

# **Analysis of Flow Features in Queued Traffic on a German Freeway**

Prospectus for Dissertation Research  
Submitted for the Advancement to Candidacy Examination

Roger Lindgren  
College of Engineering & Computer Science  
Department of Civil & Environmental Engineering  
Portland State University  
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*Examination Committee:*  
Robert L. Bertini, Chair  
James Strathman  
Roy Koch  
Katharine Hunter-Zaworski  
Robert Fountain, Graduate Office Representative

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## **1 INTRODUCTION**

The objective of this research is to study the evolution of traffic from freely flowing to congested conditions at freeway bottlenecks located near off-ramps. Preliminary investigations have found that a bottleneck is formed approximately 2000 m upstream of a freeway off-ramp at a location on a German Autobahn. The long-run flow past the point of bottleneck formation is on the order of 10% lower than pre-bottleneck flows.

The research proposed in this prospectus would continue these preliminary investigations by analyzing multiple days' data. These analyses would detail traffic features present on the freeway beginning at a time prior to the onset of queuing continuing until queue dissipation or bottleneck deactivation. The analysis tools used in the proposed research will be curves of cumulative vehicle arrival number versus time and curves of cumulative time-averaged velocity versus time. The data required to construct these curves are available in archived form from inductive loop detectors embedded in the freeway. These cumulative curves will be transformed in such a way that high-resolution plots will be created and details of traffic flow will be revealed. These high-resolution transformed curves will allow for the identification of key time-dependant features related to the bottleneck. Further discussion of the transformation technique is described later in this prospectus.

The proposed research will concentrate on bottleneck features found on a freeway near Frankfurt am Main, Germany. This research is part of an international partnership with the Technical University of Dresden and represents the first time that this type of analytical approach has been applied to German data. To the extent possible, the bottleneck features identified at this site will be compared to other freeway bottlenecks in Europe and North America.

Bottlenecks are the building blocks of a freeway system, and the understanding of the details of bottleneck characteristics is of critical value to freeway planners, designers and managers. With improved traffic flow models based on empirical evaluation of real-time freeway loop detector data, freeway system managers may be able to eliminate the accompanying queues with control measures such as ramp closures, ramp metering and alternate routing via variable message signing.

The following section of this prospectus will provide relevant background including a summary of previous research efforts in this area. Motivation for the work is provided in the third section. A discussion of the primary diagnostic tools as well as a summary of the preliminary investigations is provided in the fourth section. The fourth section also contains a description of the research site and the freeway data. A fifth section contains the research plan projected for completing this proposed work. The prospectus ends with some concluding remarks.

## **2 BACKGROUND**

Understanding how a freeway system operates requires sound knowledge about the behavior of traffic on all elements of the network. These elements include long, homogeneous freeway sections as well as merge areas, diverge areas and other geometric features. Freeway bottlenecks are undesirable, yet necessary attributes near merge and diverge areas. A bottleneck is a restriction that separates upstream queued traffic from downstream unrestricted traffic (Daganzo 1997). Bottlenecks can be static (e.g., a tunnel entrance, lane drop, diverge area) or dynamic (e.g., an incident or a slow moving vehicle). As shown in Figure 1, a bottleneck is considered "active" when it meets the definition presented above and is deactivated when there is either a

decrease in flow or when a queue spills back from a downstream bottleneck (Bertini, Leal, & Lindgren 2003).

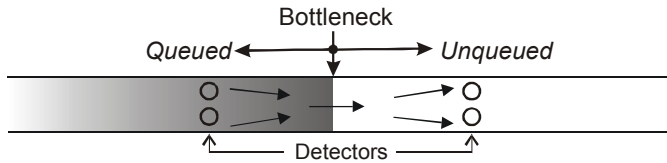


Figure 1 Active bottleneck

While discussing the state of traffic flow theory in 1965, Newell stated that “the main object” of traffic research should be “to study time-dependent flows, to determine velocities of propagations of disturbances,” and to determine “how...traffic adjusts to some time- or space-dependent influences such as traffic lights, bottlenecks, etc. (Newell 1965)” Newell expected that modern data collection and analyses techniques would soon refine the theories of the early 1960's, yet thirty years later Newell reported that little had been added to the understanding of dense traffic flow (Newell 1995). Therefore it is appropriate to study and understand freeway bottlenecks of all kinds—including merges, diverges, lane drops and other configurations.

Recently, Kerner (2002) reported on empirical studies of congested traffic on this same German Autobahn (A5 north of Frankfurt). Kerner, using techniques different from those discussed in this prospectus, and without making his data available to other researchers, identified a bottleneck in a similar location to that identified in this prospectus. Kerner postulated a new "theory" of three-phase traffic--consisting of free flow, synchronized flow, and wide moving jams. Synchronized flow was defined as a condition where the average speed in adjacent freeway lanes is nearly the same (Kerner 1999a). Kerner reported that on the northbound A5 section studied for this prospectus an *isolated effective bottleneck* existed upstream of which is *synchronized flow* where *wide moving jams* spontaneously emerged. In other work (Kerner 1999b) researchers reported the spontaneous formation of queues on German freeways. It appears that this would require queuing to occur without bottlenecks, something that seems to be counterintuitive (Daganzo 1997, Cassidy & Bertini 1999). The research proposed in this prospectus may allow for independent assessment of Kerner's findings, this would be the first time this has been possible.

