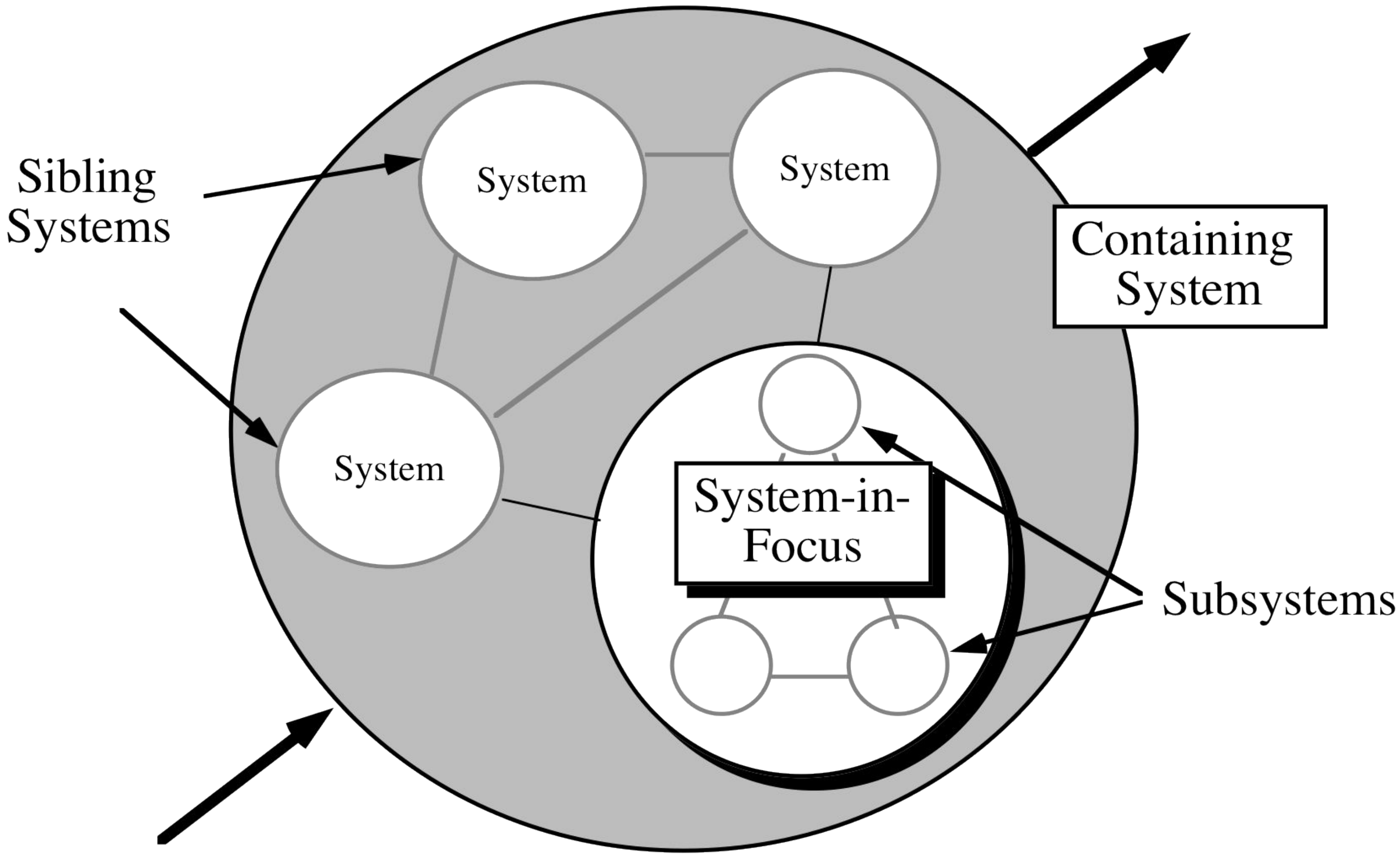
Ministry of Education and Science of the Republic of Kazakhstan
D.Serikbaev East Kazakhstan State Technical University

Faculty of engineering
Department of “Technological machinery and transport”

