of as many elements, as many information processing elements occur on each control level.

Information, coming from all the elements of an upper control level to the input of all the elements of a control level is obtained by summing information elements of a planar matrix. This matrix consists of as many rows, as many elements there are on the control level considered for input, and of as many columns, as many elements there are on the single upper control level from which the input information in question departs. That is:

$$\mathbf{I}_{\gamma S y_{(a+1)}} = \mathbf{I}_{\gamma S_1 y_{(a+1)}} + \mathbf{I}_{\gamma S_2 y_{(a+1)}} + \mathbf{I}_{\gamma S_3 y_{(a+1)}} + \ldots + \mathbf{I}_{\gamma S m_{(a+1)} y_{(a+1)}} = \\ = \sum_{j=1}^{m_{(a+1)}} \mathbf{I}_{\gamma S j y_{(a+1)}} = \sum_{i=1}^{m_y} \sum_{j=1}^{m_{(a+1)}} \mathbf{I}_{\gamma ij} \tag{13}$$

With regard to the forthcoming it is also important to know, what amount of input information may go to the input of all the elements of a given control level from all the information processing elements on each of the control levels above the given level.

To this aim, elements of an information array should be summed, which can be fitted into a spatial matrix. This matrix may be decomposed into as many planes, as many elements there are on the $(a + 1)$ th control level, containing information processing elements examined for input. Elements in each plane will be inserted into rows and columns as it was done for input of an element in conjunction with relationship 12.

$$\mathbf{I}_{\gamma S y_{(a+1)_g}} = \mathbf{I}_{\gamma S_1 y_{(a+1)_g}} = \mathbf{I}_{\gamma S_2 y_{(a+1)_g}} + \mathbf{I}_{\gamma S_3 y_{(a+1)_g}} + \ldots + \mathbf{I}_{\gamma S m_{(a+1)} y_{(a+1)_g}} = \\ = \sum_{j=1}^{m_{(a+1)}} \mathbf{I}_{\gamma S j y_{(a+1)_g}} = \sum_{i=1}^{m_y} \sum_{i=1}^{m_{(a+1)}} \sum_{l=(a+2)}^{n} \mathbf{I}_{\gamma y ij} \tag{4}$$

Finally if, for a general survey of the railways information system we wish to know *the amount of information received by all the levels from every element of the upper information levels*, then summation $\mathbf{I}_{\gamma S y}$ calculated for one level should be accomplished as many times, as many control levels are likely to receive information from above $(n - 1)$.

$$\mathbf{I}_{\gamma S} = \sum_{i=1}^{m_y} \sum_{i=1}^{m_{(a+1)}} \sum_{k=1}^{n} \sum_{l=(a+2)}^{n} \mathbf{I}_{\gamma y ijkl} \tag{15}$$

bc. *Information, flowing within the same control level*

Analysis of the control information system requires also knowledge of information flowing between elements on the same control level.

Information arriving from output of other elements on a level to the input of a single element on the same level is defined by the following relationship (see Fig. 4):

$$\mathbf{I}_{IBHSxy} = \mathbf{I}_{IBHSy_1} + \mathbf{I}_{IBHSy_2} + \mathbf{I}_{IBHSy_3} + \ldots + \mathbf{I}_{IBHSym_y} = \sum_{j=1}^{m_y} \mathbf{I}_{IBHSyj}$$

where: H refers to the horizontal division.

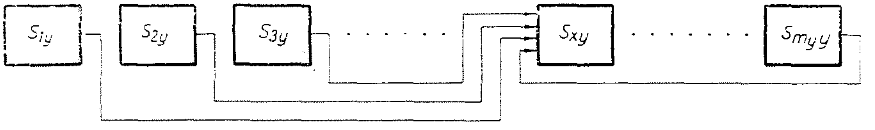

Fig. 4

Simplifying the index gives the following equation: $IBH = \delta$

$$\mathbf{I}_{\delta Sxy} = \mathbf{I}_{\delta Sy_1} + \mathbf{I}_{\delta Sy_2} + \mathbf{I}_{\delta Sy_3} + \ldots + \mathbf{I}_{\delta Sym_y} = \sum_{j=1}^{m_y} \mathbf{I}_{\delta yj} \quad (16)$$

As the information, appearing on the own output of the information processing element Sxy, but flowing towards its own input, is also a term of this equation, there are two alternatives. If for some purpose it is important to know the own feedback information of an element, then that term also may be included. Else, this term will be reduced to zero.