### 3 MOTIVATION FOR RESEARCH

The uncertainty that currently exists regarding the causes and effects of bottlenecks motivates this proposed research. The preliminary experiments described in the next section of this prospectus indicate that methodologies exist to permit a systematic examination of the key features of these bottlenecks. A greater understanding of bottleneck features is required so that future traffic flow models may improve the abilities of freeway managers to predict and manage the formation of freeway queues. Researchers have recently reported on studies of bottlenecks near on-ramps (Cassidy & Bertini 1999) and off-ramps (Cassidy & Rudjanakanoknad 2002) and have suggested that more research is needed.

### 4 PRELIMINARY INVESTIGATION

This section describes the preliminary work accomplished to date. It includes a description of the freeway site and the traffic data, a description of the research methods and some initial findings.

#### 4.1 Site and Data Description

The study site for the preliminary investigation, as shown in Figure 2, is a thirty-kilometer section of the northbound lanes of Autobahn 5 (A5) near Frankfurt am Main, Germany. The freeway is equipped with thirty vehicle detectors (D1 through D30). Data are currently available for six days in 2001; Friday May 18, Friday August 17, Friday September 14, Wednesday September 19, Thursday September 20, and Tuesday December 4.

A detailed analysis was conducted using the May 18, 2001 data from nine detector stations (D17 – D25) with spacing ranging from 400 m to 1420 m as shown in Figure 2(b). The site is upstream of an off-ramp located near station D25. The weather was partly cloudy with slight winds, clear visibility, no recorded precipitation and temperatures ranging from 10°C to 13°C (Weather Underground 2002).

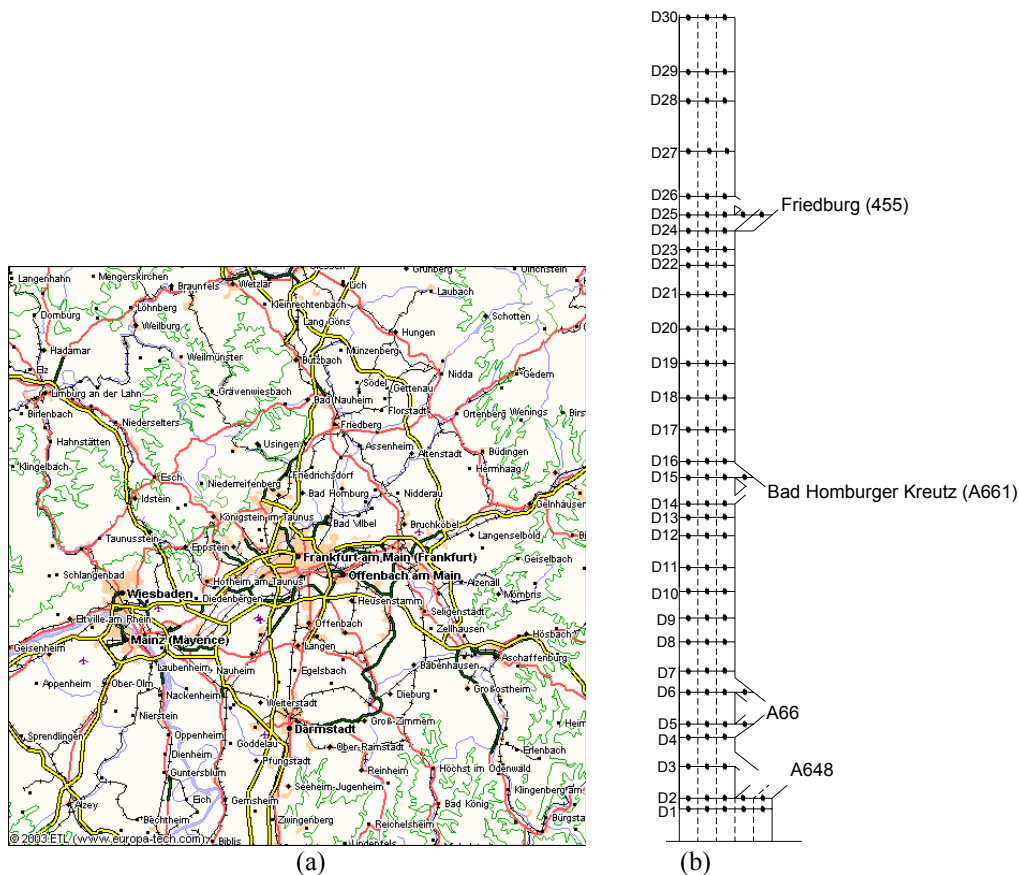


Figure 2 Autobahn A5 site, Frankfurt am Main, Germany (a) and schematic plan (b)

Each detector site consists of two closely spaced inductive loops (a “speed trap”) in each travel lane. A roadside controller records counts and average vehicle speeds over one-minute periods for two vehicle types. The two vehicle types, segregated by vehicle lengths, are reported as autos and trucks.

#### 4.2 Research Methods & Preliminary Findings

The spatial and temporal limits of congested traffic conditions were first identified by speed contour plotting as illustrated in Figure 3. The  $x$ -axis of this figure is time; the  $y$ -axis is distance

with station D1 at the extreme south of the study site. The average speed of all vehicles (both autos and trucks) for each one-minute period in all travel lanes was plotted in color, high speed traffic ( $> 110$  km/h) is shown in green, moderate speed traffic (40-110 km/h) is shown in yellow, slower speed traffic ( $< 40$  km/h) is shown in red. It is apparent from this plot that substantial changes in speed occurred near stations D22 and D23; a bottleneck near this location is suspected.

