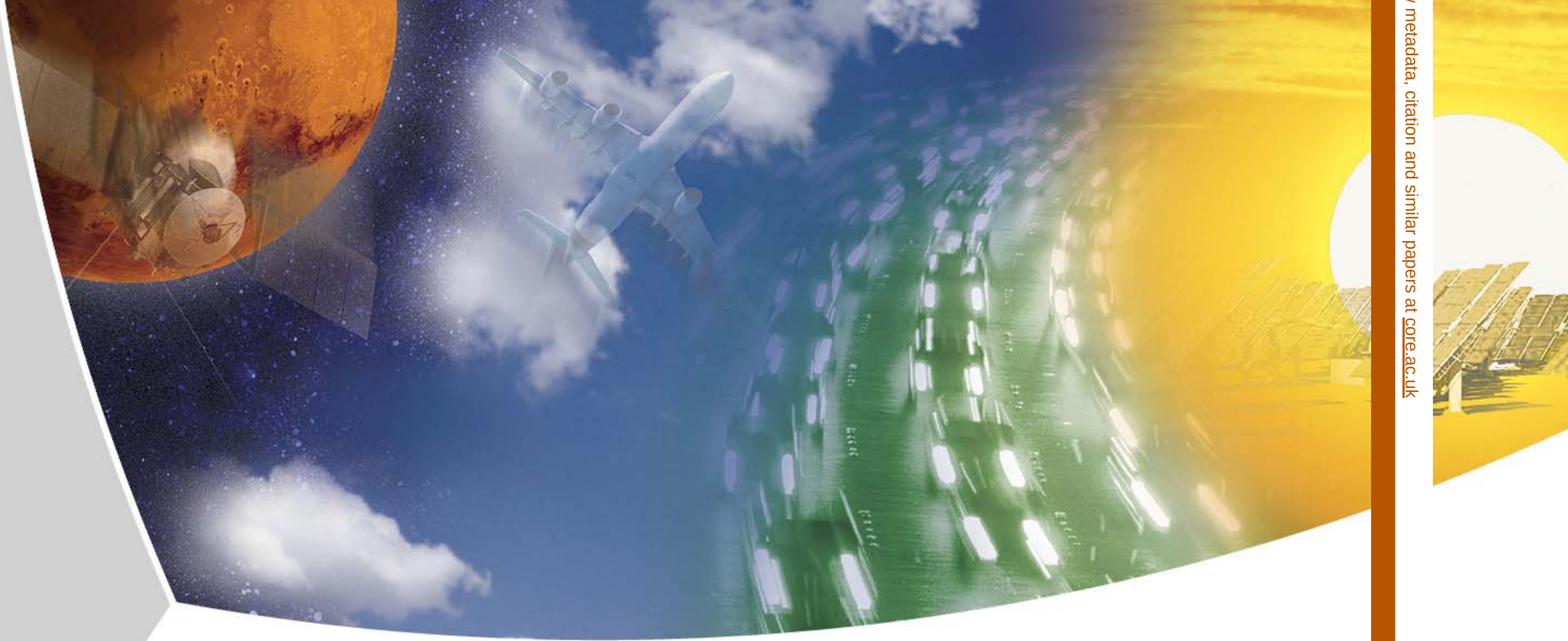
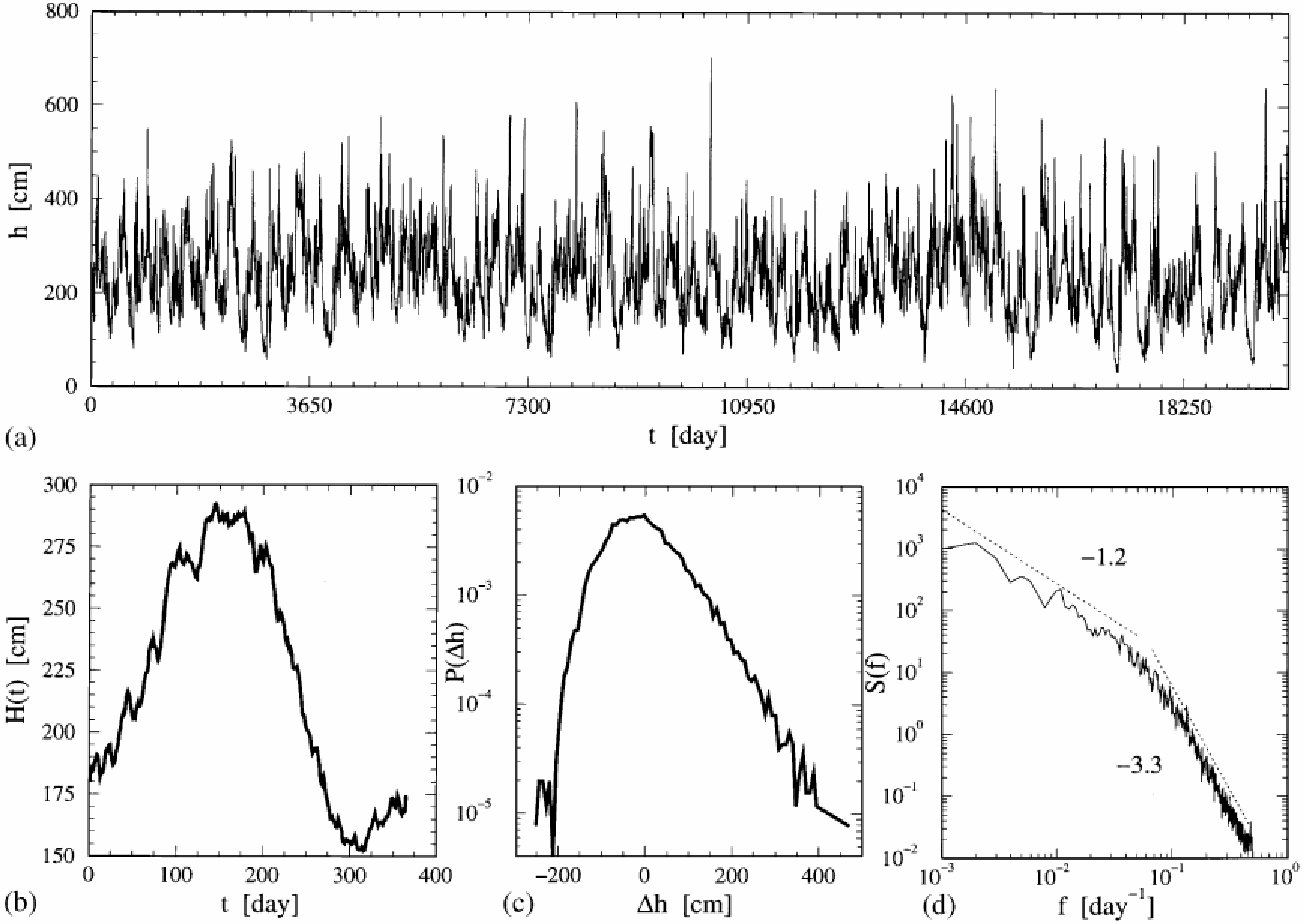