In order to develop the railways control information system it is also necessary to know the amount of information coming to all the elements on a level, from other elements of the same level. Knowledge of this type of information gives indication of closeness of relations between control level elements. This information is apparently defined by considering information flowing from the same level to one element with regard to all the elements, that is, flow, taken up for one element $|Sxy|$ will be examined, to the sense, for all the elements and then:

$$\mathbf{I}_{\delta Sy} = \mathbf{I}_{\delta S_1 y} + \mathbf{I}_{\delta S_2 y} + \mathbf{I}_{\delta S_3 y} + \ldots + \mathbf{I}_{\delta Sm_y y} = \sum_{i=1}^{m_y} \mathbf{I}_{\delta Siy} = \sum_{i=1}^{m_y} \sum_{j=1}^{m_y} \mathbf{I}_{\delta iyj} \quad (17)$$

The two alternatives, mentioned in relation to considering output information of terms, examined for input (relationship 16) here also exist.

Sum of input information, derived from in-level components of elements on all the control levels may be defined analogously to summation of the previously studied information types. The whole amount of these types of information within the complete control information system will be calculated this way. Elements considered for this summation may be arranged into a spatial matrix. This spatial matrix consists of as many planes, as many control levels are distinguished in the information system. Within each plane the number of both columns and rows can be described by the number of information processing units on the control level belonging to that plane. Since going upwards in the information system, the number of elements in each control level goes diminishing—according to the relationships already discussed (1.) — consequently, the form of the spatial matrix is similar to a truncated pyramid. The relationship itself is the following:

$$\mathbf{I}_{\delta S} = \mathbf{I}_{\delta S_1} + \mathbf{I}_{\delta S_2} + \mathbf{I}_{\delta S_3} + \ldots + \mathbf{I}_{\delta S n} = \sum_{k=1}^{n} \mathbf{I}_{\delta S_k} = \sum_{i=1}^{m_y} \sum_{j=1}^{m_y} \sum_{k=1}^{n} \mathbf{I}_{\delta ijk} \qquad (18)$$

c. *Information flowing to the inputs of the railways information system from external organs*

The information system for railways traffic control is able to fulfil its duty only by maintaining suitable information links with information systems of non-railways organizations (e.g. of the organizations, demanding transport). Else it could not be get informed e.g. about goods to be transported. This is why it is also important to know the composition of information, supplied to the entire railways information system by non-railways information systems. The described railways information system, represented by alphanumeric symbols, displays a rather complicated form, and — as we have seen it — often renders the survey of the model very difficult. There is no reason to assume that the information systems in e.g. all the organizations demanding transports would be much simpler than the information system of the railways organizations. Upon this consideration it would be most lenghty, although not infeasible to create a model of alphanumeric symbol which would represent information flowing between every railways information element and all non-railways information elements. At the same time it is a commonly known fact that internal information traffic of the most different organizations is much greater than the external one. In conformity with this, as structure of information coming from external control information systems to the railways control information system, it is sufficient to set up a model which displays information, flowing from external systems to the input of each component of the railways information system, only quantized by certain external control unit circuits.

Consequently, external information flowing to elements on various levels of the railways information system will not be numbered according to elements of the external information system. Knowing that external information flow is meagre, information received from information elements belonging to the same external control level will be simply distinguished by the symbol of the given control level, then within it, by a simple serial number. After the introduced simplification, the information flowing from external information organizations to the input of the railways information system elements, will be fit into an alphanumeric model with the structure in Fig. 5.

In the railways information system, the information coming from external information organs by control levels to the input of a single processing element on any control level is defined by the following relationship:

$$\mathbf{I}_{IKISxy} = \mathbf{I}_{IKI_1} + \mathbf{I}_{IKI_2} + \mathbf{I}_{IKI_3} + \ldots + \mathbf{I}_{IKI_g} = \sum_{i=1}^{g} \mathbf{I}_{IKIi}$$

where g — number of control levels in the external organization (see Fig. 5.).