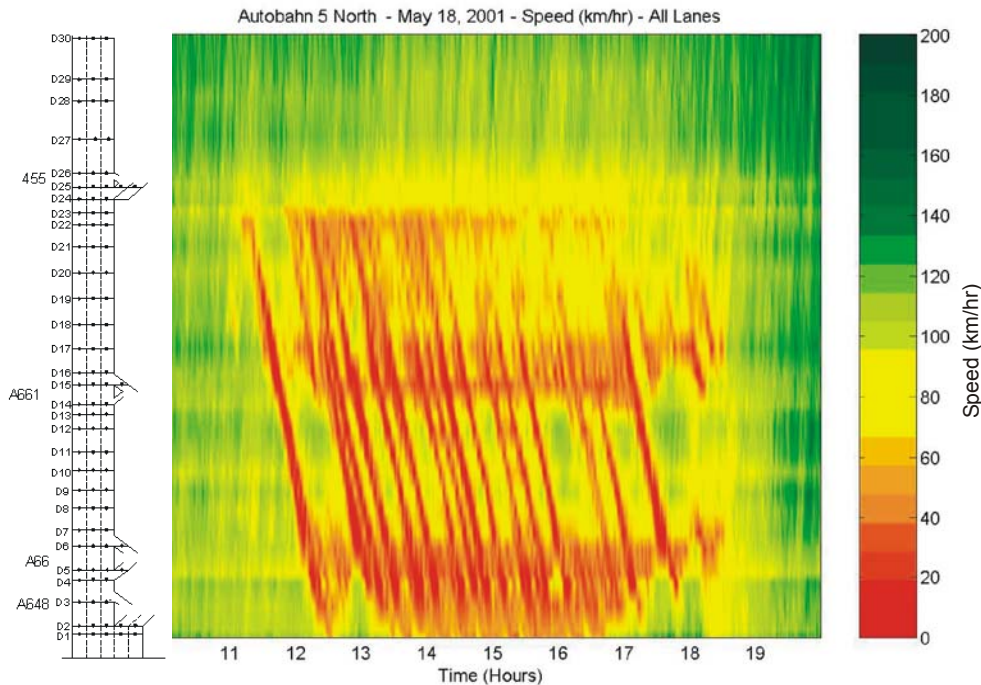


Figure 3 Speed Contour Plot, Autobahn A5, May 18, 2001

Further investigation of the suspected bottleneck was conducted using transformed cumulative plots known as oblique cumulative plots. A standard cumulative plot is the graph of a function  $\tilde{N}(t)$  with vehicle number ( $N$ ) on the  $y$ -axis versus time,  $t$  on the  $x$ -axis at which each vehicle passes a stationary point (Daganzo 1997). As shown in Figure 4(a), a cumulative count plot of vehicles is a step-function,  $\tilde{N}(t)$ , in this case with equal time steps, whereas a smooth function,  $N(t)$  is established by interpolating a line through the near-side top of each step. All cumulative count plots in this prospectus will be smooth function  $N(x,t)$ . When a smooth function is used, the instantaneous flow  $q(t)$  is first derivative of  $N(t)$  with respect to  $t$ .

Figure 4(b) presents hypothetical curves of  $N(x_i,t)$ , where  $N$  is the cumulative number of vehicles that pass a location  $x_i$  by time  $t$ . The time,  $t$ , is measured from the passage of a hypothetical reference vehicle,  $J$  and  $i=1,2$  (Newell 1982). The  $N(x,t)$  in Figure 4(b) were constructed for the same collection of vehicles. Imagine an observer at the upstream station  $x_1$  recording and cumulatively graphing the arrival times of vehicles as they pass his location, the result would be the curve  $N(x_1,t)$ . If the vehicles are assumed to pass through the system in a first-in-first-out (FIFO) order (e.g., no exit or entry points and no lane changing), the times when these same vehicles pass an observer at  $x_2$  could also be plotted cumulatively to create the curve  $N(x_2,t)$  (Bertini 1999, Windover 1998).