Systematic Data Analysis

Senior lecturer, PhD student
Kim Alina Igorevna

1 LECTURE
"INTRODUCTION: BASIC DEFINITIONS"

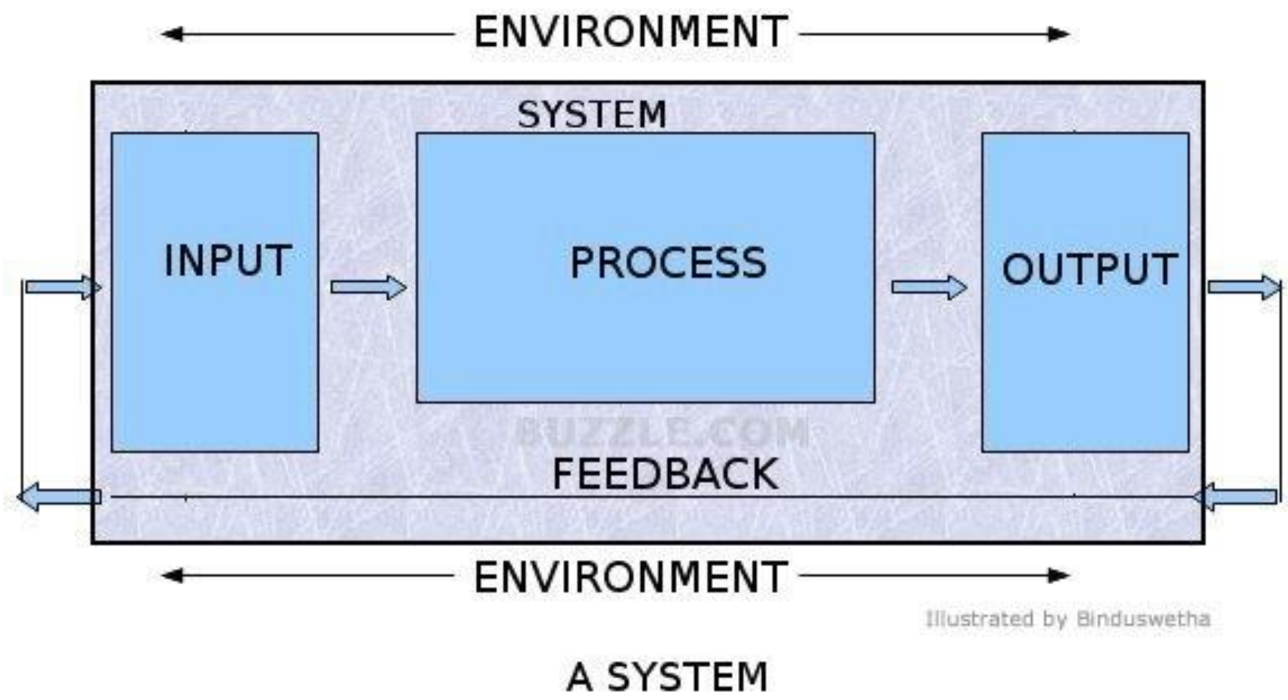


The system is an object or a process where elements are related by some connections and relationships.

The need for the "system" definition occurs in those cases where it is impossible to portray, represent (for example, using a mathematical expression), but it have to be emphasized that this will be a big, complex, not fully understood at once (the uncertainty) and the whole, unified. For example, "the machine control system".

Features of the "system" term such as **ordering, integrity and availability of certain laws** - appear to display mathematical expressions and rules - "the system of equations", "numbering system", "system of measures", etc. We do not say: "the set of differential equations" or "set of differential equations" - namely, "a system of differential equations", to emphasize the ordering, integrity, availability of certain laws.

Interest in system representations is evident not only as a convenient the generalizing term but also as means of setting goals with great uncertainty. the



Four **basic properties of the system** can be identified:

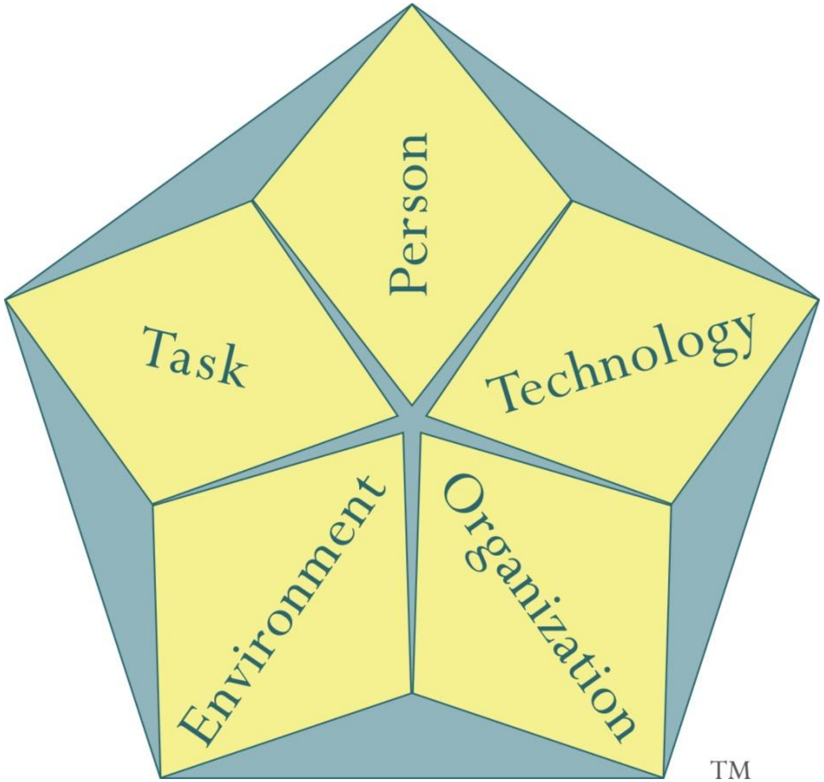
- system is a set of elements that could be considered as a system under certain conditions;

- existence of significant relationships between the elements and (or) their properties, superior in power (force) the relationship of these elements to the elements not included in the system. Under significant relationships are understood those that naturally, with the need to determine the integrative properties of the system. This property distinguishes the system from a simple conglomerate and distinguishes it from the surrounding environment;

- availability of a specific organization;

- the existence of integrative properties, i.e., inherent in the system as a whole, but not typical to any of its components separately. Their existence indicates that although the system properties depend on the elements properties, but they are not completely surround them. I.e. the system is not limited to a simple set of elements, and by breaking the system into separate parts, it is impossible to know all properties of the system as a whole.