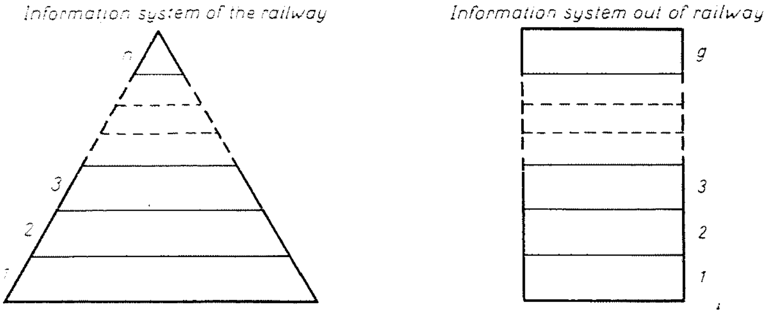

Fig. 5

As informations received from each external level should be given a serial number index in the course of detailed expansion, and in addition, in order to show a closer similarity of the structure to the earlier described relationships, let us introduce this index simplifying notation:

$$IKI = \varepsilon$$

Then the previous equation takes this form:

$$\mathbf{I}_{\varepsilon Sxy} = \mathbf{I}_{\varepsilon_1} + \mathbf{I}_{\varepsilon_2} + \mathbf{I}_{\varepsilon_3} + \ldots + \mathbf{I}_{\varepsilon_g} = \sum_{i=1}^{g} \mathbf{I}_{\varepsilon i} \tag{19}$$

Because of earlier mentioned reasons it is necessary to define *information arriving from all the elements of the external information system to all the elements on a railways control level*, by means of equation:

$$\mathbf{I}_{\varepsilon Sy} = \mathbf{I}_{\varepsilon 1y} + \mathbf{I}_{\varepsilon 2y} + \mathbf{I}_{\varepsilon 3y} + \ldots + \mathbf{I}_{\varepsilon my} = \sum_{j=1}^{m_y} \mathbf{I}_{\varepsilon jy} = \sum_{i=1}^{g} \sum_{j=1}^{m_y} \mathbf{I}_{\varepsilon ij} \tag{20}$$

where 1, 2, 3, ... m_y are the serial numbers of elements on the railways control level for which the information coming from outside, is considered.

Accordingly, information coming onto a railways control level from outside may be arranged in a matrix having as many rows, as many elements there exist on the railways control level in question, and as many columns, as many control levels there are assigned in the non-railways information organization.

Information, flowing from external organizations to the entire railways information system is apparently given by summing external information in accordance with equation 20 as many times, as many control levels there were distinguished in the railways organization.

$$\mathbf{I}_{\varepsilon S} = \mathbf{I}_{\varepsilon S_1} + \mathbf{I}_{\varepsilon S_2} + \mathbf{I}_{\varepsilon S_3} + \ldots + \mathbf{I}_{\varepsilon S_n} = \sum_{k=1}^{n} \mathbf{I}_{\varepsilon S k} = \sum_{i=1}^{g} \sum_{j=1}^{m_g} \sum_{k=1}^{n} \mathbf{I}_{\varepsilon ijk} \qquad (21)$$

32. *System of output information*

a. *Information flowing from outputs of the railways information system towards the material energy system*

If the output information of the railways control information system, as an information processing organization of various complexity is to be systematized, then the structure is essentially the same as it was in the case of input information. The information organization components to be considered, that is, information processing constituents and information flow links between constituents, apart from the direction, are the same as those examined in the system of input information. The basic difference is that with output information, the direction of information flowing between elements is just the reverse than for the input information. Since when writing the information structure, the indices I and O or in the case of using indices of Greek letters, the indices $\alpha, \beta, \gamma, \varepsilon, \delta$ and $\vartheta, \iota, \varkappa, \lambda, \mu$ refer *a priori* to the information being input or output, the distinction of the flow direction is accomplished. The processing elements appearing in relationships supplying different information flow groups display the same structure, as for input information. Therefore, to avoid unnecessary repetitions we do not describe in detail the elements, summation of which will supply the particular groups of output information.

Having discussed input and output information flows, let us consider now the model of information, stored in the railways information system components.

4. Model of information, stored in system elements producing output information from input

Each information processing component is only able to function if in addition to receiving current input information for processing operations they are in possession of earlier information, too. Information, stored earlier, may be placed into several groups.

