4 Basis of Three-Phase Traffic Theory

4.1 Introduction and Remarks on Three-Phase Traffic Theory

To explain empirical spatiotemporal features of congested patterns, in 1996–1999 the author introduced three-phase traffic theory, in which the empirical complexity of freeway traffic was explained in terms of diverse spatiotemporal features of three traffic phases: free flow, synchronized flow, and wide moving jam [205,207–211].

In this and the next chapters of Part I of this book, we will try to show from the fundamental hypothesis of three-phase traffic theory (Sect. 4.3) and from empirical spatiotemporal traffic pattern features [166,167,203,205,207–211] (Sect. 2.4) how the main conclusions and results of the three-phase traffic theory [205,207–211,218] can be derived without complex mathematical formulae or mathematical traffic flow models.

The three-phase traffic theory is a qualitative theory. This should help readers understand the main ideas and results of this theory. Detailed considerations of the empirical basis [166, 167, 203, 205, 207–211, 218] and of mathematical results of three-phase traffic theory [329–331] are considered in Parts II and III of this book, respectively.

To make the three-phase traffic theory as easy as possible to understand, we neglect and simplify certain real traffic features. However, we try to retain salient freeway traffic features. For example, in this simplification we do not consider the very real difference between traffic in different lanes of multilane traffic. All vehicles and all drivers are considered to have the same mean parameters and characteristics, e.g., all vehicles have the same length, all drivers have the same desired (maximum) speed in free flow, they exhibit the same reaction time, and so on. We also neglect or simplify some other (sometimes seemingly important) effects. These simplifications enable us to highlight in the three-phase traffic theory some of the most important features of traffic.

We will see that fundamental qualitative features of congested pattern emergence observed in empirical investigations [208,218] (Sect. 2.4) can be explained in the three-phase traffic theory even when all drivers are suggested to have the same characteristics and all vehicles are suggested to have the
same parameters [218,329,331]. Obviously, in real traffic there can be very large differences in driver behavioral characteristics and in vehicle parameters. However, these differences are responsible for some specific effects and they change usually quantitative characteristics of *fundamental* spatiotemporal congested pattern features only (see Chap. 20). Therefore, differences in driver characteristics and in vehicle parameters can first be neglected when fundamental spatiotemporal congested pattern features are studied.

Three-phase traffic theory discussed in this chapter and Chaps. 5–8 below is an attempt to explain the author’s three-phase traffic theory [205, 207–211, 218] in the simplest way, beginning with some basic empirical background [166, 167, 203, 205, 207–211].

In 1992–1995, when the author began to work in traffic science, he had strongly believed that the fundamental diagram approach would be the correct mathematical approximation for a description of empirical traffic flow phenomena (see early papers by the author et al. [366, 367, 381, 382]). The empirical findings [205, 207–211] were the reasons why the author was forced in 1996–1999 to change his mind fundamentally about the correctness of the well-known and generally accepted fundamental hypothesis of the fundamental diagram approach to traffic flow theory and modeling (see Chap. 3).¹ That is why the author introduced and developed the three-phase traffic theory [205, 207–211], which rejects almost all earlier theoretical results about features of spatiotemporal congested patterns and phase transitions in freeway traffic.

### 4.2 Definition of Traffic Phases in Congested Traffic Based on Empirical Data

#### 4.2.1 Objective Criteria for Traffic Phases in Congested Traffic

In Chap. 1 when we discussed Fig. 1.2 and also in Sect. 2.4, we mentioned the empirical (objective) criteria for two phases in congested traffic, “synchronized flow” and “wide moving jam.” These objective criteria are related to some *spatiotemporal* congested patterns features. Here we consider these objective criteria in more detail.

¹ The author was fortunate to work in 1994–1995 for the traffic engineering consulting firm Heusch/Boesefeldt GmbH in Aachen (Germany), where he met many good traffic engineers. Here he had his first opportunity to begin a study of empirical data on congested freeway traffic. The author thanks all colleagues at this firm, in particular Heinz Heusch, Jochen Boesefeldt, Heribert Kirschfink, Hubert Rehborn, Ulrich Uerlings, and Thomas Scheiderer, for their help, critical discussion of earlier traffic flow theories, and their fruitful cooperation.