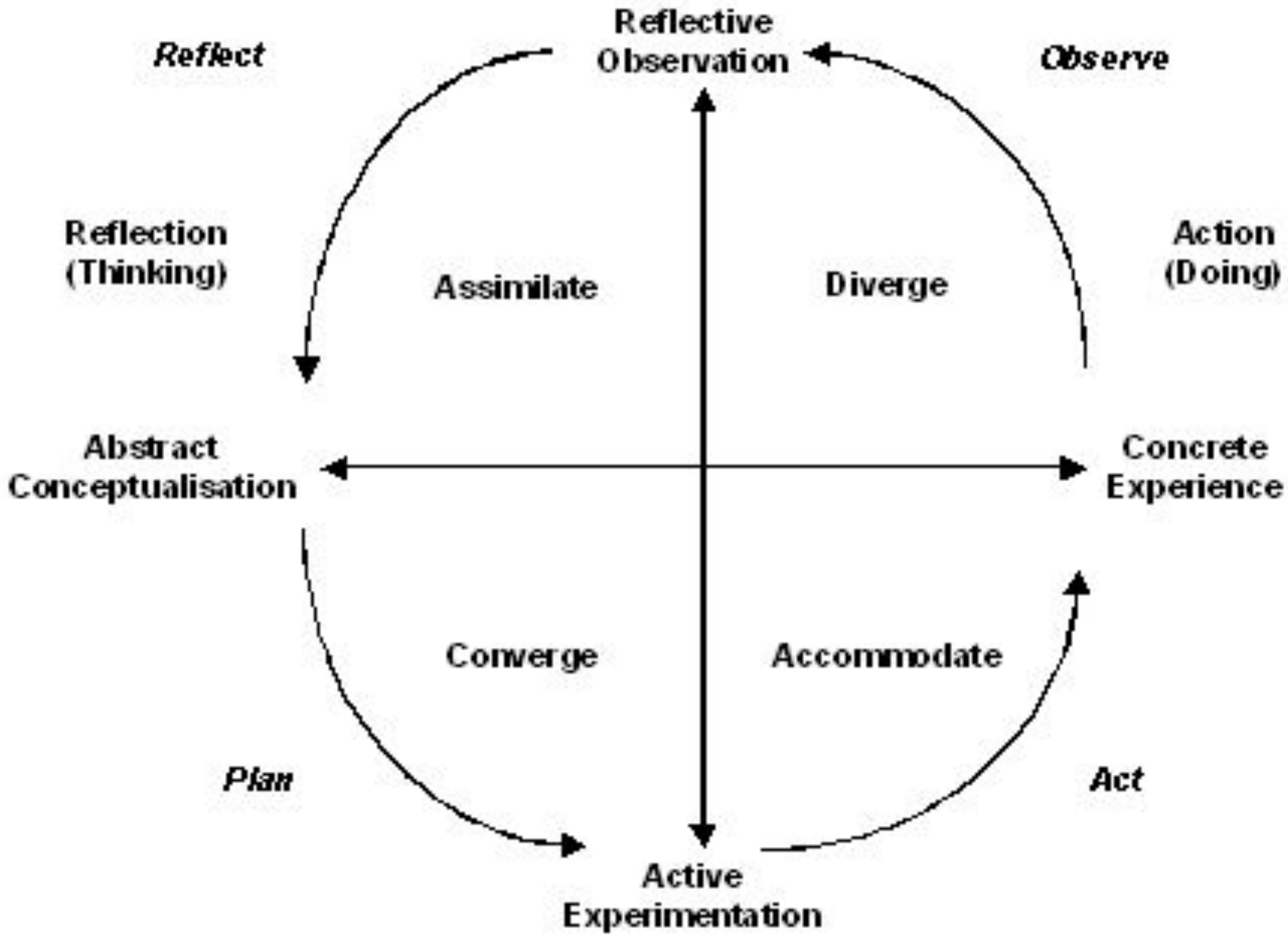
System approach - direction of scientific knowledge methodology and social practice, which is based on the consideration of objects as systems. Systematic approach orients researchers to disclose integrity of the object, to identify the multiple relationships and bringing them into a single theoretical picture.



Systemic approach requires in the study of any object or phenomenon, the Systemic approach may be represented as a sequence of **the following stages**:

- allocation of the study object from the total mass of phenomena or objects. Determination the contour system limits, its major subsystems, components, relationships with the environment;