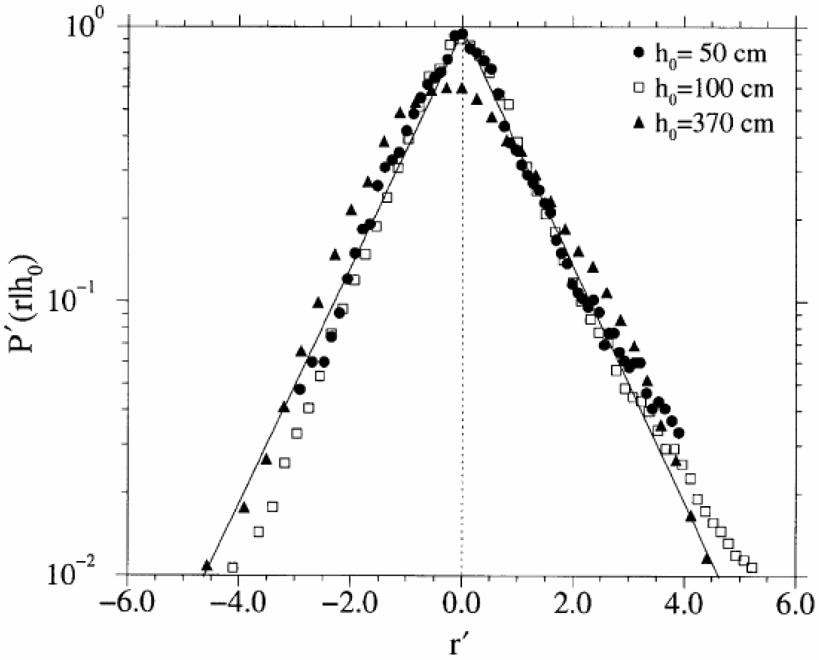
Statistics of Extremes, traffic jams and natural disasters

Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft



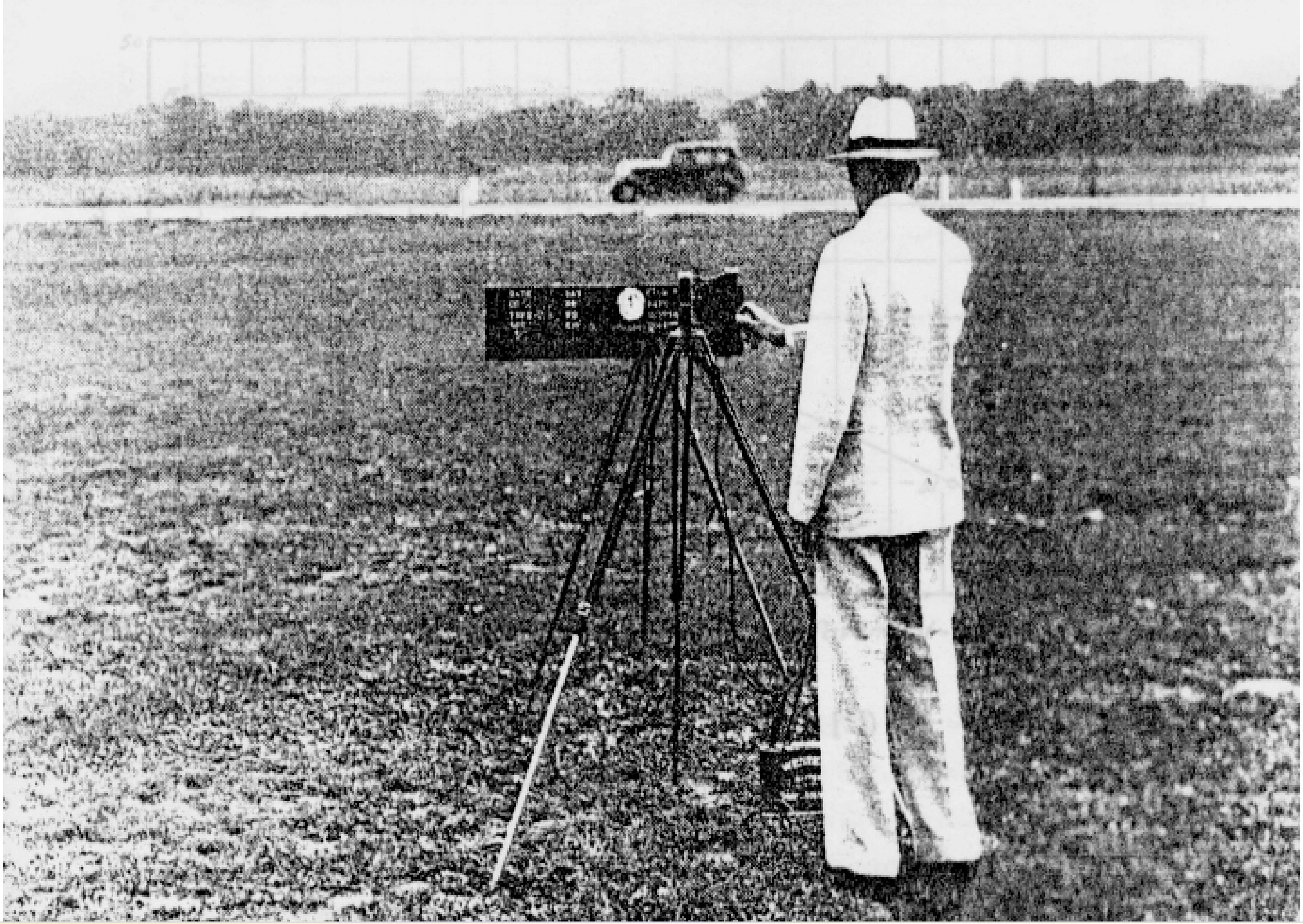
(a) 20 000 data of daily water level of the river Danube, measured at Nagymaros from 1st of January 1901 [7]. (b) Seasonality of the average daily water for one year [see Eq. (1)]. (c) Probability density distribution P(h) of the water level ucuations h [see Eq. (2)]. Note that the vertical scale is logarithmic. (d) Power spectrum of the detrended time series obtained by the standard FFT method. Dotted lines show two scaling regimes, at low frequencies (f<0:05 day−1) the characteristic exponent is 1:20:1, at large frequencies (f>0:1 day−1) the exponent value is 3:3 0:1.

