5.2. Control in Organizations and Other Organizational Sciences

The aim of the present section is to demonstrate the place of the approach to applied mechanism design followed in this book, the so called **theory of control in organizations** [43], within the system of contemporary management and organizational sciences. Note that below we use the terms "organization" and "organizational system" as synonyms.

- List
- Classify
- Compare

To succeed, let us perform the following steps:

- Define a common system of classifications to compare different fields of organizational sciences.
- Briefly list and classify modern schools and theories that investigate various problems of organizational control and management
- Compare control in organizations (CO) with other theories in terms of the chosen system of classifications; notably, demonstrate their common and distinguishing features.

Listing of the theories is accompanied with some references to the selected monographs and textbooks when their subject is related to the topics discussed here.

5.2.1. The Principles of Schools' Classification

We will distinguish between a *scientific field* (as a branch of scientific knowledge) and a *school* (a concept or a theory with a certain conceptual framework, methods and research principles [41]). The latter generally represents a smaller structure and appears closely associated with a specific group of researchers, an organization or a tradition. Generally, several competing or complementary (in the sense of approaches and results) schools may exist simultaneously within the same scientific field.

Classification of the theories

- Subject
- Tasks
- Methods

Schools could be classified according to their object (more precisely, to their subject as the object often belongs to the real world, while the subject provides its theoretical description), problems (functions), tasks of research and methods of research.

According to the *subject of research*, sciences are traditionally divided into natural sciences (studying nature), human and social sciences (studying human beings and society), as well as technical sciences (studying the design and operation principles for engineering technology). A separate group is formed by abstract sciences (e.g., mathematics, cybernetics, or systems theory). Their methods are applicable to the objects of arbitrary nature.

The subject of management and organizational sciences lies in organizational systems, i.e., social and economic systems. Most probably, it should be attributed to social sciences.

Tasks (functions) of scientific research are classified as follows:

- Description (phenomenology of certain objects or processes);
- Explanation (of reasons that underlie the observed phe-

nomena, processes, relationships, and laws);
- Forecast (of future events, states of the objects and processes),
- Recommendation (decision-making policies for specific situations).

Describe so as to explain
⇓
Explain so as to forecast
⇓
Forecast so as to recommend

Every subsequent task of research generalizes and extends the preceding one. As is generally admitted, to explain the causes of a phenomenon one requires their proper description, to make good forecasts of a situation one must have a reliable system of explanations. Finally, suggesting well-grounded recommendations is only possible under a correct forecast of multivariate scenarios implementation, of various alternatives' consequences, etc. However, many scientific fields concentrate on a specific type of problems (for instance, multi-agent modeling [49] deals with forecasting problems, while operations research [51] specializes on making recommendations) and employ explanatory and descriptive models from other sciences (e.g., mental science and economics).

Methods
- empirical
  - observation
  - measurement
  - experiment
  - ...
- theoretical
  - conceptual models
  - simulation models
  - mathematical models
  - ...

The whole variety of research methods is divided into empirical methods (observation, measurement, experiment and so on) and theoretical ones (different types of abstracting and modeling, such as conceptual models, simulation, mathematical models and others) [41].

As a matter of fact, a general tendency in science consists in extending the set of methods being employed. A typical line of development is gradual formalization of a scientific field following the template of natural sciences, primarily, physics. For example, social sciences have relatively recently adopted planned experiments; the only methods widely used before were observation and generalization.

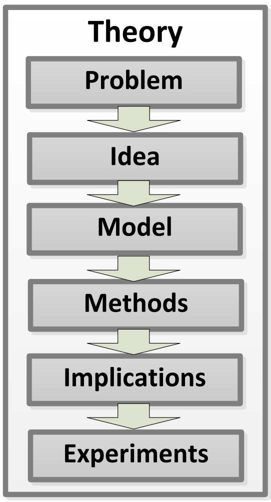

Fig. 5.14

In addition, the following classification seems fruitful for a better comparison of scientific fields and schools. According to K.R. Popper's theory of deductive inference, scientific research starts with formulation of the issue (problem statement) within a certain application domain. The next stage is to formulate a hypothesis, an idea or a **model**. The hypothesis is analyzed via specific methods enabling deduction of different implications. Validity of the derived results is checked during experiments. Being successfully verified, the hypothesis obtains the status of a theory. This reasoning provides yet another basis for classification of scientific theories.