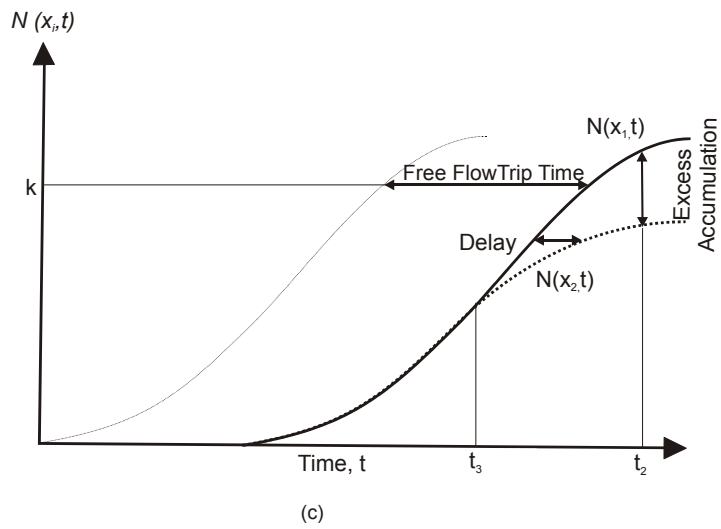
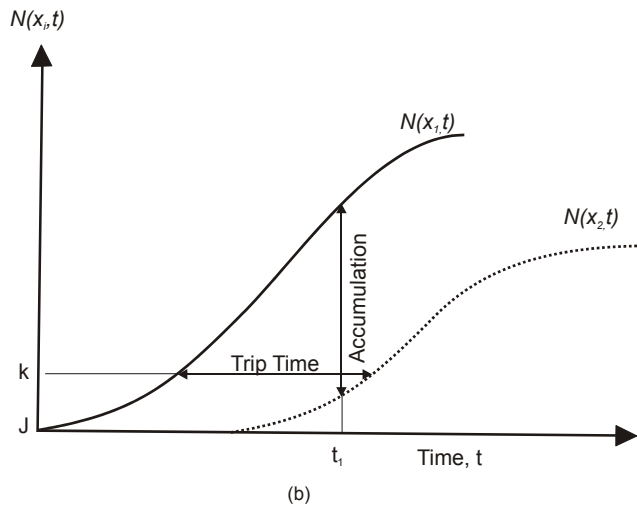
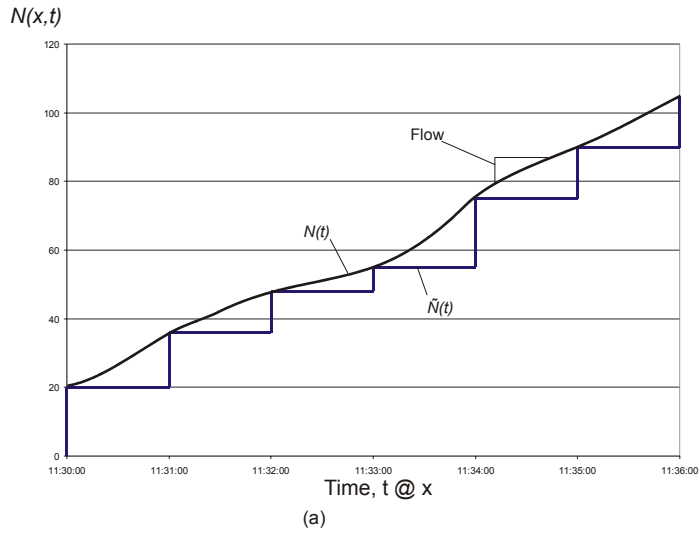


Figure 4 Sample construction of cumulative curve of vehicle counts (a), cumulative curves at adjacent stations (b), and shifted cumulative curves (c)

In analyzing Figure 4(b) some important parameters are revealed. The horizontal distance between the curves at  $N=k$  for example, is the  $k^{\text{th}}$  vehicle's trip time from  $x_1$  to  $x_2$ . The vertical distance between the curves at  $t=t_1$ , for example, is the number of vehicles accumulated between locations  $x_1$  and  $x_2$ .

Figure 4(c) shows the upstream curve,  $N(x_1, t)$  from Figure 4(b), shifted horizontally to the right by the measured  $x_1-x_2$  free flow trip time. The result is a shifted  $N(x, t)$ . Note that absent the queue, flow changes are passed downstream. The horizontal separation is the excess trip time, commonly called delay. The vertical distance between the curves is excess accumulation. At  $t=t_2$ , for example, the vertical distance is the number of vehicles accumulated between locations  $x_1$  and  $x_2$  less the accumulated vehicles that would be expected under free-flow conditions. Very small excess accumulations can be expected even under free flow conditions since vehicles' speeds will vary stochastically due to imperfect throttle control and interaction among vehicles. If the excess accumulation and delay are large enough, then a queue is present between  $x_1$  and  $x_2$ . Furthermore, the time at which the curves diverge, for example at  $t=t_3$  on Figure 4(c), is the time at which an upstream moving queue arrives at the upstream measurement location (assuming that the queue starts somewhere between measurement locations). Shifted  $N(x, t)$  allow delay and excess accumulations to be depicted graphically and additionally allow the time of the onset of queuing to be visually revealed.

Figure 5(a) shows shifted  $N(x, t)$  for detectors D21 and D22 of the northbound lanes of A5 north of Frankfurt on May 18, 2001. The vehicle counts were measured across all three travel lanes. The downstream curve,  $N(D21, t)$ , was shifted in the downstream direction by the free flow travel time between stations, resulting in two time scale axes.

While the idealized Figure 4(c) clearly revealed a change in traffic conditions, the large scale required to display  $N(x, t)$  for freeways with high numbers of vehicles results in the loss of ability to visually locate subtle but important features such as the precise time of the onset of queuing. Due to the y-axis scaling necessary to plot  $N(x, t)$ , the two  $N(x, t)$  of Figure 5(a) appear as nearly superimposed straight lines and little can be discerned with regards to queuing.