Quelle: Imre M. Janosia; Jason A.C. Gallas: Growth of companies and water-level ucuations of the river Danube; Physica A 271 (1999) 448-457



Rescaled probability density distribution P0=p2(h0)P(rjh0) as a function of the rescaled logarithmic rate of change r0 = p2[r − r(h0)]=(h0) for the data shown in Fig. 2a. The data approximately collapse upon the universal curve Eq. (5) (thin solid line).

Quelle: Imre M. Janosia; Jason A.C. Gallas: Growth of companies and water-level uctuations of the river Danube; Physica A 271 (1999) 448-457



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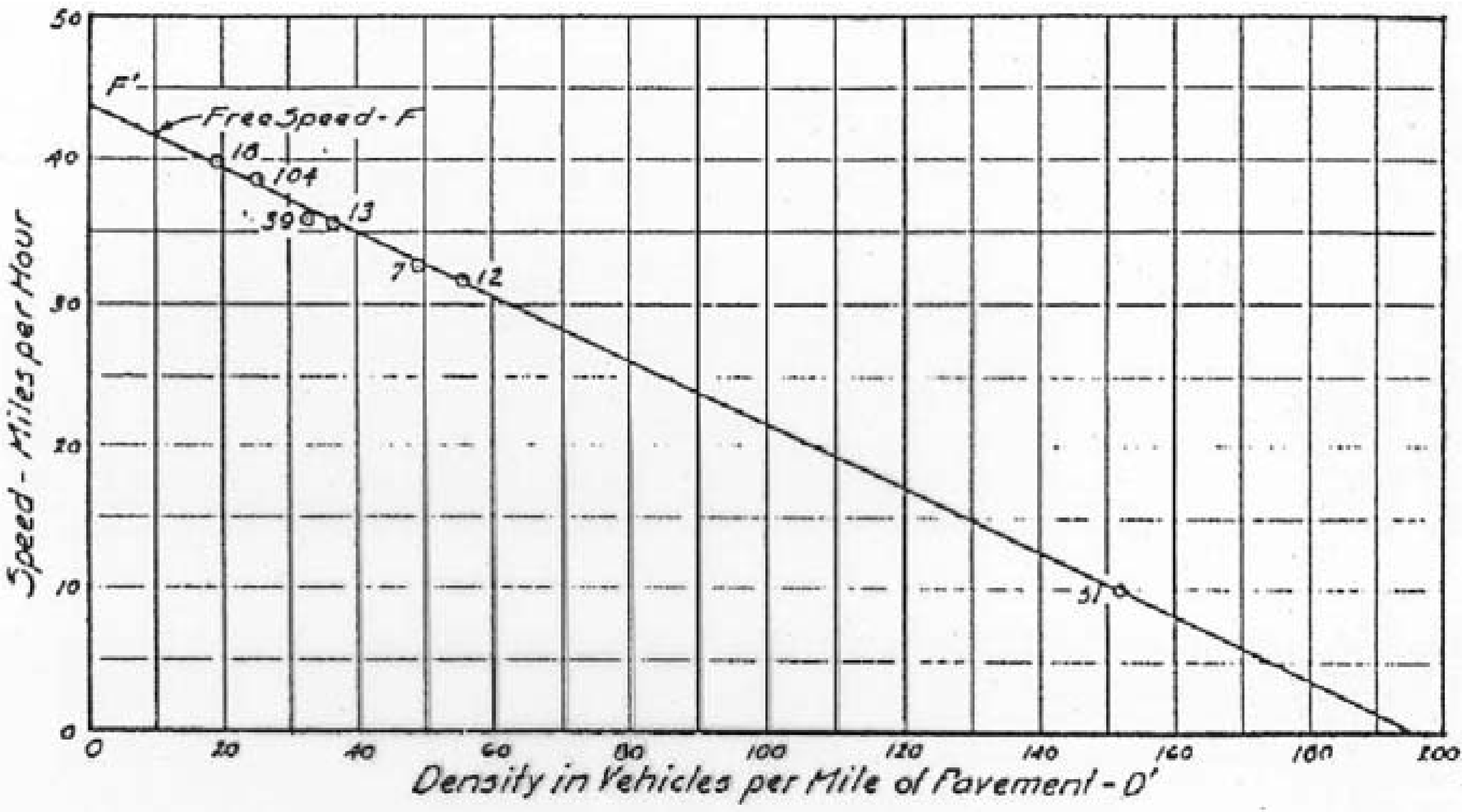
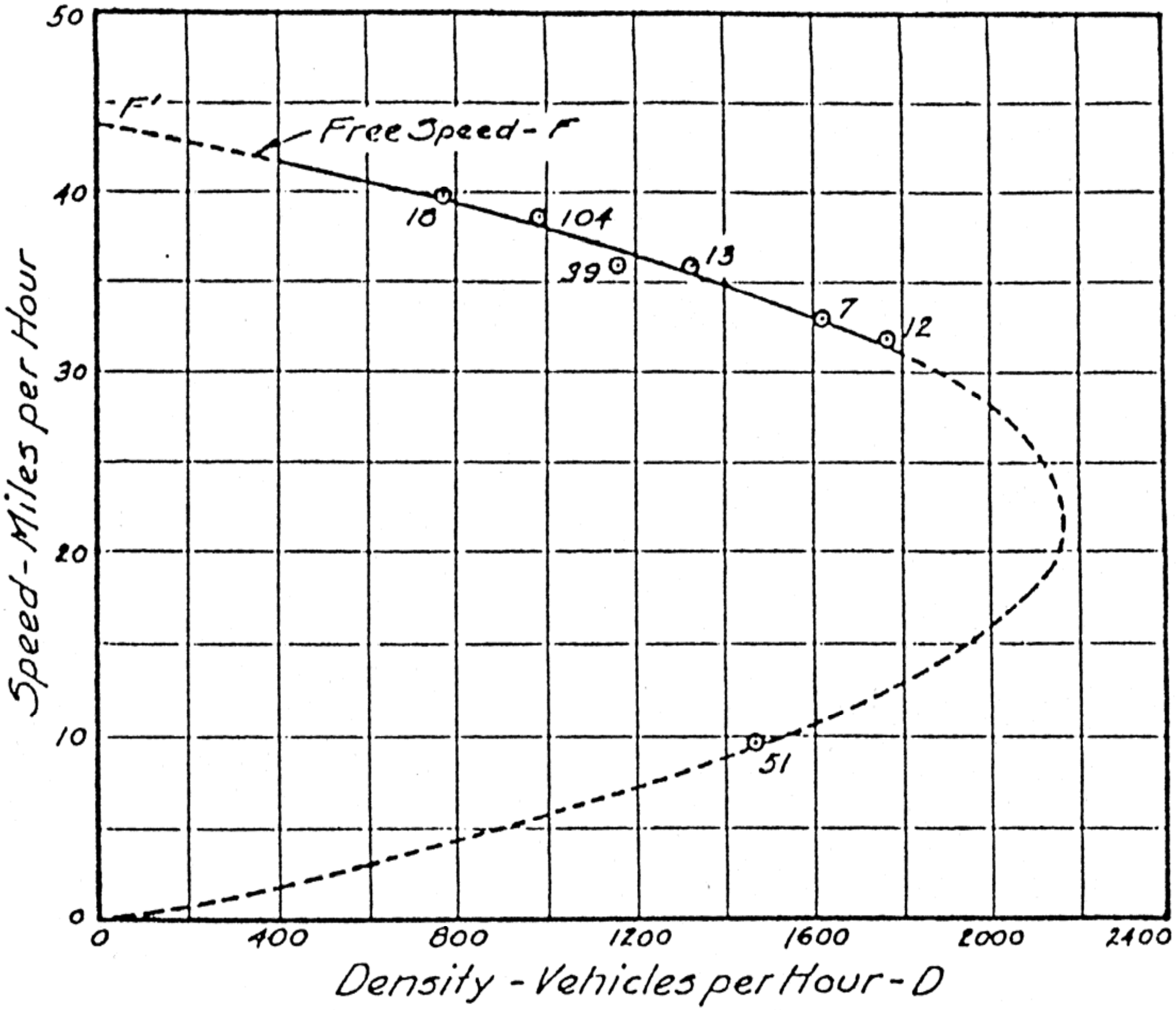
LEHRSTUHL VERKEHRSPLANUNG UND VERKEHRSLEITTECHNIK (VuV)