Those scientific theories engaged in studying a single object (an application domain) by means of different models and methods could be referred to as "**subject-based sciences**." Probably, this is the most common alternative for applied sciences; for instance, mineralogy studies minerals, engineering science focuses on the design and operation principles of machines, while medical science concerns human health.

At the same time, some fundamental sciences (a striking example is provided by mathematical disciplines) concentrate on the development of research methods (e.g., mathematical analysis, linear programming, etc) being appropriate to investigate diverse models in many application domains. These theories are logically referred to as "**method-based sciences**."

Constructing the model (as a concretization of the initial idea) forms the most complicated and creative problem. Consequently, the investigator's desire to extend the new fruitful idea (that has been tested for a specific problem) to other problems in the same or different application domain seems reasonable. This is either the case for his or her desire to use new methods in studying a "successful" model. Schools that exploit a single powerful idea or model (we will call them "**model-based sciences**") appear rather common, as well[9]. For instance, as long ago as in the beginning of the 19th century economics was a subject-based science. However (under "**economic imperialism**," i.e., dissemination of the methods used in neoclassic economic theory to other application domains), by today it has become both a model- and method-based science. Notably, it studies purposeful (economic) behavior of individuals and collectives in the fields lying far from traditional economic applications.

In many respects, the above-given classification is subjective (any object or method having sufficiently general character could be considered as several smaller ones, while a model could be partitioned into special-case submodels). Yet, this classification seems rather convenient for the comparative analysis of the character and focuses of scientific theories.

5.2.2. Modern Schools Studying Theoretical and Practical Problems of Control in Organizations

Below one may find a diagram (see Fig. 5.15) representing the scientific fields and schools using a two-coordinate system; notably, the horizontal axis serves for **subjects** of research, while the vertical one includes **tasks** (functions) of research. These axes determine a certain space being partitioned into "cells." Every cell corresponds to a solution of a separate problem (description, explanation, forecasting or recommending) within the application domain of a specific science. Scientific schools under analysis (note they are *inter alia* characterized by a proper group of **methods**) are specified by the domains in the space considered. The domain describing a certain school covers those cells corresponding to the problems (within the application domains) being posed and solved by the methods of this school (at modern development stage).

To a large extent, this diagram seems subjective (or even "self-centered") and by no means exhaustive. For instance, we have not separated such general sciences as *mental science* and *sociology*. The diagram is intended to demonstrate (within a common space) existing interrelations among the basic theories and scientific schools that deal with control of organizations. Hopefully, introducing such space and defining the place of CO

[9] Within reasonable limits, such approach corresponds to the principle of Occam's razor and appears rather productive. Meanwhile, model-based sciences are always in danger of losing the neutrality while distributing a beautiful idea and substituting experimental verification with "aesthetic" considerations. Numerous *naïve* attempts to extend thermodynamic models to the area of social and economic sciences are often subject to this sort of problems.

among numerous scientific schools would let the reader to do the following. Add a scientific school (he or she is concerned with) to Fig. 5.15 independently if it has been not mentioned here.

MBA programs –

- Marketing and sales
- Production management
- Personnel management
- Financial management
- Project management
- Strategic management
- ...

The core of modern scientific schools studying organizational control lies in classic **management theory** as empirical and applied science. This science is mostly taught in business faculties of many universities around the world; it is included in MBA (Master of Business Administration) programs, as well. Management theory is a well-developed field of knowledge with a complicated internal structure. According to internal specialization of management activity, the following management types are often identified: project management [30], financial management [9], personnel management [25], and enterprise resources management (see a common list of specialties provided by any standard MBA program).