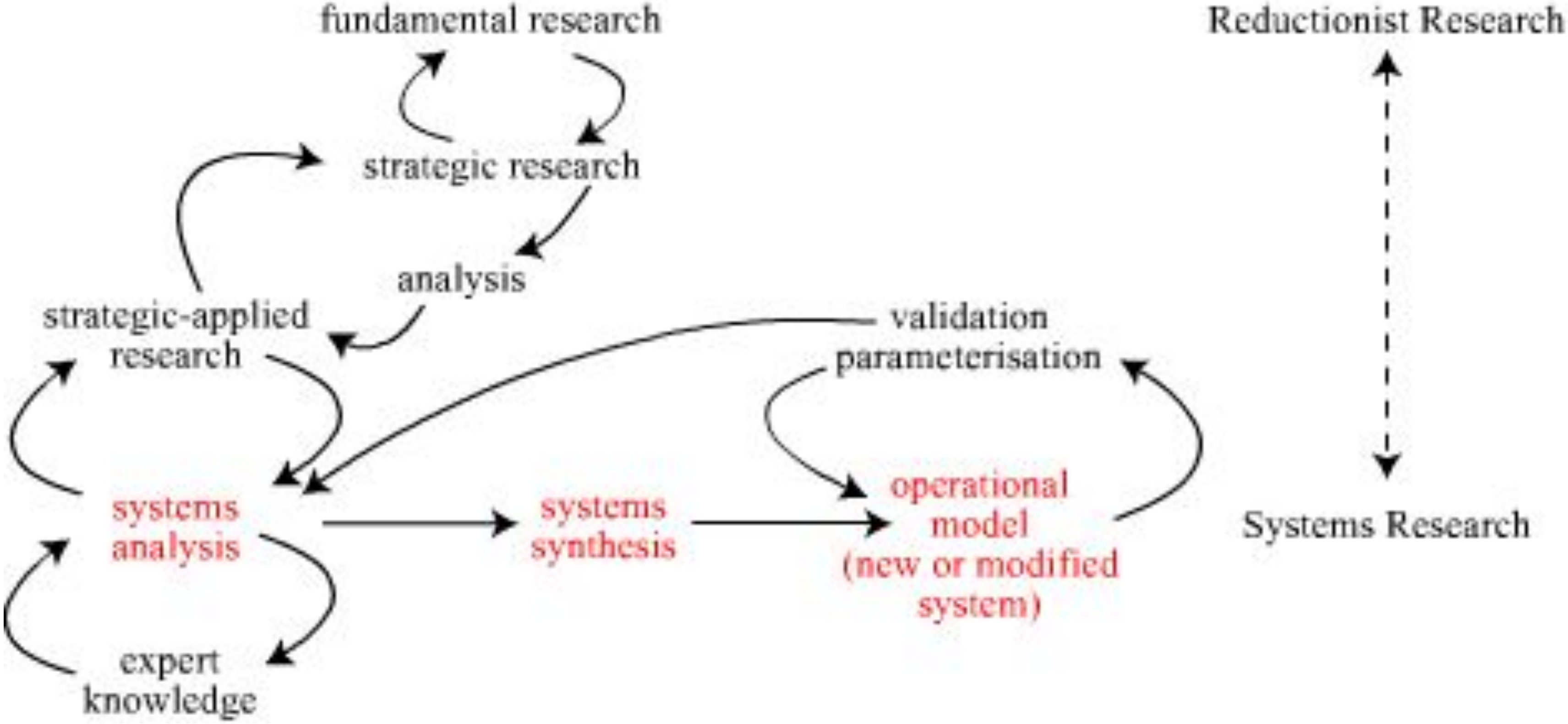
- establishment of research objectives: the definition of system functions, its structure, management and operation mechanisms;


Reflective
Observation
Reflect
Observe
Reflection
(Thinking)
Assimilate
Diverge
Action
(Doing)
Abstract
Conceptualisation
Concrete
Experience
Converge
Accommodate
Plan
Act
Active
Experimentation

- definition of the basic criteria describing a targeted operation of the system, the main restrictions and conditions of existence (functioning);

- identifying alternatives when choosing structures or elements to achieve a given goal. If possible, it is necessary to take into account factors that affect the system, and solutions to the problem;

The Systems Approach



- preparation of the system model functioning, taking into account all significant factors. The significance of factors determined by their influence on determining the target criteria;

- optimization of the functioning of the system or model. Selecting solutions based on their performance in achieving objectives;

- designing of optimal structures and functional activities of the system. Determination of the optimal scheme of regulation and control;
- supervision of the system, determination of its reliability and efficiency.
- establishing a reliable feedback on the results of the operation.

2 LECTURE
SYSTEM RESEARCH

System research is set of scientific theories, concepts and methods, where the research object is considered as a system.

The **object of system research** is the system, representing a plurality of interconnected elements as a whole with its internal and external relations and properties.

The main methodological features of system research:

1. System Studies characterized by special type of the studied reality - it is usually multi-functional (number of different tasks are solved, often attributed to the widely separated scientific disciplines).

2. The possibility and necessity of using the methods and means of various sciences in one systematic research put forward the problem of object reference, i.e., identifying adequacy of one or another group of assets the research subject.

3. High level of system research abstraction creates the possibility of formation a large empirical material for each studies. On the one hand the breadth of empirical field allows you to quickly get theoretical findings, on the other - it is an obstacle when you have to make the transition from abstract theoretical systems to obtain results given subject.

The systemic study identified **three aspects**:

- development of theoretical foundations of systematic approach;

- research unit formation of adequate system approach (formal sphere);

- application of system ideas and methods (applied sphere).

There are "soft systems methodology" and "hard system methodology.«

The general scheme of "soft systems methodology" includes seven main stages of the process:

1. Awareness of the presence of a problem situation and possible accumulation of more complete information describing the situation.

2. Fixing of a problem situation in the form of some description.

3. "Basic definitions" development of appropriate system that reflects the fixed problematic situation.

4. Creating and testing of conceptual models aimed at identifying ways to complete or partial resolution of the problem.

5. Comparison of the simulation results with the problem situation description.

6. Determination of complex and feasible changes in the initial situation based on previous step.

7. Actions of the subject on the practical implementation of these changes.

The basis of **"hard system methodology"** is definition of the alternative ways to achieve set objectives and choice of alternatives that meets specific criteria. In order to do this, model that allows generating and comparing various alternatives is created.