First Measurements to fundamental diagrams by Greenshields (1934)

Speed Density Relation V (ρ)





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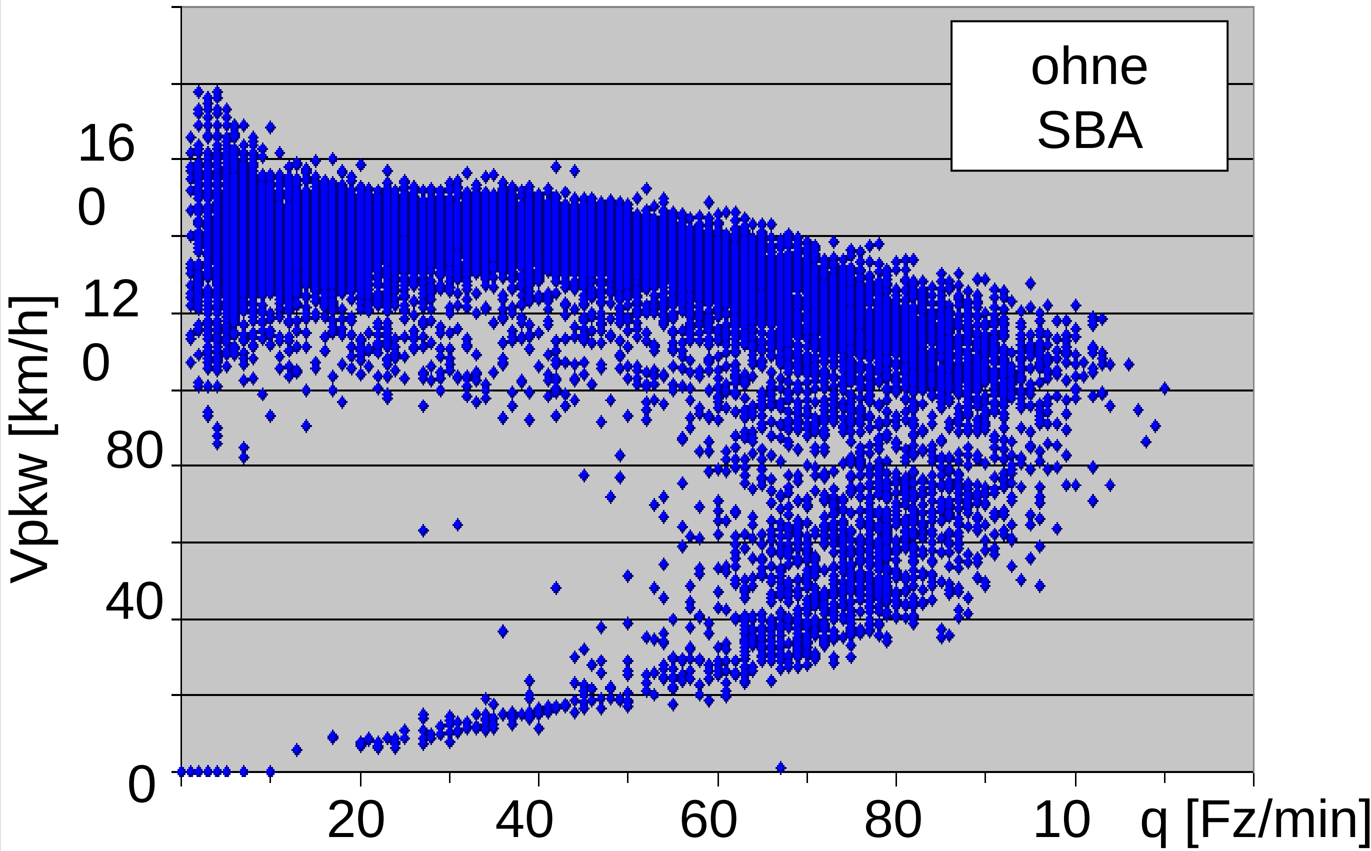
The first Fundamental Diagram