Representing a purely applied field of scientific knowledge, management theory concentrates on making recommendations regarding efficient organizational control. However, the underlying forecasting and explaining models appear mostly informal and are reduced to listing the so-called *business cases* (observations of particular cases of successful – *best practices* – or unsuccessful solution of management problems) or, at best, to their generalization.

Traditionally, management theory extensively employs the approaches and results derived in mental science. Nevertheless, Fig. 5.15 shows no branches and scientific schools of mental science; indeed, the latter focuses not on organizations, but on an individuak and his behavior in different contexts and environments (social psychology, production psychology, organizational behavior, etc).

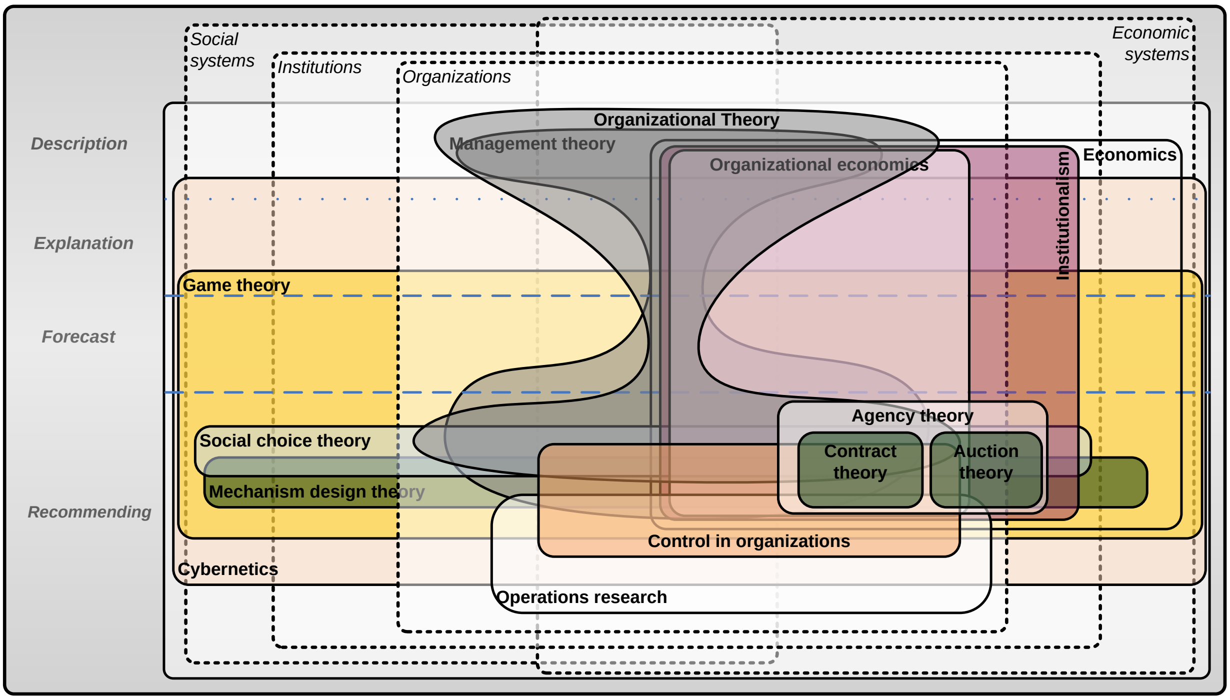

Fig. 5.15 Scientific schools studying organizations:
"Subjects of Research" (horizontally) vs. "Tasks of Research" (vertically)

Organizational theory

Similar approaches to investigations are intrinsic to the so-called **organizational theory** (e.g., see [47]) which studies the phenomenon of *organization* in the context of social and economic systems. The subject of this theory appears even more comprehensive against that of management science; the point is that organizational theory concerns not only with the applied aspect, but also with philosophic issues of the reasons why different organizational forms arise.

Operations research

One should identify quantitative theory of management as keeping aloof of the stated (to a large extent, informal) knowledge domains. In foreign research, it is sometimes referred to as management science [3] or **operations research** [23]. Note the latter term is often used in a wider sense; it means universal theory of making rational or optimal decisions, and the corresponding application domain goes beyond organizational control [51].