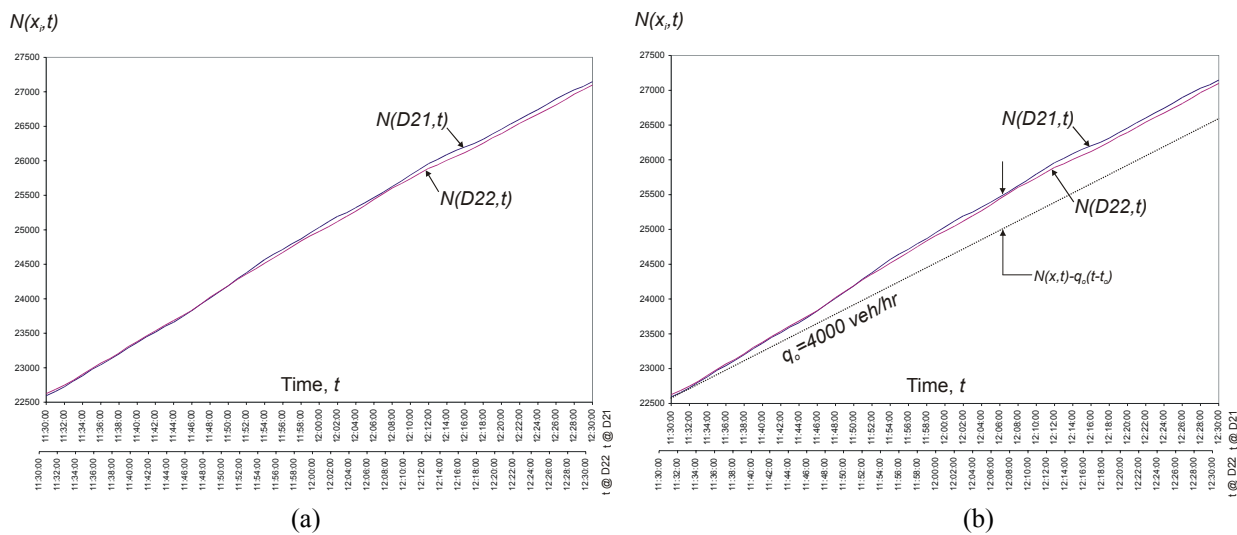


Figure 5 Shifted  $N(x, t)$  (a), and shifted  $N(x, t)$  with  $q_0$  (b), Autobahn A5, May 18, 2001

This scaling problem can be overcome by plotting  $N(x,t)$  on an oblique coordinate system, defined by two non-orthogonal families of individually labeled parallel lines as described in Muñoz and Daganzo (2002). Effectively, this involves a re-scaling of the  $y$ -axis created by subtracting a value  $q_o(t-t_o)$  from each ordinate, where  $t-t_o$  is the elapsed time from the passage of some reference vehicle and  $q_o$  is the so-called background flow (Bertini 1999).

Figure 5(b) shows the same shifted  $N(x,t)$  as those shown in Figure 5(a), added is a line with the slope  $q_o=4000$  vehicles per hour (vph). The optimal  $q_o$  value was chosen graphically by iteration to obtain the best visualization that magnified the traffic features of interest. The vertical difference between the line with slope  $q_o$  and each  $N(x,t)$  is  $N(x,t)-q_o(t-t_o)$ . These vertical differences,  $N(x,t)-q_o(t-t_o)$  were plotted as ordinates against an  $x$ -axis scale of time. Figure 6 shows oblique  $N(x,t)$  for detectors D21 and D22 with  $q_o = 4000$  vph. An oblique  $N(x,t)$ , with a properly chosen value of  $q_o$ , provides a plot with the fidelity required to identify the time-dependant features of the traffic stream. Since the ordinate  $N(x,t)-q_o(t-t_o)$  has units of vehicles and the  $x$ -axis is time, the slopes of oblique  $N(x,t)$ , like those of the  $N(x,t)$  depicted in Figure 4(a), have the dimension of vehicles/time or flow.

If a plot of  $N(x,t)$  had the same slope as the  $q_o$  curve, the oblique  $N(x,t)$  for the same period would have ordinates,  $N(x,t)-q_o(t-t_o)$  of zero and therefore plot as a horizontal line of zero slope. Therefore, an oblique  $N(x,t)$  exhibits a negative slope when the prevailing flow is less than  $q_o$ . Positive and negative slopes of an oblique  $N(x,t)$  can be interpreted visually as flows greater than or less than, respectively,  $q_o$ .

Figure 6 shows oblique  $N(x,t)$  as thick colored lines for detectors D21 and D22. The thin dark lines denote long run average flows. The flows on each line are labeled in units of vehicles per hour (vph). Downward pointing vertical arrows denote times at which long run flow changes occurred at detector D21. These piecewise linear approximations were made by eye with the maximum deviation from the straight line being approximately 20 vehicles. Freely flowing