q - v Diagram from 5 minutes interval

[A9 München – Holledau, Zeitraum 27.07.-09.08.2000, i.l. 20160 measurement values]



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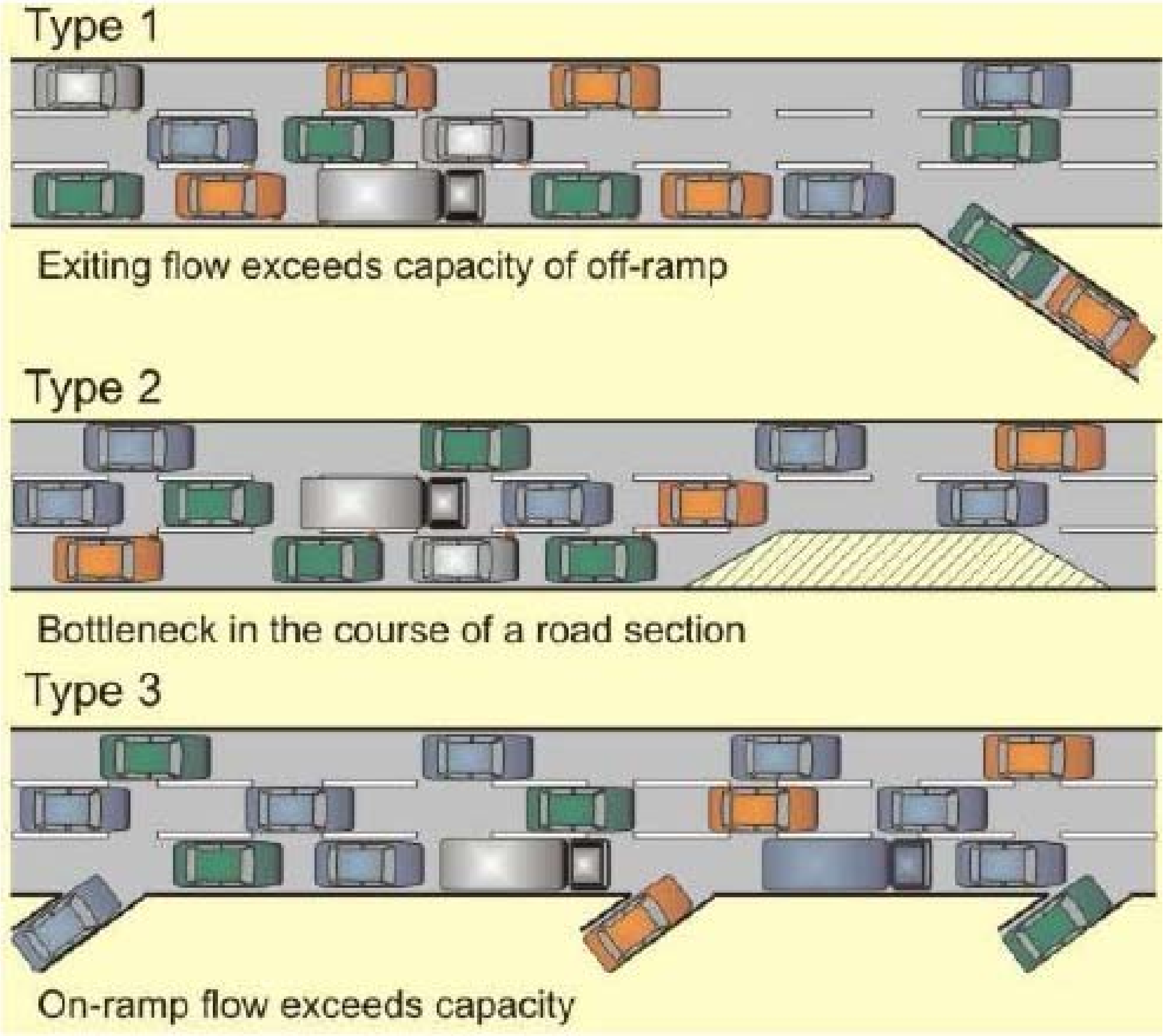
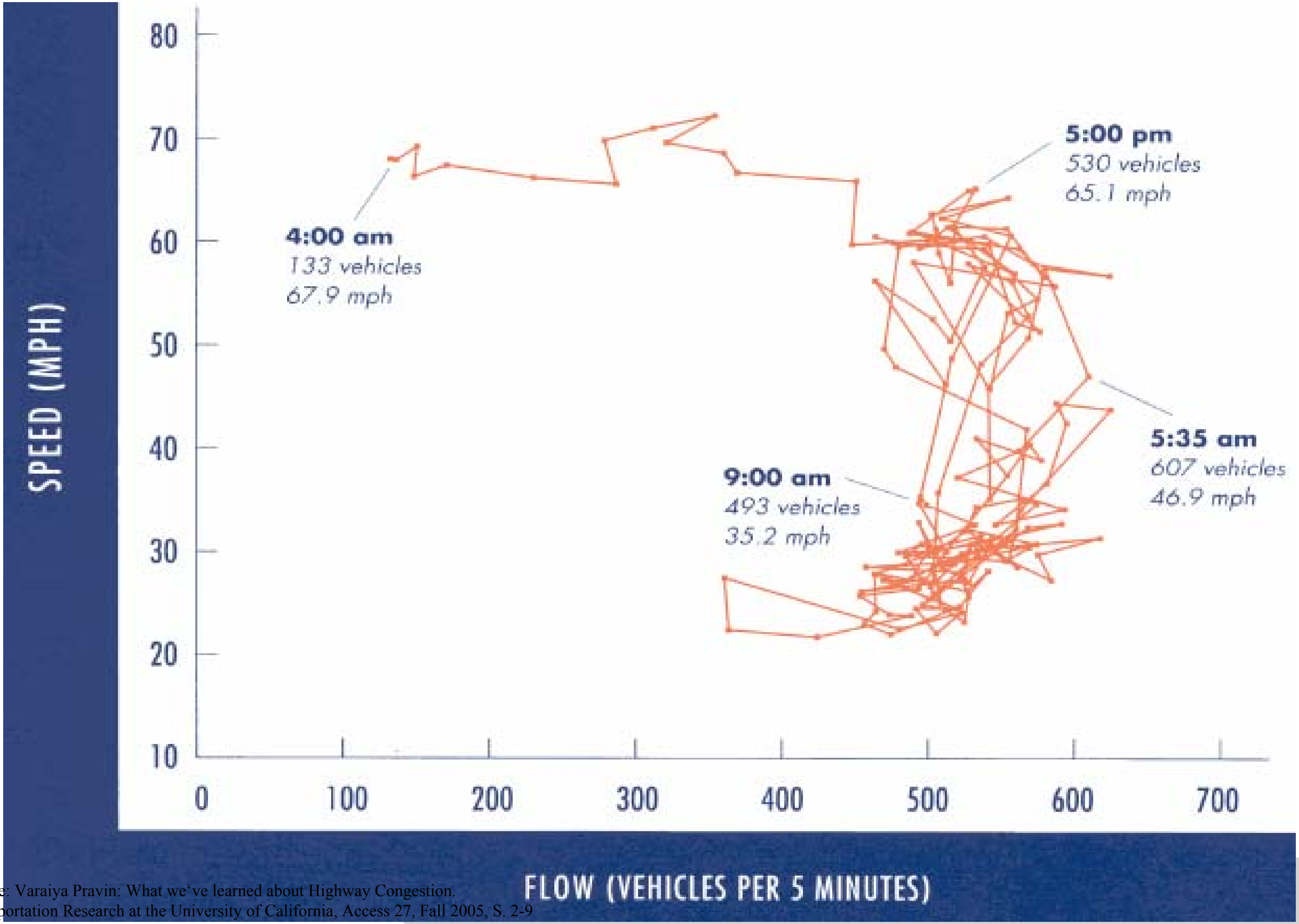
Typical bottleneck situations