Founded feature and **the difference between "soft system approach"** is comparison phase of models describing the original problem situation.

The system research specifics are determined by extension of new approach principles of the study subject. In its most general form, this approach is reflected in the effort to formulate a complete picture of the object and it is characterized by the following provisions:

- investigating object as system element or description has not self-sufficient character, because the element is described taking into account its place in the whole;

- the same material acts in a system research as possessing at the same time different characteristics, parameters, functions and even various principles of structure. One of manifestations is hierarchal structure of the system;

- the system research is inseparable from a functioning conditions research;

- specific point of system approach is the problem of whole properties generation from elements properties and vice versa, generations of elements properties from whole characteristics.

3 LECTURE
"SYSTEM ANALYSIS"

System analysis - a set of concepts, methods, procedures and techniques for the study, description, implementation of the phenomena and processes of different nature and character, interdisciplinary problems; a set of general laws, practices, methods of investigation of such systems.

System analysis provides for use in a variety of sciences, the following **system methods and system procedures** :

1) **Abstraction and concretization**.

Abstraction is usually described as the process of mental distraction of any properties or object feature from object and its properties. This is done in order to further consideration the subject, isolating it from other objects and from other properties or attributes.

Concretization - operation, unilaterally fixing one or other subject characteristics, without taking into account links with other characteristics, i.e., without connecting them together, and studies each individually.

2) Analysis and synthesis, induction and deduction.

Analysis is mental separation of an object or phenomenon in the forming part or mental selection its individual properties, characteristics, qualities.

Synthesis is mental connection of individual parts of subjects, or combination of their individual mental properties.

Induction - a transition in the research process from the particular to general knowledge.

Deduction - transition in the learning process of general knowledge about a certain class of objects and phenomena to the particular and individual knowledge.

3) Formalizing.

Formalizing is the method of objects investigating by presenting their elements in the form of a special symbolism.

4) Composition and decomposition.

Composition - drawing up a whole object from its parts.

Decomposition - separation of the whole object into parts. Also decomposition it is a scientific method that uses the structure of problem and allows to replace solution of one large problem to solving a series of smaller tasks, albeit interrelated, but more simple.

5) Linearization and selection of non-linear components.

Linearization - one of the most common methods for the analysis of nonlinear systems. Linearization idea - the use of a linear system to approximate the behavior of a nonlinear system solutions in the neighborhood of an equilibrium point. Linearization allows to indicate majority of qualitative and especially quantitative properties of nonlinear systems.

6) Structuring and restructuring.

Structuring is the process of information organizing; as a result the elements are connected in the sense of complete group or several such groups.

7) Prototyping.

Prototyping is a form of research project modeling, simulation in volumetric images. The model provides information about the three-dimensional structure, size, proportions, the nature of the surfaces, plastic, color-texture making and others.

8) Reengineering.

Reengineering - is a radical rethinking and redesigning processes to achieve dramatic, juddering improvements in the main indicators.

9) Algorithmization.

Algorithmization - stage of problem solution, consisting of finding the algorithm on the problem formulation and its solution.

10) Modeling and experiment.

Modeling - objects investigation of knowledge on their models; Construction and investigation of real objects models, processes or phenomena in order to obtain an explanation of these phenomena, as well as to predict the phenomena which interested researchers.

Experiment as a cognitive activity tool is a process based on the systematic repetition, with some artificially set conditions.

11) Clustering and classification.

Classification - systemic distribution of studied objects, phenomena, processes, by type, stile, for some essential features for the convenience of their studies; grouping of basic concepts and their location in a certain order reflecting the degree of similarity.

Clustering - according to some principle, orderly set of objects that have similar classification features (one or more properties) selected to determine the similarities and differences between these objects.

