Organizations play a key role in the modern world. The rapid scientific, social and technological progress of the last centuries resulted into a great variety of organizational forms and types of interaction between them. The complexity of a structure and behavior of an organization depend on the environmental conditions in which the organization is situated. To be successful an organization should effectively and efficiently organize its internal structure and activities, in such a way that the fit with the environment is achieved.

Many modern organizations involve many parties with diverse goals performing for a wide range of tasks. Often such organizations function in the constantly changing environmental conditions with insufficient amount of resources. Because of high structural and behavioral complexities of modern organizations, different mistakes, inconsistencies and performance bottlenecks may occur in the organizations that may have serious consequences for the organizational performance. Only a small part of such problems can be easily identified and solved. Many latent problems require a more profound and detailed analysis.

The approaches developed in Social Science (in Organization Theory, in particular) are to a great extent fragmentary and informal, however useful for understanding the functioning of an organization. Therefore, such methods cannot form the reliable basis for detailed analysis of organizations. For more precise evaluation of the organizational performance, for identification of performance bottlenecks and organizational conflicts, and for estimation (prediction) of consequences of different environmental influences, organization structures and behaviors on organizational performance, detailed organizational analysis based on a formal organization model should be performed. The first formal approaches for analysis of organizations have been developed based on techniques from Operation Research and System Dynamics. These methods abstracted from separate events, objects and actors, and considered an organization at a high level of abstraction. Because of abstraction much information about local events and interaction between actors was lost. Nowadays, one distinguishes three levels of abstraction, at which structures and behavior of an organization can be investigated: macro (the level of interaction between an organization and its environment), meso (the level of interactions between actors and/or groups of actors in the context of an organization) and micro (the level of an actor, its properties and the behavior in an organization).

All three levels are related to each other and influence each other. Therefore, the understanding of the organizational functioning at each of these levels is important for reliable analysis. Nowadays, the concept of a multi-agent system is often used to model the behavior of actors and interactions between them. Agent is an autonomous entity that can independently make decisions and interacts with its environment (for example, with other agents). In this context an organizational model describes an assignment of agents to roles of the organization (sets of functions of an organization), that stand in some relations to each other. On the one side, actions of agents may influence the behavior of a whole organization. On the other side,
organizations enforce some norms and rules that should be followed by agents. Depending on the type of an organization, agents are provided with a certain degree of autonomy. Thus, a formal language for modeling of organizations should have the expressive power to specify both the formal structures and prescriptions of an organization, as well as autonomous behavior of agents. The existing methods in the area of multi-agent systems focus on the latter aspect mostly. These methods provide wide possibilities to specify externally and internally observable behavior of agents, whereas the specification of formal structures and behavior of organizations does not receive much attention. One of the reasons is that the organizational paradigm is used in these approaches with the purpose to improve distributed algorithms, based on multi-agent systems.

For the design of plausible models of real (human) organizations the identification of diverse aspects of the organizational structure and behavior is required. To decrease the complexity of modeling, different aspects of organizations are investigated from four perspectives (or views) in this thesis: the performance-oriented view, the process-oriented view, the organization-oriented view and agent-oriented view. The performance-oriented view describes organizational goal structures, performance indicators structures, and relations between them. The process-oriented view contains information about the organizational functions and processes, how they are related, ordered and synchronized and the resources they use and produce. Within the organization-oriented view organizational roles, their authority, responsibility and power relations are defined. In the agent-oriented view different types of agents with their capabilities are identified, models of agent behavior are specified based on social theories, and principles of allocating agents to roles are formulated. The views are related to each other through certain relations. For example, the goals of an organization can be achieved by execution of processes; the processes are related to roles, which will be eventually allocated to agents.

The languages developed for specifying the concepts and relations of each view are based on the expressive many-sorted predicate logic. To specify dynamic properties and to reason about them, the Temporal Trace Language (TTL) is used. The formal basis (syntax and semantics) has been developed in the frames of this dissertation. The languages of the views and TTL can be used for specifying quantitative as well as qualitative properties of a system (for example of an organization).

By means of the proposed languages the precise definitions have been given to the concepts and relations of the views. Furthermore, the axioms have been formulated, which describe the rules of correct use of the elements of the languages and the integrity constraints imposed on organizational models. For the definitions of these rules and constrains a theoretical basis from Social Science has been used (more specifically, from Organization Theory). In such a way, a connection between the formal logical fundament and the results of empirical research has been established. The dissertation describes methodological principles for the design of an organization model using the proposed languages.

To enable automated analysis of organizational specifications the modeling language should be executable. To this end, the dissertation describes several executable sublanguages of TTL. Furthermore, an automated procedure has been developed in the frames of the thesis for the transformation of complex, non-executable specifications in TTL into executable format.
The dissertation describes a number of automated analysis techniques, which aim at identifying different types of mistakes, inconsistencies and performance bottlenecks in organizations. A part of them is based on generic analysis methods for logical specifications (e.g., model checking), whereas others are based on specialized algorithms for verifying certain properties of organizations (e.g., the consistency of a goal structure, requirements for the process execution, the integrity of interaction and power structures). Moreover, the dissertation describes methods for performing simulations and automated verification of system properties based on the simulation results. Also, a similar approach has been developed for automated analysis of empirical data of an organization.

The developed approaches have been applied in three projects from the areas of logistics, incident management and air traffic control. Due to a high expressive power of the modeling languages all important aspects of the considered organizations have been represented in the organizational specifications. The developed techniques allowed identifying organizational problems that were not known before. The plausibility of the identified problems has been confirmed by the domain experts.

The formal methods for modeling and analysis of the structures and dynamics of different types of organizations, proposed in this thesis, proved to be practicable and useful for the understanding of the organizational functioning, for the identification of organizational errors and inconsistencies, and for the investigation of the organizational dynamics in different environmental settings.