Source: R. Kühne, R. Mahnke, J. Hinkel: Modelling the Effects of Corridor Control Systems on Road Capacity; ISHC Yokohama Juli 2006

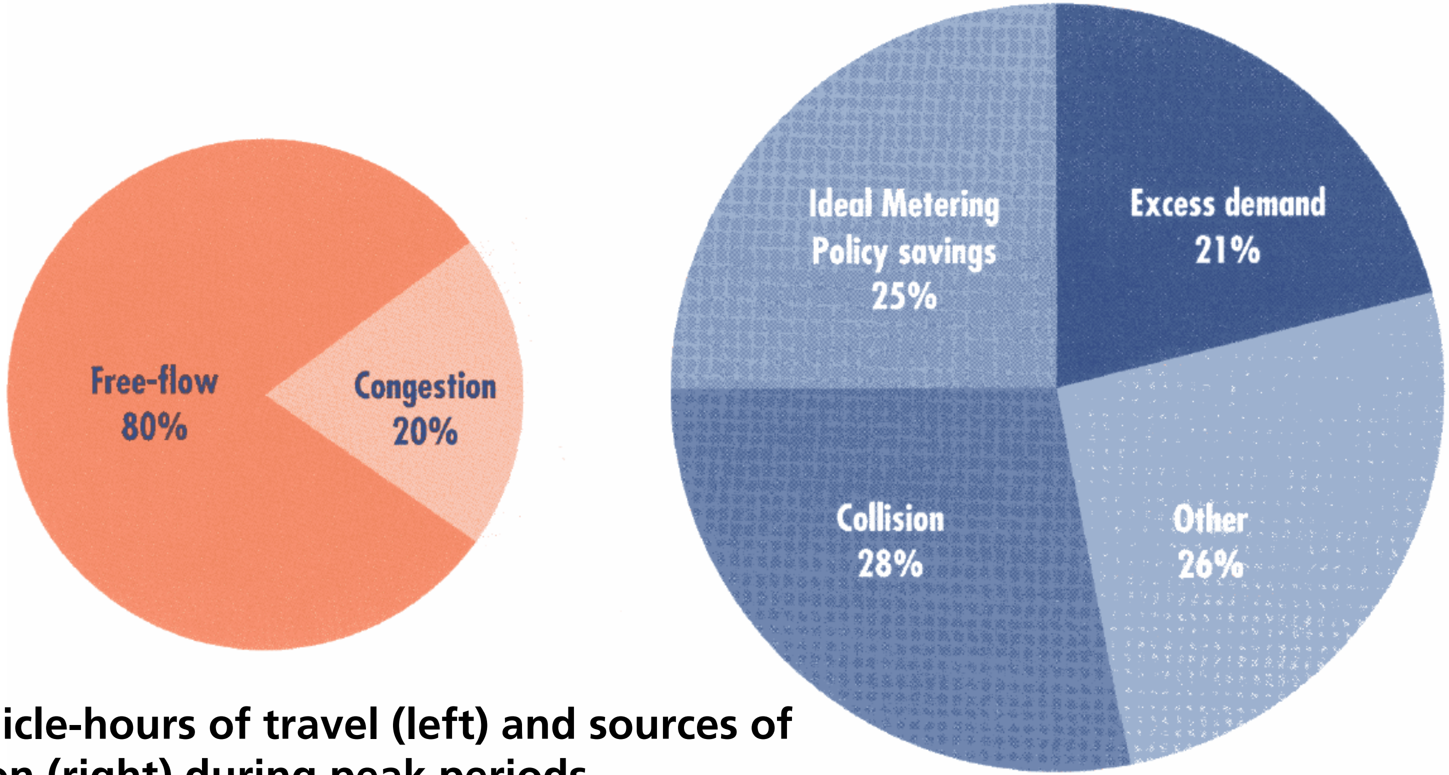
Speed vs. Flow on I-10 westbound in 5 minute intervals from 4am to 6pm