In a narrower sense, operations research is defined as a science studying rational utilization of resources by organizations. The underlying approach consists in formalization of problems being solved by managers, as well as in reduction of decision-making problems to **optimization problems**. As the results of solving the optimization problem, *recommendations* are formulated concerning rational choice of management actions (whether production plans or promotion budget are considered). Just as in classic management theory, the recommendations are based on forecasting models; yet, these are formal mathematical or simulation models.

Systems analysis

From a general point of view, control problems in organizations are treated within the framework of **system theory** and **systems analysis** [33] that study universal laws of existence and development of systems having an arbitrary nature (including organizations). The area of systems analysis is too wide to show it on the diagram.

Notably, a principle describing operation of complex systems lies in the demand for communication and control. **Cybernetics** is a universal control and communication science [5, 53], and organizational control forms one of its numerous applications.

Cybernetics

A certain tendency in cybernetics consists in adopting approaches and results (that have been tested in control of technical systems) for organizational control. The corresponding example is solution of the optimal control problem based on state-space dynamic governed by differential equations [17]. Thus, cybernetics poses and solves the problems of making recommendations; *per se*, the latter are expressed by solutions of specific optimization problems. However, cybernetics deals with general control laws and, consequently, with the problems of forecasting, explanation or even description (though, to a smaller degree). The aforesaid is illustrated by Fig. 5.15, as well.

Organizational economics
- Property rights theory
- Transaction

An alternative view on the problems of organizational control is provided by economics. First, the object of **microeconomics** research [32] was rational utilization of resources by the compa-

costs theory
- Agency theory

nies and farms. Following the development of **neoinstitutionalism** [52] (in particular, **organizational economics** [35] and **theory of the firm** – see, e.g., [54] or the corresponding papers in [50]), the attention was focused on the complete intrafirm activity, including social and legal norms of firms operation.[10] The basic branches of organizational economics are **property rights theory** (which studies the relation between the distribution of property rights for means of production and the efficiency of economic activity), **transaction costs theory** (which compares the costs of organizations and markets), and **agency theory** (also known as *principal-agent theory*; it investigates the problems of incomplete information in interaction of *economic agents*).

Agency theory
- Contract theory
- Auction theory

On the other hand, the principal-agent relations are mostly analyzed within the models of **contract theory** [6], dealing with contracts (labor, insurance, etc) between a *principal* and an *agent*. Such relations are also considered within the models of **auction theory** [29, 34] (which studies interaction mechanisms for equal in rights economic agents at markets with asymmetric information).

Microeconomic theory states and solves all above types of problems. However, traditionally the primary purpose of the theory is to describe and explain phenomena (making forecasts and recommendations are not the case). In fact, the latter problems are often considered in the light of *normative* approach, which aims to find efficient economic forms in the sense of social welfare. Generally speaking, the range of such problems economists are concerned with goes beyond the scope of management science.

Game theory

A common mathematical foundation for the majority of discussed economic theories is given by **game theory**. It studies decision-making process in conflict situations [14, 39]. In particular, **mechanism design** analyzes models, where the principal chooses a game directive for agents, striving to ensure their required behavior. A similar model serves as a basis in the **theory of hierarchical games** which investigates mathematical aspects of relations among the hierarchically ordered agents. A distinctive feature of the mechanism design theory lies in greater pragmatism used in formulation of research problems, and in a priori orientation towards making management recommendations. These scientific schools (as well as game theory) should be treated as model-based theories seeking for new applications of fruitful mathematical models of conflict situations.

Today, game-theoretical models are widely involved by many scientific schools. In some classifications, game theory is considered as a branch of decision-making theory (i.e., as a subbranch of operations research in a comprehensive understanding). And vice versa, game theory is often positioned as a branch of microeconomics, while in game theory a certain branch is sepa-

[10] We should also acknowledge the so-called **business economics** (managerial economics) [46]. This scientific school applies the methods of mathematical-economic analysis (in particular, the concept of market equilibrium) to decision-making processes of managers.

rated which studies typical conflict models of organizational control (**game theory and management**) [11].