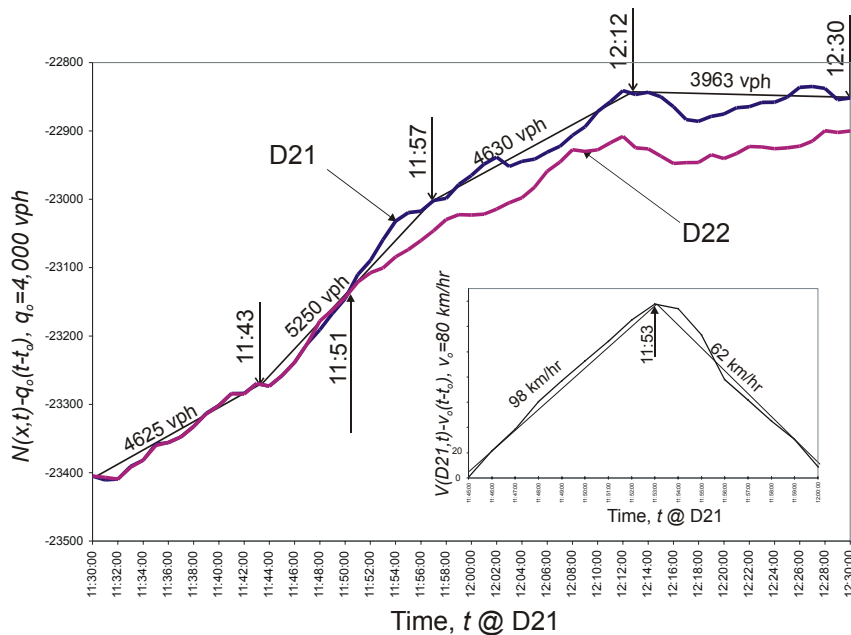


Figure 6 Oblique  $N(x,t)$ , D21 and D22, Autobahn A5, May 18, 2001

traffic between detectors D21 and D22 is evidenced by the fact that from 11:30 to approximately 11:51, the curves are essentially superimposed and all flow changes during this time pass downstream. The vertical displacement between the curves beginning at approximately 11:51 (as shown by the upward pointing vertical arrow) indicates an excess accumulation of vehicles between these stations and therefore the presence of vehicular delays.

Curves of cumulative time-averaged velocity versus time were also used in these investigations to verify the features revealed by the oblique  $N(x,t)$ . Oblique  $V(x,t)$  are plots of  $V(x,t) - V_o(t-t_o)$  versus time,  $t$ . The  $V(x,t)$  ordinate is established by plotting cumulatively the time-averaged velocity for each averaging period (i.e., 1 minute in the case of this A5 data). The  $V(x,t)$  values nominally have the dimension of velocity since they represent a cumulative total of velocity values. However, the  $V(x,t)$  values will increase at a rate that is inversely proportional to the duration of the averaging period. For example, if the averaging period were one hour, the cumulative total would simply equal the average speed over this hour; yet if the averaging period were one minute, the average hourly velocity would be obtained by multiplying the cumulative total by 1/60 hour. Thus the  $V(x,t)$  values have the dimensions of speed  $\times$  time, which is distance. With a construction process similar to that used for oblique  $N(x,t)$ , the  $V(x,t)$  values are then plotted on an oblique axis by subtracting a value  $V_o(t-t_o)$  from each value, where  $t-t_o$  is the elapsed time from the passage of a reference vehicle and  $V_o$  is the background average velocity. The value  $V_o$  is graphically represented as the slope of an arbitrary line drawn on a cumulative velocity plot. The value  $V_o$ , being the slope of a cumulative time-averaged speed versus time curve, therefore has the dimensions of distance/time or velocity.

The inset to Figure 6 shows an oblique  $V(x,t)$  over the time interval 11:45 to 12:00 for detector D21. The  $V_o$  value for this plot is 80 km/hr. The thick black line is the oblique  $V(x,t)$  for detector D21. The thin dark lines denote long run average speeds. The speeds on each line are labeled in units of kilometers per hour (km/h). Upward pointing vertical arrows denote times at which long run speed changes occurred.

If a plot of  $V(x,t)$  had the same slope as  $V_o$ , the oblique  $V(x,t)$  for the same period would have ordinates,  $V(x,t) - V_o(t-t_o)$  of zero and therefore plot as a horizontal line of zero slope. Therefore, an oblique  $V(x,t)$  exhibits a negative slope when the prevailing speed is less than  $V_o$ . Positive and negative slopes of an oblique  $V(x,t)$  can be interpreted visually as speeds greater than or less than, respectively,  $V_o$ .

Further examination of the inset to Figure 6 reveals that at detector D21 a substantial change in long run velocity occurred at approximately 11:53, with an abrupt drop in velocity from 98 km/hr to 62 km/hr. The oblique  $N(x,t)$  of Figure 6 shows the presence of a queue beginning at approximately 11:51. The delay between the onset of queuing at some point between detectors D21 and D22 and the drop in velocity at detector D21 are consistent with a backward moving queue arriving at detector D21. Next, oblique  $N(x,t)$  constructed for stations upstream and downstream of detectors D21 and D22 will be examined to further expand upon the traffic features revealed thus far.

Figure 7 shows oblique  $N(x,t)$  for all lanes of traffic for detectors D17 through D23, each curve has been transformed by the technique described earlier and with the same value of  $q_o$ . Note that for this day, detectors at station D20 were malfunctioning and were removed from all analyses. Each oblique  $N(x,t)$  was shifted by the free flow travel time observed from detector D17.

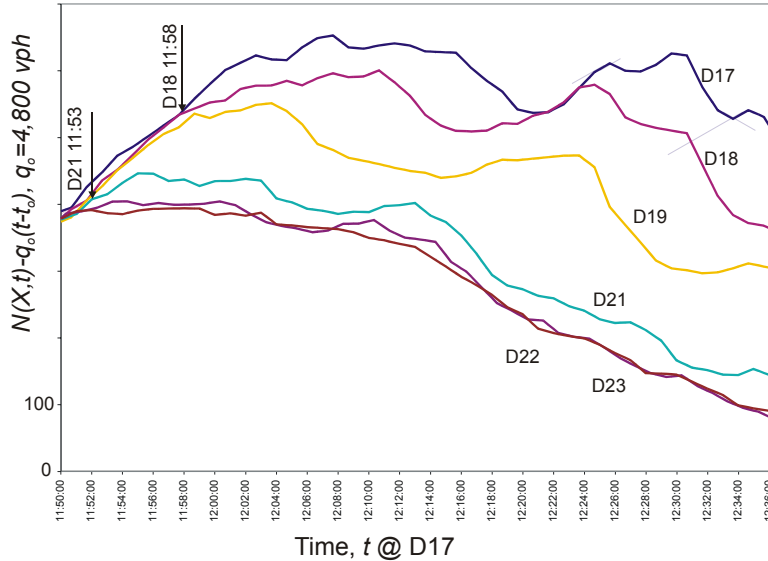


Figure 7 Oblique  $N(x,t)$ , D17-D23, Autobahn A5, May, 18, 2001

Oblique  $N(x,t)$  for all stations were initially superimposed indicating freely flowing traffic throughout the entire freeway section. The oblique  $N(x,t)$  for detectors D22 and D23 remain nearly superimposed throughout the entire time period shown, indicating that traffic remained freely flowing between these stations. Substantial vehicle accumulation is visible between detectors D21 and D22 as a result of flow reductions which were seen at detectors D22 and D23 starting at approximately 11:51 as evidenced by both Figures 6 and 7.