First group of stored information will have been acquired by the processing element before starting the operation, in order to know the method of processing. Information belonging to this group, may be divided into further subgroups. One of these subgroups should contain information derived from *transformation of the controlled system in the interest of processing*, as e. g. wagon rolling stock, locomotive stock, track system, etc.

The other group is composed of information *on ways of information processing, conditions of solving its algorithm*, (e.g. knowledge of mathematical formulae for calculating turn-around time of wagons).

The further two groups of stored information directly stored portion of input information, and information, stored after intermediate and final processing.

In the first approach it is not possible to define for each of the railways information organization components a restriction which would exclude the presence of some stored information. So we could create the model of stored information in the railways information system for all types. But in order to avoid any superfluous repetition, the model is created only once, for information type $\mathbf{I}_T$. Creation of a model corresponding to any deeper breakdown consists of replacing the index T by the indices TP, TM, TPL, TPA, TMK, TMF or $TMFV$.

In building up the model, the information division of the organization shown in Fig. 1 to 5 employed already related to input and output information, is taken into account. According to this, *stored information in case of a single element is:*

$$\mathbf{I}_{TSxy} \tag{22}$$

where each letter symbol has the meaning as described in the foregoing.

Information stored on one control level:

$$\mathbf{I}_{TSy} = \mathbf{I}_{TS1y} + \mathbf{I}_{TS2y} + \mathbf{I}_{TS3y} + \ldots + \mathbf{I}_{TSm_y y} = \sum_{i=1}^{m_y} \mathbf{I}_{TSiy} \tag{23}$$

where 1, 2, 3, . . . m_y serial numbers of elements on any level.

Information stored for all the elements of the entire railways information organization:

$$\mathbf{I}_{TS} = \mathbf{I}_{TS_1} + \mathbf{I}_{TS_2} + \mathbf{I}_{TS_3} + \ldots + \mathbf{I}_{TSn} = \sum_{j=1}^{n} \mathbf{I}_{TSj} = \sum_{i=1}^{m_y} \sum_{j=1}^{n} \mathbf{I}_{TSij} \qquad (24)$$

With the present human structure it is not possible to map all the details of information, stored in elements of the information organization. It is conceivable that research, attempting to include automatic elements, will detect additional types of stored information. Nevertheless their models will probably be analogous to the above indicated ones.

5. Model of algorithms needed to produce output from input and stored information

A transformation procedure takes place in each information processing element. This transformation is characterized by a processing procedure, inserted between purposeful output information and input and stored information. This procedure is controlled by an algorithm. An algorithm is an unambiguously defined schematic procedure for solving information processing problems, depending on uniquely defined sequence of order of the basic operations. Consequently, elements of the railways information system are constituted by input, output and stored information as well as algorithms. In a broader sense, the concept of algorithm covers the uniquely defined operation sequences of receiving the input information, issuing the output information and storing the information to be stored. For modelling, however, it is sufficient to denote all the algorithms needed in each element by one symbol, with the remark that by introducing proper indices, this model will be apt to express a deeper breakdown of the algorithms. In modelling, algorithms will be assigned to the systems Sxy, Sy, S.

The algorithm needed for a single element is designated by:

$$\mathbf{A}_{Sxy} \qquad (25)$$

where $\mathbf{A}$ — notation, referring to the algorithm.

The algorithm, needed for all the elements on a control level:

$$\mathbf{A}_{Sy} = \mathbf{A}_{S1y} + \mathbf{A}_{S2y} + \mathbf{A}_{S3y} + \ldots + \mathbf{A}_{Sm_y y} = \sum_{i=1}^{m_y} \mathbf{A}_{Siy} \qquad (26)$$

where $1, 2, 3, \ldots m_y$ — serial numbers of the elements on one level.

The algorithm needed for all the elements in the entire railways information system:

$$\mathbf{A}_S = \mathbf{A}_{S1} + \mathbf{A}_{S2} + \mathbf{A}_{S3} + \ldots + \mathbf{A}_{Sn} = \sum_{=1}^{n} \mathbf{A}_{Sj} = \sum_{i=1}^{m_y} \sum_{j=1}^{n} \mathbf{A}_{Sij} \qquad (27)$$

The complex railways information system could be created by purposeful linking the system of flowing information (modelled in point 3), the system of stored information (modelled in point 4) and the proper elements of information processing algorithms (modelled in point 5). Unambiguous linking of the elements modelled in the above indicated three points is allowed by the structure of the model system which takes into account in all three cases the information processing system of a dissection *Sxy*, *Sy*, *S*.