The methods of game-theoretic analysis are widely used in modern economic theories to describe purposeful (economic) behavior of individuals and collectives, including the areas being far from traditional fields of economics application. Therefore, it was exactly game theory that became a "common denominator" relating the language, terminology and views of neoinstitutionalism, operational management and even political theory in many issues.

Social choice theory

An example of a synthetic mathematical theory concentrating on the problems of coordinating individual interests in collective decision-making is provided by **social choice theory** [38, 40]. It employs the same methods as agency theory to solve more specific problems in a wider application domain.

Experimental behavioral theories

Science never stands still. The subject, tasks and methods of scientific theories vary as time evolves. For instance, in recent decades many scientific schools have faced a substantial divergence between the basic assumptions used by them and the existing reality (e.g., decision-making principles actually used by the people). A topical problem now is to describe behavioral aspects using the approaches and results of mental science (*viz.*, experiments with real people). Almost any of the discussed scientific theories could be assigned the terms "**behavioral**" ([4, 8, 10]) or "**experimental"** [31]. Thus, one obtains a relevant scientific school solving the problems of full-size description of human behavior in a proper application domain involving experimental methods of modern psychology and/or sociology, see Fig. 5.16.

Experiment in management

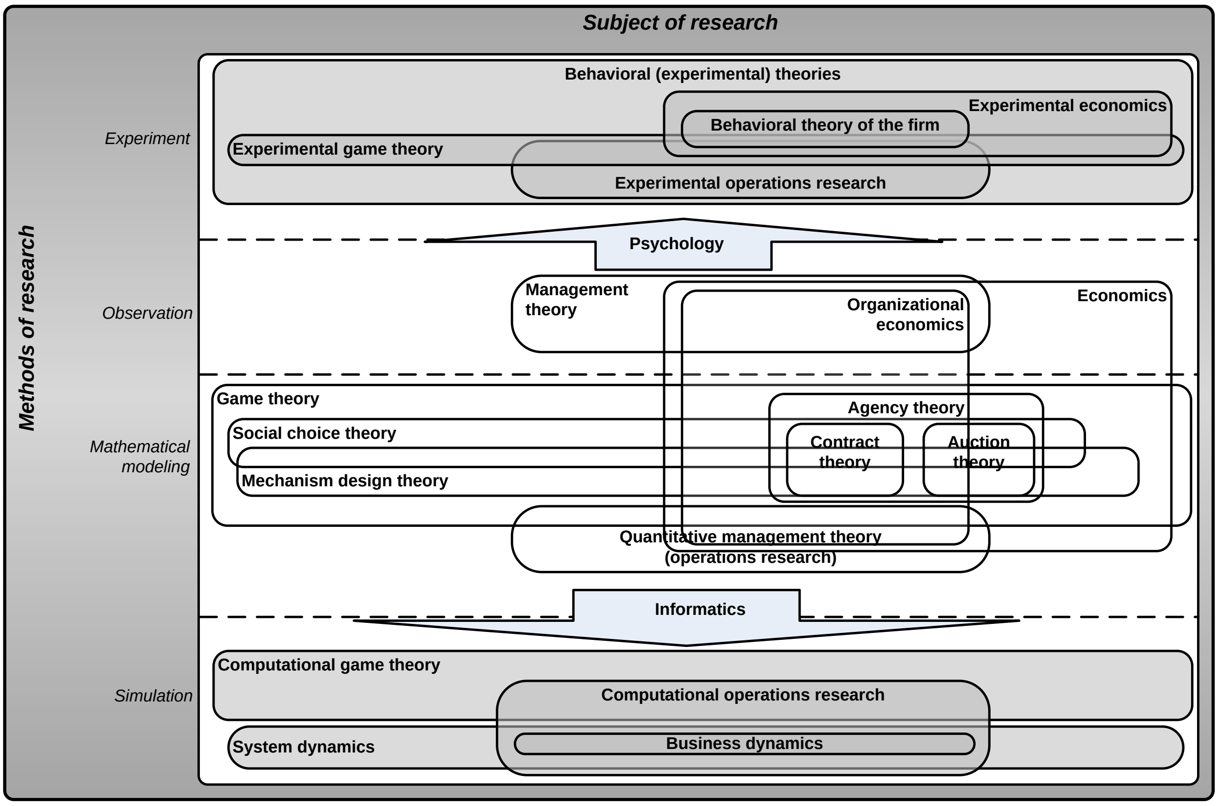

Fig. 5.16. Behavioral theories and experimental theories, computational theories and

algorithmic theories: ”Subject of research” vs. “Method of research”

Similarly, the demand for implementation of recommendations of normative theories in practical management (generally, by automating the corresponding management processes) compels investigators to seriously treat the problems of computer-based realization (including numerical algorithms and their computational complexity). Consequently, the terms “**computational**” or “**algorithmic**” shift any of the above scientific schools to the area of computational mathematics and information science in the sense of methods utilized.

The corresponding examples are **algorithmic game theory** and **algorithmic mechanism design** [1], **computational economics** [19] and others.

Notably, **system dynamics** [48] (including **business dynamics**) represents the development of systems approach in the direction of simulation (mostly, computer-based) of complex systems as time evolves.

The identified tendency is clear from analyzing the references, as well. For instance, many modern textbooks on quantitative management theory (e.g., see [55]) are supplemented with practical exercises illustrating the material presented by numerical examples (Microsoft™ Excel® is often used as software tool).