The presence of freely flowing traffic between detectors D22 and D23, indicated by the near-superimposition of the oblique  $N(x,t)$  for these stations, accompanied by the excess accumulation of vehicles upstream of detector D22 reveals that a bottleneck was located somewhere between detectors D21 and D22.

Figure 7 also traces the spread of the queue upstream beyond detector D21. As shown in the figure, curves for detectors D17 - D21 remained essentially superimposed for a short period following the flow reduction at detectors D22 and D23. At approximately 11:53 the curve for detector D21 diverges indicating the arrival of a backward moving queue at detector D21. Further diverges are shown until the queue arrives at detector D18 at approximately 11:58.

Figure 8 shows oblique  $N(x,t)$  for detectors D17 and D23 for a time period from late-morning to early evening. The two curves are essentially superimposed at the start and end of this time scale, indicating that vehicles are freely flowing. The full period over which the bottleneck remained active is clearly shown by the excess accumulations that begin at approximately 11:50 and persist until approximately 20:09.

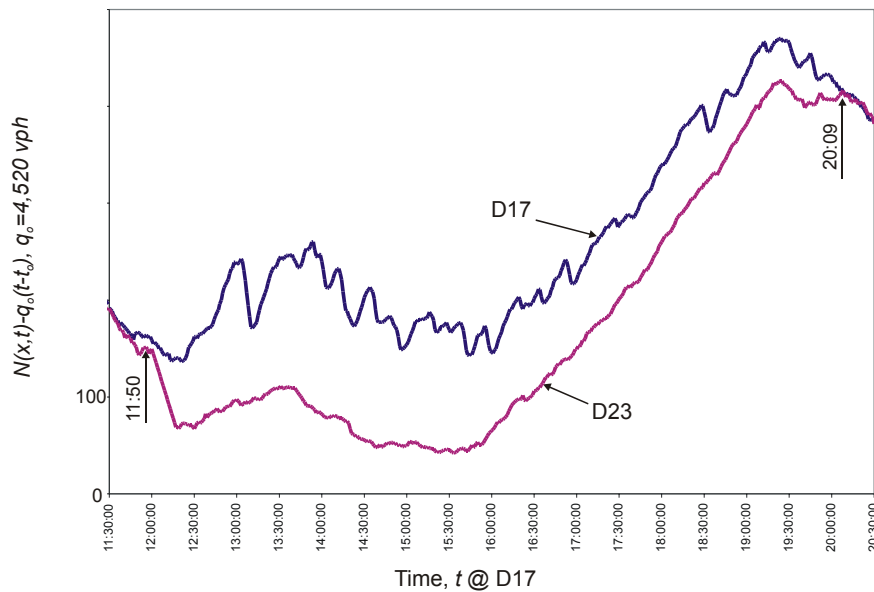


Figure 8 Oblique  $N(x,t)$ , D17 and D23, Autobahn A5, May 18, 2001

Figures 6, 7, and 8 have verified the bottleneck's location, the time it became active and the time that it was deactivated. Now it is possible to examine the active bottleneck's features. An oblique  $N(x,t)$  constructed from D22 data is shown in Figure 9, this detector is downstream from the bottleneck. Figure 9 shows that between about 10:50 and 12:09 (the beginning of queue discharge) a flow of 4,723 vph was measured. Upon queue discharge, a long run average flow of 4,166 vph persisted for about one hour. This figure confirms that queue discharge was accompanied by a drop in flow of approximately 11.8%. This value is consistent with the findings from some researchers (Bertini 1999, Bertini, Leal & Lindgren 2003). Other researchers (Kerner 2000) have found this flow drop to vary.

This section of the prospectus has shown that methodologies exist for the systematic examination of the spatial-temporal features of congested traffic. The next section outlines the proposed research plan.

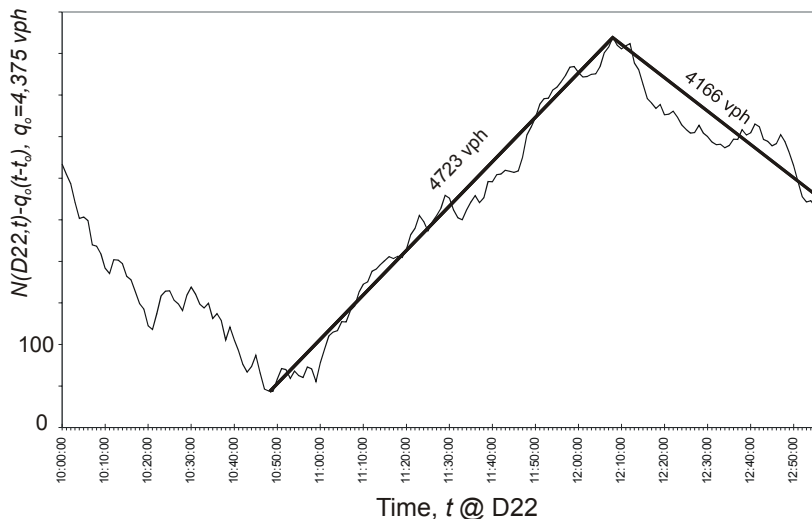


Figure 9 Oblique  $N(x, t)$ , D22, Autobahn A5, May 18, 2001

## 5 RESEARCH PLAN

This section presents the proposed research plan. Section 5.1 describes the data, Section 5.2 outlines the proposed research tasks, and Section 5.3 presents a time schedule for the research.