6. Structure differentiation of the analysing model in conformity with the chronological order of information operations

Discussion of the chap. 1—5 defined a single requirement to be met by flowing output and input information as well as by algorithms, namely: they should assure coordinated, purposeful (regulated) interactions, activities of the railways organization elements, based on the mutual consideration of status changes as Wiener has meant it. The relevant time requirements have not been discussed. In the real railways system, however, this factor is most important, because the railways control organization is supposed to supply information for controlling elements which are moving intensely in time in the railways network. This fact justifies a further differentiation of elements of the model built up in points 3—5. — a differentiation oriented for cycle times, that is for repetition periods.

It is well known, that in the railways operations each material energy process, that is, every constituent sub-process of controlling the complete transport process, requires repeated receipt of control (output) information after elapse of time periods corresponding to seconds, minutes, hours, days weeks, months, years. Therefore for the flow of output, input and stored information, appearing in the above constructed model, the algorithms producing output information should be decomposed according to such a scale, and time differentiated models derived in this way.

As in the beginning of analysing and creating the information system it is unknown, which information system component would appear in which time cycle, consequently, when constructing general, a time-differentiated model we start with the consideration that any component, symbolized in points 3—5 may be affected in all the cycle time types. The cycle times are symbolized by Roman numerals in turn, in ascending order. In such a way for constructing the general model, differentiated by cycle times, it is sufficient to complete the indices of all the elements symbolized in points 3 to 5 by Roman numerals, designating the possible cycle times. Since we do not intend to reckon with more than ten cycle time deviations, the Roman numerals used as indices range from I to X. Now the form, differentiated by time cycles, will be shown only for one information processing element.

For the flowing information:

$$\mathbf{I}_{\alpha Sxy} = \mathbf{I}_{\alpha Sxy\mathrm{I}} + \mathbf{I}_{\alpha Sxy\mathrm{II}} + \mathbf{I}_{\alpha Sxy\mathrm{III}} + \ldots + \mathbf{I}_{\alpha Sxy\mathrm{X}} = \sum_{i=\mathrm{I}}^{\mathrm{X}} \mathbf{I}_{\alpha Sxyi} \tag{28}$$

For the stored information:

$$\mathbf{I}_{TSxy} = \mathbf{I}_{TSxy\mathrm{I}} + \mathbf{I}_{TSxy\mathrm{II}} + \mathbf{I}_{TSxy\mathrm{III}} + \ldots + \mathbf{I}_{TSxy\mathrm{X}} = \sum_{i=\mathrm{I}}^{\mathrm{X}} \mathbf{I}_{TSxyi} \tag{29}$$

For the information processing algorithms:

$$\mathbf{A}_{Sxy} = \mathbf{A}_{Sxy\mathrm{I}} + \mathbf{A}_{Sxy\mathrm{II}} + \mathbf{A}_{Sxy\mathrm{III}} + \ldots + \mathbf{A}_{Sxy\mathrm{X}} = \sum_{i=\mathrm{I}}^{\mathrm{X}} \mathbf{A}_{Sxyi} \tag{30}$$

Structure of Equs. 28 to 30 clearly expresses derivation of the time differentiated model. So no more equations will be derived, just noting that information, covered by Equs. to 1 to 27 may be further broken down by time cycles, using the Roman numerals as indices.

Summary

The presented model is essentially that of a complex man-machine information system, linking the processing algorithms with input and output informations, and permitting a breakdown of variable depth. The model is valid for both simple and complex control cases, and the time-sequence differentiation, presented at last, permits a superposed development of an on-line, real-time system in conformity with an integrated aspect. The presented model permits a conversion to signal or operation system models of identical structure. These latter, however, allow to survey demands of the complex control organism concerning information input, transfer and processing, to select man-machine systems of the proper performance and quality, in function of the motion intensity of the material-energy component and of the spatial position of the entering parts.

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