12) Program control and regulation

13) Recognition and Identification

14) The expert evaluation and testing

15) Verification

4 LECTURE
“MODELING OF SYSTEMS”

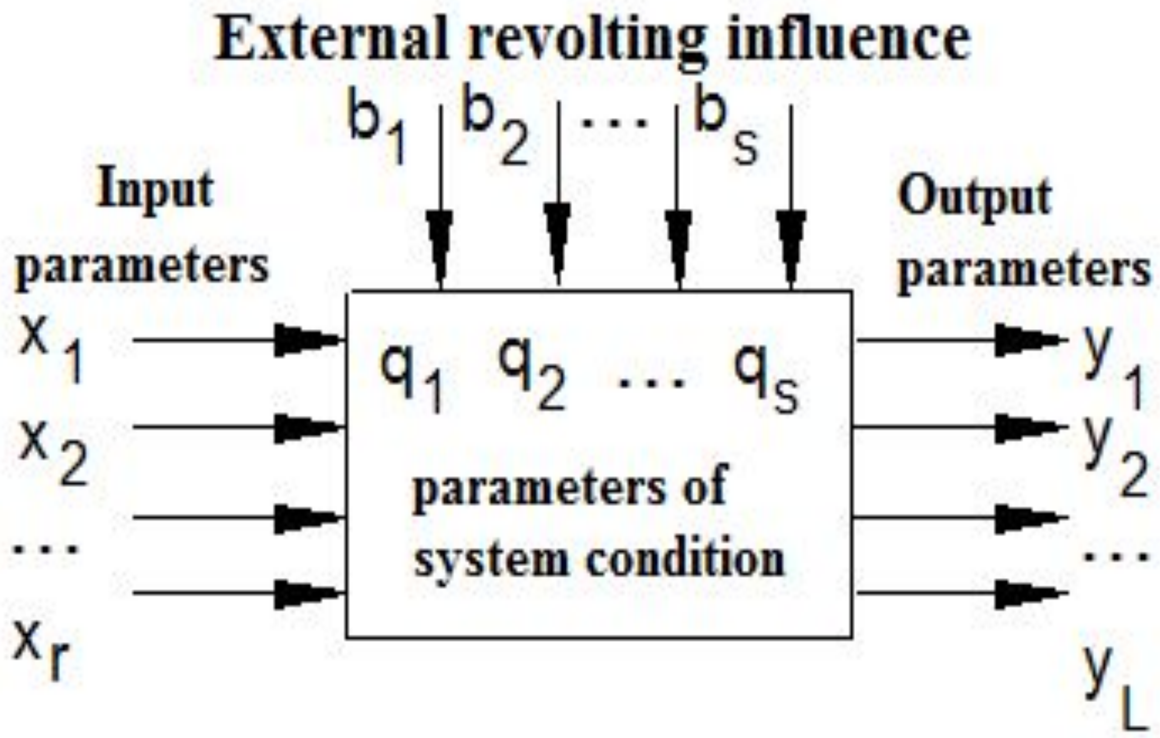
4.1 THE TERMS "MODEL" AND "MODELLING". ABSTRACT MODEL ARBITRARY NATURE OF THE SYSTEM

The general system theory considers not some specific systems, but general in various systems irrespective of their nature; a subject of its studying is abstract models of the corresponding real systems.

The model is representation of real object, system or concept in some form different from their real existence form.

Every model is a certain analogy: for one system, there has to be other system which elements from some point of view are similar to elements of the first. There has to be a display, which for elements of the modelled system puts in compliance elements of some other system - modeling. Besides, there has to be a display, which for properties of elements of the modelled system puts in compliance of elements properties of the modeling system.

In most cases, the abstract model of arbitrary nature system can be represented by scheme shown in Figure below, which, in fact, is an illustration of the introduced concepts.



The system does not exist by itself, but it stands out from the surrounding environment at any systemically lines, often serves the purpose of the system. System interaction with the external environment is carried out through a system of input and output (number of input and output parameters).

Input parameters of the system are understood as a complex of parameters of the external environment (including output parameters of systems, external in relation to considered, for example, control systems) exerting considerable impact on a state and value of output parameters of the considered system and giving in to the account and the analysis means, available the researcher.

Output parameters - a set of system parameters that have a direct impact on the external environment and significant in terms of the purpose of the study.

An important functioning feature of complex systems is the fundamental uncertainty of the true state of the environment at any given time. The nature of the uncertainty associated with the presence of number of reasons, the most important is caused by the following factors.

- Perhaps, parameters of the external environment which are directly influencing behavior of system (that is parameters which should be referred to category of "entrance") the researcher often doesn't know about some, and, therefore, can't consider it.

- Some parameters of the external environment can't be measured owing to technical impracticality of information means.

- Numerical values of the considered parameters are estimated with the errors of measurements defined on the one hand - internal noise of measuring devices, and another - external hindrances.

Impact on system of similar unaccounted factors is compensated by introduction to additional communications model - the external revolting influences or "noise".

The system can be in different statuses. The status of any system at given time can be described, with a certain accuracy, set of parameter values *(q)* of a status.

Thus, ***the system is characterized by three groups of variables***:

1. Input variables which are generated by systems, external rather researched;
2. Output variables defining impact of the researched system on the environment;
3. Condition parameters that characterize the dynamic behavior of the studied system.

At the research of the majority of systems all three groups of entered sizes are assumed by functions of time.

4.2 Physical and mathematical modeling

As the concept "*modelling*" is rather general and universal, so various approaches as, for example, a method of membrane analogy (physical modeling) and methods of linear programming (optimizing mathematical modeling) are among ways of modeling. To order the use of the term "modelling", classification of various ways of modeling is entered. In the most general form of modeling two groups of various approaches determined by the concepts "physical modelling" and "ideal modelling" are allocated.

Physical modelling is carried out by reproduction of the researched process on the model having generally the nature, other than the original, but an identical mathematical process description of functioning.

The set of approaches to research of difficult systems determined by the term *"mathematical simulation"* is one of varieties of ideal simulation. Mathematical simulation is based on use for system research of mathematical ratios set (formulas, equations, operators, etc.) defining structure of the researched system and its behavior.

The mathematical model is a set of mathematical objects (numbers, symbols, sets, etc.) reflecting the properties of technical object, process or system, major for the researcher.

Mathematical modeling is a process of mathematical model creation and operating for the purpose of obtaining new information on a research object.

Creation of mathematical model of real system, process or the phenomenon assumes the solution of two classes tasks connected with creation of the "external" and "internal" description of system. The stage connected with creation of the external description of system is called macroapproach. The stage connected with creation of the internal description of system is called microapproach.