### 5.1 Data

The study site is a thirty kilometer section of the northbound lanes of Autobahn 5 (A5) near Frankfurt am Main, Germany (see Figure 2). Data from six weekdays have been collected for this site and more archived data is available through a research partnership with the Technical University of Dresden. This research will focus on an eight kilometer section of A5 from detectors D17 to D25 as shown in Figure 2.

### 5.2 Research Tasks

The following tasks will be completed:

#### Task 1: Literature Review

A review of the recent and relevant literature relating to empirical analysis of traffic dynamics will be conducted—much of this literature is limited to ten or fewer authors. In particular, recent studies of German freeways by Kerner (Kerner 1999, 2000, 2002) will be carefully reviewed, with the specific goal of extracting particular claims that have not been corroborated due to the lack of access to the German data. A list of these claims and theoretical pronouncements will be documented and reviewed by the dissertation advisor early in the research process.

#### ***Deliverables***

- An annotated bibliography of key related works.
- A list of a limited number of claims eligible for potential validation or critique based on the newly available data.

### Task 2: Data Preparation

In this task, the archived loop detector data will be organized, cleaned, and analyzed to prepare basic performance measures (flows and speeds) for each detector location, including mainline lane-by-lane analysis and on-ramp and off-ramp analysis.

#### ***Deliverables***

- Speed contour plots will be constructed for each day to be analyzed.
- Time series speed plots will be constructed for each detector location.
- Cumulative count plots will be prepared for each detector station (sum of all lanes) and each individual lane and ramp.

### Task 3: Preliminary Data Analysis

This task, described in fourth section of this prospectus, began with the application of oblique cumulative curve methodology to one day's data consisting of an eight kilometer section of A5. The research product will be a series of plots and accompanying text fully describing one day's data on this freeway section.

#### ***Deliverables***

- A comprehensive description of the evolution of traffic flow during one day for this eight kilometer data set. This will include explicitly documenting bottleneck locations, activation times and deactivation times and definitively tracing and documenting the propagation and dissipation of their queues.
- Figures and a narrative describing discharge flows related to active bottlenecks.
- A narrative on causes that can be attributed to bottleneck activation (e.g., lane changing, high truck flow, high on-ramp flow, geometric conditions, incident or off-ramp backing up onto freeway). This will likely include the comparison of oblique  $N(x,t)$  constructed from single lane data at stations proximate to the location of queue formation in order to assess the extent of lane-changing influences on bottleneck formation. Temporal changes in flow and speed measured at detectors on off-ramps and on-ramps will be studied to determine if changes are related to bottleneck activation.
- Analyses of truck flow and auto flow during time periods preceding, during, and after bottleneck formation to determine the influence that vehicle type had on queue formation.
- A narrative describing shock wave propagation as shown on oblique  $N(x,t)$  constructed from data from several stations upstream of the location of bottleneck formation.

### Task 4: Final Data Analysis

This task will continue the analyses begun in Task 3 using data from other days on the same site in order to confirm whether the preliminary findings are reproducible. The same analysis methods of Task 3 will be followed, though they may be less detailed.

#### ***Deliverables***

- A tabular summary of the features that are found to be reproducible particularly in the context of the major “controversial” issues identified in Task 1. This will likely include such parameters as bottleneck location, discharge flow, shock speed, wave speed and a determination of whether observed traffic characteristics corroborate the findings of other research on German freeways. Particular emphasis will be placed upon definitively

identifying the bottleneck's location and activation/deactivation times, so that the mistakes of previous researchers are not repeated.

- A narrative on how the traffic characteristics of this German freeway compare with the collection of empirical evidence contained in Daganzo's behavioral description of multi-lane traffic flow. (Daganzo 1999a, 1999b) This will include a detailed listing of empirical evidence accumulated over the past fifty years.

### Task 5: Final Report

#### ***Deliverable***

- The final report meeting the criteria established by Portland State University will be compiled from the research products described above. Throughout the research, figures and accompanying text will be prepared in as flexible a format as possible to allow for easy incorporation into final documentation. It is expected that during this research phase, several conference/journal publications will be prepared; so many aspects of the research will be documented as the work progresses.

### **5.3 Research Schedule**

<b>MONTH</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>
Literature Review												
Data Preparation												
Prelim. Data Analyses												
Final Data Analyses												
Final Report												

## **6 CONCLUDING REMARKS**

The proposed study is aimed at a greater understanding of freeway bottlenecks and to detail and describe their reproducible features. It is hoped that this understanding will lead to more efficient freeway management strategies. The proposed work will complement recent research by Windover (1998), Bertini (1999), Mauch & Cassidy (2002). In summary, the proposed research plan, along with available data, describe a project that can be accomplished in a reasonable time period and should lead to notable traffic flow theory findings.

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