5.2.3. The Position of Control in Organizations

Game-theoretic modeling appears one of the basic research methods used by the theory of **control in organizations** (CO) [43], as well. In current section we compare this theory with other scientific schools.

CO =
systematic accounting for control activity * (systems approach + operations research + game theory)

CO is positioned as a branch of control science (more specifically, cybernetics) which deals with control in the so-called **active systems**. The elements of active systems are people possessing individual interests, being able to choose actions independently and to manipulate information. In fact, the subject of CO was systematic accounting for activity phenomenon in control problems based on systems approach and using the methods and results of operations research and game theory.

CO became a subject-based theory owing to the models and methods of operations research, discrete mathematics and others. On the other hand, the reason was integration of intrinsic achievements in the field of management consulting and applied results of other theories (economics, mental science and management theory). The primary task of CO lies in designing efficient mechanisms of organizational control (taking into consideration purposefulness of control subjects or not).

The techniques suggested by modern CO appear rather comprehensive. In comparison with operations research, describing purposeful behavior of people by game-theoretic models in CO (TAS) started much earlier. At the same time, application of game theory in CO is different. Pragmatic normative approach (a game conflict is a priori considered in the view of a single part, i.e., a client) becomes intrinsic to CO. This is in contrast to standard descriptive approach in economics (when a conflict is viewed indirectly). In the stated sense, the theory of hierarchical games turns out "congenial" to CO among all branches of general game theory.

Utilitarian character of CO is either obvious when comparing this theory with the approaches adopted by agency theory. Notwithstanding formal resemblance of mathematical models, motivation of the research often varies. The interests of CO are mostly limited to optimal mechanism design (i.e., construction of the best mechanisms in the view of a principal, see the papers in [1]), whereas efficiency (in the sense of welfare economics [32]) is overshadowed.

Note that the models studied by CO bear the imprint of informal problems. For instance, despite their formal reducibility to a social choice problem [1] (in a certain statement), resource allocation problems [14, 32, 38], and auctions [29, 32, 34] are traditionally considered separately, as the ones arising at different stages of organizational control cycle.

CO =
applied problems +
optimization +
game theory

Therefore, the basic idea of CO consists in combining maximum usability in formulation of organizational control problems with wide adoption of formal models (including game-theoretic ones).