Macroapproach - a way of carrying out the external description of system. At a stage of external description creation the emphasis on joint behavior of all elements of system is placed, it is precisely specified how the system responds to each of possible external (entrance) influences . The system is considered as "black box" which internal structure is unknown. In the course of creation of the external description the researcher has an opportunity, influencing variously a system entrance, to analyze its reaction to the corresponding entrance influences.

At the same time degree of a variety of entrance influences essentially is connected with a variety of conditions of system exits. If the system reacts to each new combination of entrance influences in unpredictable way, experiment needs to be continued. If on the basis of the obtained information the system, in accuracy repeating investigated behavior, can be constructed, the problem of macroapproach can be solved.

So, the method of "black box" consists in revealing structure of system and principles of its functioning, observing only entrances and exits. The similar way of the system description is similar to a tabular task of function.

When microapproaching the structure of system is supposed well-known, i.e. the internal mechanism of transformation of entrance to exit signals. The research comes down to consideration of separate elements of system. The choice of these elements is ambiguous and is defined by research problems and the nature of the studied system. Using microapproach, the structure of each allocated elements, their functions, set and range of possible changes of parameters is studied.

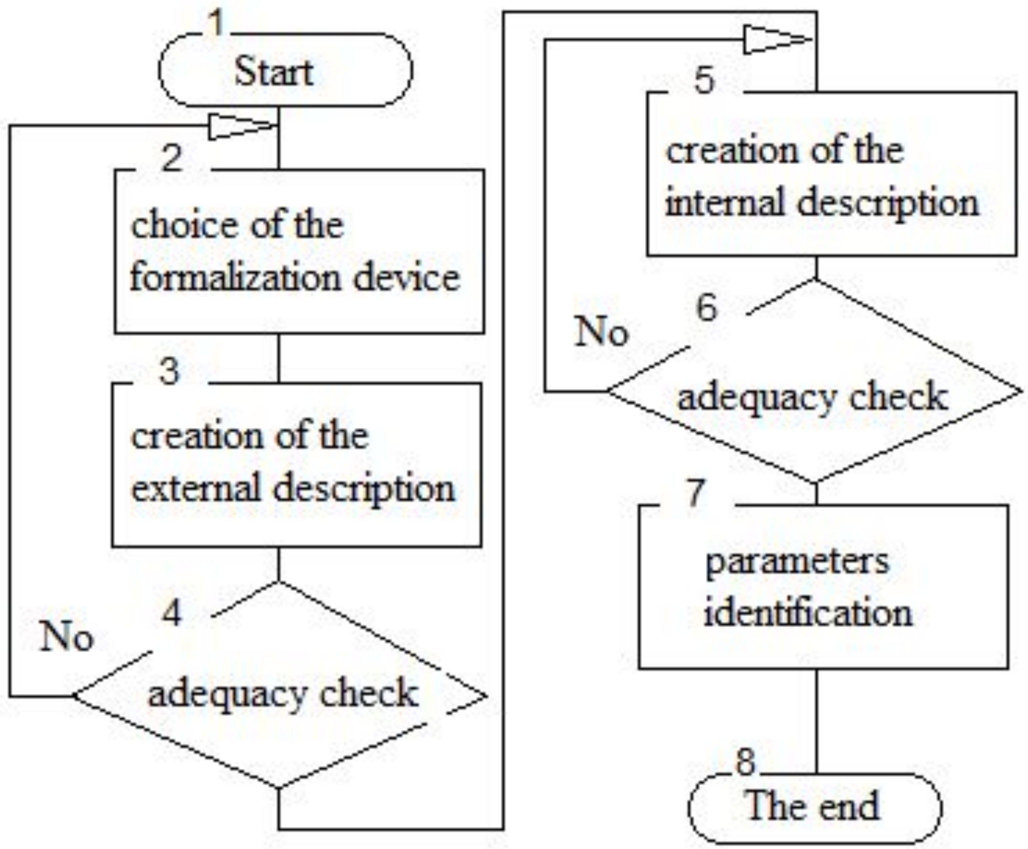
Microapproach - a way of carrying out the internal description of system, i.e. the description of system in a functional form.

The result of this study phase should be the conclusion of dependencies that determine the connection between sets of input parameters, state variables and output parameters of the system. The transition from the external system to describe its internal task description is called realization.

The problem of realization consists in transition from the external description of system to internal description. The problem of realization represents one of the major tasks in research of systems and reflects the abstract formulation of scientific approach to creation of mathematical model. In such statement, the problem of modeling consists in creation of set states and entrance-exit display of the studied system on the basis of experimental data. Now the problem of realization is solved in a general view for systems which have a display an entrance-exit linearly.

4.3 Algorithm of mathematical model creation

The procedure of mathematical model creation of real system, process or the phenomenon can be presented in the algorithm form. The flowchart illustrating an algorithm of mathematical model creation is provided on fig. 1.



Main stages of mathematical model creation.

1. Allocation of system from the external environment. Allocation of communications with the external environment, splitting set of communications into input and output parameters. Observation of system, information accumulation sufficient for hypotheses promotion of system structure and its functioning.

2. The choice of the formalization mechanism is carried out by the researcher and depends on many factors, in particular - on the purposes of modeling, the available information, the obtained experimental data.

3. Creation of the external description comes down to search of definition range (in space of entrance influences) and areas of values (in exit space) which dimension has been defined at a stage 1, and definition of compliance between input and output parameters.

