The use of railway transportation among different alternatives (e.g. road and air transportation) brings many profits such as less carbon dioxide emission and energy consumption. Although the infrastructure and the signaling costs of railways are high, they provide more environmental friendly and affordable solutions. Railway signaling systems are divided into two main categories named as fixed-block (conventional) and moving-block signaling systems. Independent of the signaling category, the vital component of railway systems which provides safe travel and transportation is the signaling system, namely, the interlocking software. Since railway signaling systems are classified as safety-critical systems due to the high risk value, the design and development steps of railway signaling systems are defined by international committees such as European Committee for Electrotechnical Standardization (CENELEC), International Union of Railways (UIC), The European Rail Industry (UNIFE), Union Industry of Signaling (UNISIG), and European Railway Agency (ERA). In addition to the railway related safety standards, the designers should consider the requirements and safety rules of the country where the signaling system is to be applied.

After the determination of the software requirements (both world-wide and country-based safety rules), the designer should choose appropriate modeling methods, combination of software architectures, and test procedures to achieve the required Safety Integrity Level (SIL). SIL is a discrete level for specifying the safety integrity requirements of the safety functions allocated to the Electrical, Electronic, or Programmable Electronic (E/E/PE) safety-related systems.

In this thesis, railway signaling systems are studied from the discrete event systems (DESs) point of view since railway signaling systems can be regarded as DESs because of having features like non-determinism, asynchronism, event-driven, and simultaneity. The main reason for using the DES modeling tools such as automata and Petri nets in railway signaling systems is to model the specifications of the system and to evaluate the operational requirements by analysis and re-design.

First, fault diagnosis in fixed-block railway signaling systems is studied. Detecting a fault is a critical and stringent task in railway signaling systems. The signaling system components are modeled by Petri nets and a diagnoser is designed to show diagnosability of the system.

Next, to satisfy the safety requirements of the railway related functional safety standards, a signaling system architecture which consists of two controllers and a coordinator for a fixed-block railway signaling system is studied. Based on the Petri net models of railway field components, decision making strategies including fault diagnosis are developed.

Instead of fixed-block signaling systems, moving-block signaling systems are in use to increase the transport capacity
by reducing headways on railway lines. As a final study, speed control of two consecutive trains as moving-block is realized in two levels: the modeling level and the control level. The aim of this final study is to provide safe travel of trains in moving-block signaling systems. The generalized batches Petri nets approach is used for modeling the system to cope with both discrete and continuous behavior of the moving-block signaling systems and a fuzzy logic control method is proposed at the control level.