Approaches to stating and solving optimization problems of organizational control in CO and in operations research are almost identical. CO is characterized by systematic accounting for the purposeful behavior of a control object. For instance, the methods of network planning and scheduling [27] are developed both within the frameworks of operations research and CO. Still, to solve a complex applied problem of improving the efficiency of project management, CO supplements these methods with resource allocation mechanisms under uncertain conditions, with incentive schemes for counter plans and with incentive schemes for project duration decrease [7].

The subject of management theory and organizational theory coincides with that of CO; nevertheless, the corresponding methods have dramatic differences. Management theory seems much flexible in the description of psychological aspects, while CO brings all psychological factors to the concept of *rational behavior* based on utility theory [13]. Many implications of management theory and organizational theory *per se* supplement formal analysis (performed by CO) with empirical components that could not be embedded in modern formal models, yet are relevant during implementation of theoretical results.

For instance, formal models of financial incentives developed by CO are successfully supplemented with **motivation theories**, such as F. Herzberg's motivator-hygiene theory [22] or W.G. Ouchi's theory Z [45] and others.

Integrated rating mechanisms proposed by CO provide a certain tool to design control systems for company efficiency based on different concepts, such as **management by objectives** by P.

Drucker [12] or **balanced scorecards** by Norton D.P. and Kaplan R.S. [26]. On the other hand, incentive mechanisms for operation improvement suggest a motivation support tool for **lean production** programs [44].

It should be emphasized that E.M. Goldratt's **theory of constraints** [15] appears close to project management methods being developed within the framework of CO (and operations research).

According to the viewpoint presented, blending with management theory CO may serve as a bridge (see the dashed arrow in Fig. 5.17) of the formal theoretical results towards managerial practice.

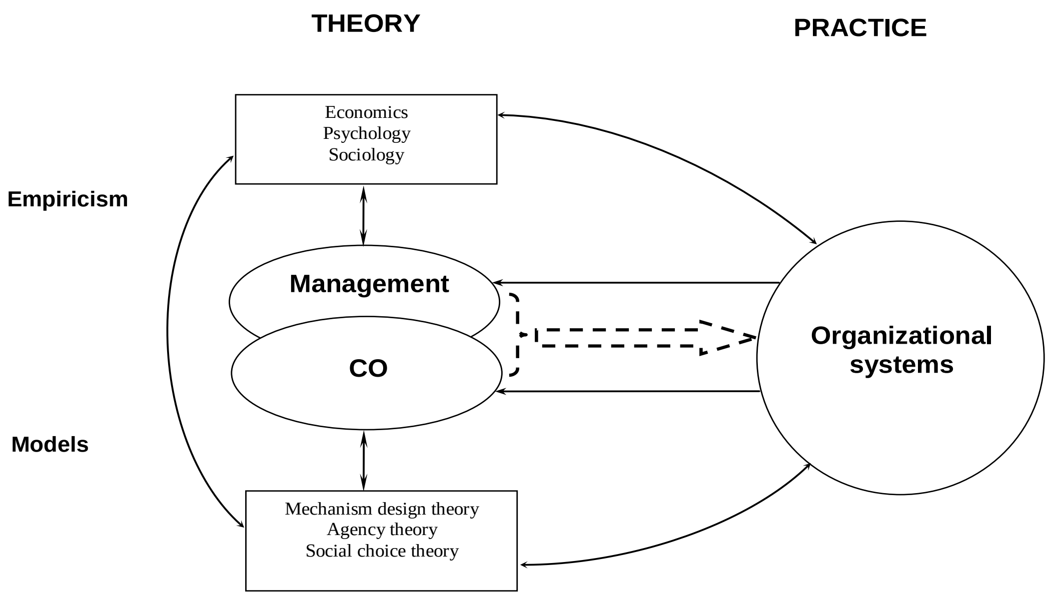

Fig. 5.17. Control: Theory and Practice

5.3. Brief Description of Basic Control Mechanisms

In Chapters 6-9 we describe the complex of common control mechanisms (Fig. 5.18); this is done according to the standard template introduced in Section 5.4. First, the reader is recommended the summary of the mechanisms (Section 5.3); chapters 6-9 provide a detailed study of a specific mechanism.