4. If check of adequacy shows that the created model doesn't meet its requirements, and more difficult nature of system behavior is the reason of it, then the choice of a new method of the mathematical description is made.

5. In case of the successful created external description, transition to the internal description is carried out, at the same time, dimension of system conditions space is made (that is dimension of a vector) has to be minimum.

6. Definition (identification) of qualitative and quantitative characteristics of the parameters defining functioning of system.

The problem of parametrical identification comes down to values search of parameters providing minimization of some mistake function. Special value at all stages of creation of mathematical model is check of adequacy, consistency of model and its sufficiency for realization of research objectives.

If the model is built not sufficiently reflect the properties of the modeled system, then there is no use of the most modern means and methods of the study may not give satisfactory results. This is an inevitable feature of using a mathematical model. All received during its study results reflect actual properties of the model, rather than the original system for the study of the model was developed.

5 LECTURE

ASSESSMENT OF COMPLEX SYSTEMS MAIN TYPES OF MEASUREMENT SCALES

5.1. Assessment of complex systems

In system approach the section of "theory of efficiency", connected with determination of systems quality and implementing processes, is selected.

The theory of efficiency – the scientific direction which learning object is question of quantitative quality evaluation of characteristics and efficiency of complex systems functioning.

Generally the efficiency evaluation of complex systems can be carried out for the different purposes. Firstly, for optimization – the choice of the best algorithm from several, realizing one law of system functioning. Secondly, for identification – determination of system which quality the most corresponds to a real object in the set conditions. Thirdly, for decision making on system management.

Four stages of complex systems evaluation:

Step 1. Definition of the estimation purpose. In the system analysis two types of the purposes are allocated. Qualitative is the purpose which achievement is expressed in a nominal scale or in an order scale. Quantitative is the purpose which achievement is expressed in quantitative scales.

Step2. Measurement of system properties recognized essential to the estimation purposes. For this purpose, the corresponding scales for properties measurement are chosen, and for the studied systems properties, a certain value on these scales is appropriated.

Step3. Reasons for quality criteria preferences and criteria of systems functioning efficiency on the basis of chosen scales of measured properties.

Step4. Actually estimation. All researched systems considered as alternatives are compared on formulated to criteria and depending on the purposes of estimation, they are ranged, get out, optimized.

5.2. Concept of a scale. Types of scales

The basis of assessment is the process of comparing the values of qualitative or quantitative characteristics of the studied system values of the corresponding scales.

Scale – the sequence of numbers serving for measurement or quantitative assessment of any sizes.

Formally, scale is called complex from three elements $\langle X, \phi, Y \rangle$, where X – real object, Y – scale, ϕ - homomorphic mapping X on Y.

In the modern theory of measurement is defined:

X = {x1, x2, …, xi, …, xn, Rx} empirical relation system, which includes a number of properties *xi*, which in accordance with the measurement objectives, some attitude *Rx* is given. In the process of measurement for each property is necessary $xi \in X$ put in correspondence with tag or number, it characterizes.

Y = {ϕ(x1), …,ϕ(xn), Ry} the sign system with the relation which is display of empirical system in the form of some figurative or numerical system corresponding to the measured empirical system.

5.2.1. The scales of the nominal type

The weakest quality scale is nominal scale (scale items, the classification scale) for which *xi* objects or groups of indistinguishable some indication is given. This feature gives only the names for no related objects. These values are either the same or different for different objects. The scales of the nominal type only allow objects distinguishing on the basis of equality relation verification on the set of these elements.

Nominal scales correspond to the simplest type of measurement which scale notes are used only as object names.

5.2.2. The scales of the order

The scale is called ***rank (order scale),*** if the set Φ consists of all monotonically increasing allowed conversions of scale values.

Monotonically increased transformation is called $\phi(x)$, which satisfies the condition: if $x1 > x2$, then the $\phi(x1) > \phi(x2)$ for all values of scale x1> x2 in the domain of definition $\phi(x)$. Property scale type allows not only the difference of objects, the nominal type, but also is used to organize objects on the measured properties.

Measuring in order scale may be used in the following situations:

- It is necessary to organize objects in time or space;
- It is needed to arrange the objects in accordance with any quality, but it is not required to produce an exact measurement;
- Any quality is measurable in principle, but at the moment cannot be measured, for practical reasons, or theoretical nature.

5.2.3. Scales of intervals

One of the most important types of scales is the type of intervals. The type of intervals scales contains scales, only to within a set of positive linear admissible transformations of type $\phi(x) = ax + b$, where $x \in Y$ scale values from range of definition Y; a>0; b – any value.

The main feature of these scales is to maintain constant intervals relations in equivalent scales:

$$\frac{x1 - x2}{x3 - x4} = \frac{\varphi(x1) - \varphi(x2)}{\varphi(x3) > \varphi(x4)} = const$$

Thus, upon transition to equivalent scales by means of linear transformations in scales of intervals there is a change both reference point and the scale of measurements.

Scales of intervals the same as nominal and order scale, keep distinction and streamlining of the measured objects. However, besides they keep also the relation of distances between couples of objects.

$$\frac{x1 - x2}{x3 - x4} = K$$

means that the distance between x1 and x2 is K times greater than the distance between x3 and x4 in any equivalent scale value is retained.