Source: Varaiya Pravin: What we've learned about Highway Congestion.
Transportation Research at the University of California, Access 27, Fall 2005, S. 2-9

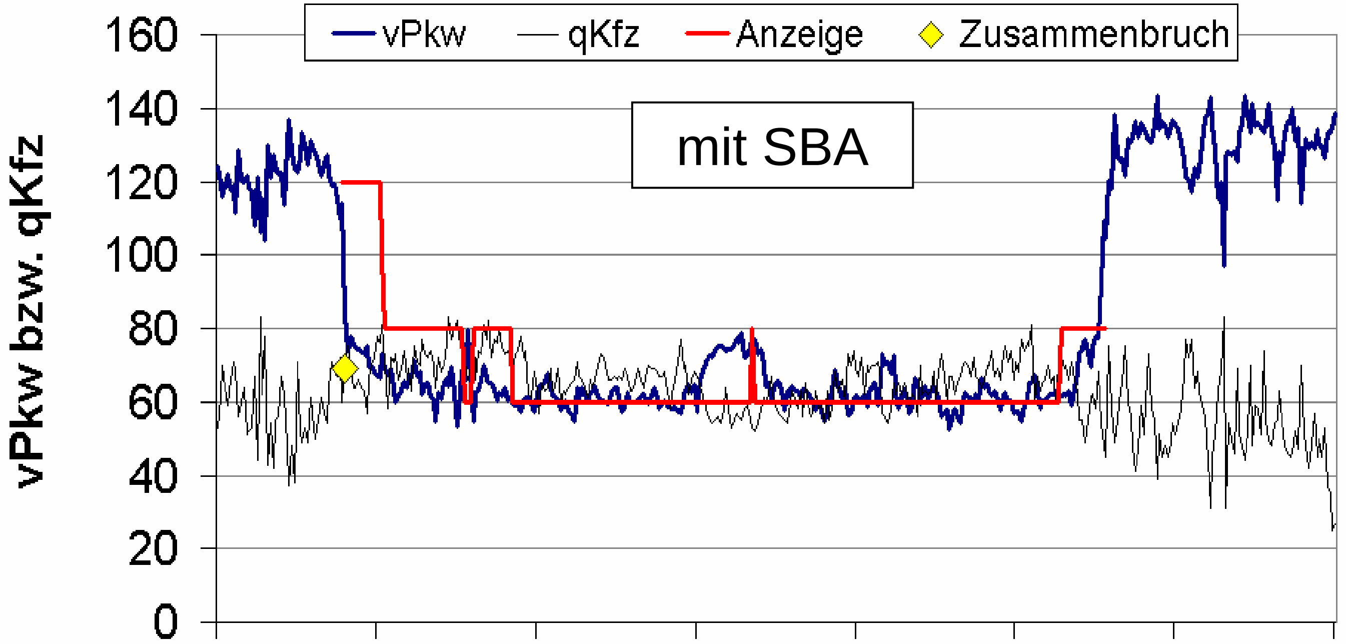
Results from Performance Monitoring System on Californias Highways (data from 26000 sensors)

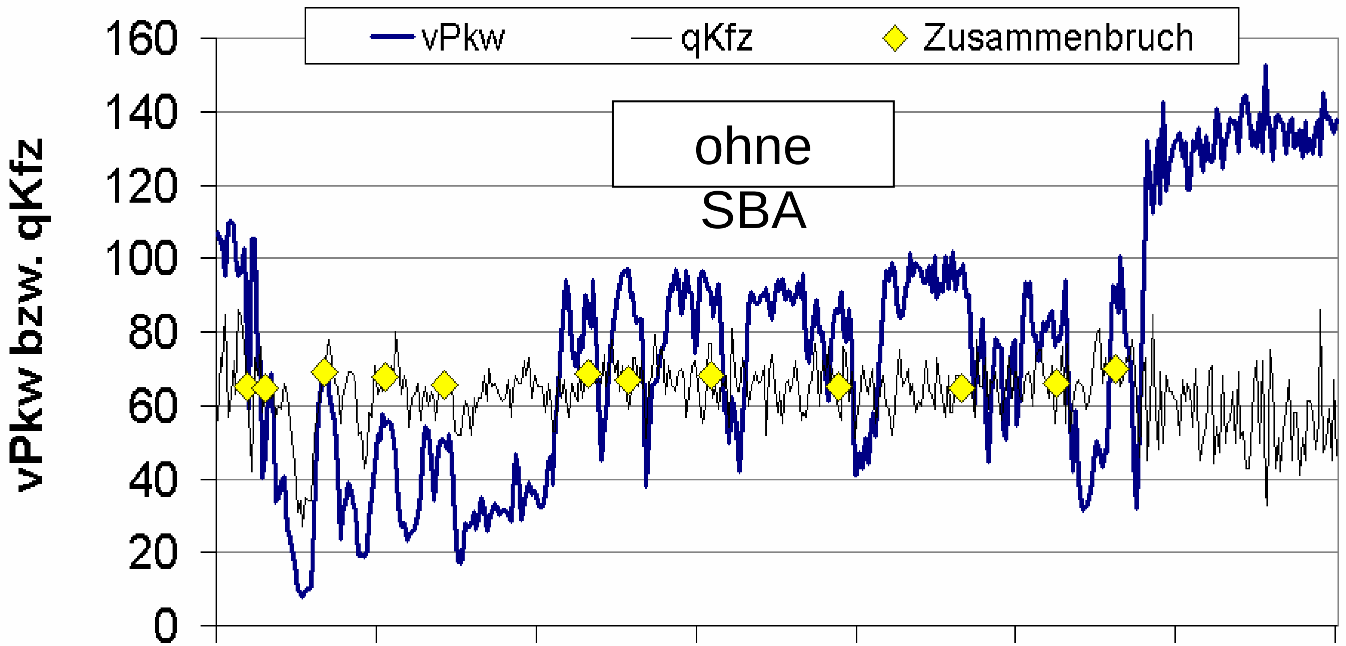
- 600 recurrent bottlenecks = 50% of weekday peak delays,
- 28% additionally peak-period congestion delay is caused by collisions,
- 10% of it accounting for 90% of all collision-induced delay



Total vehicle-hours of travel (left) and sources of congestion (right) during peak periods

Demonstration of two 5 - h - periods on two cross sections of the A9 München - Holledau





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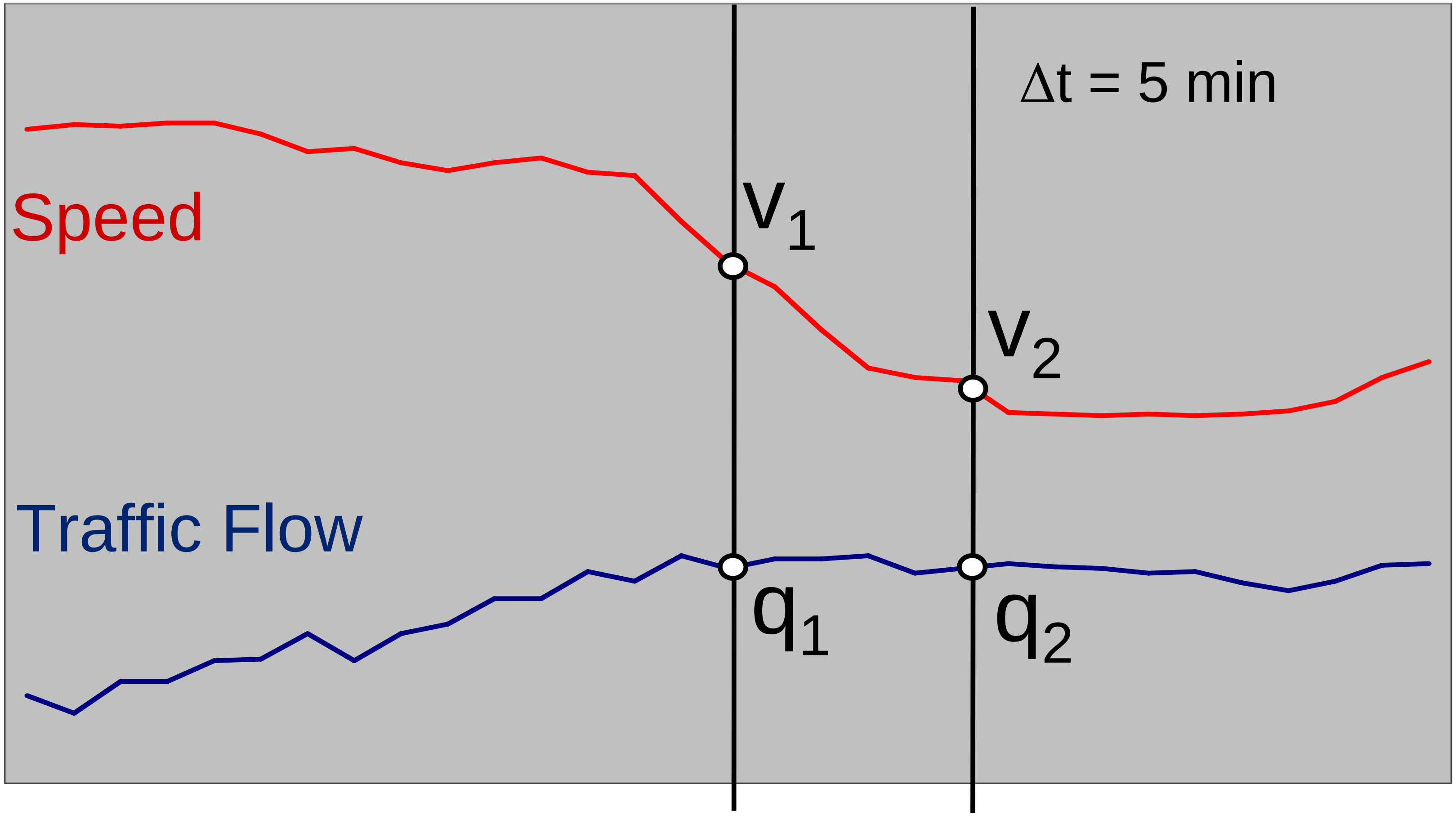
Definition of Traffic Breakdown



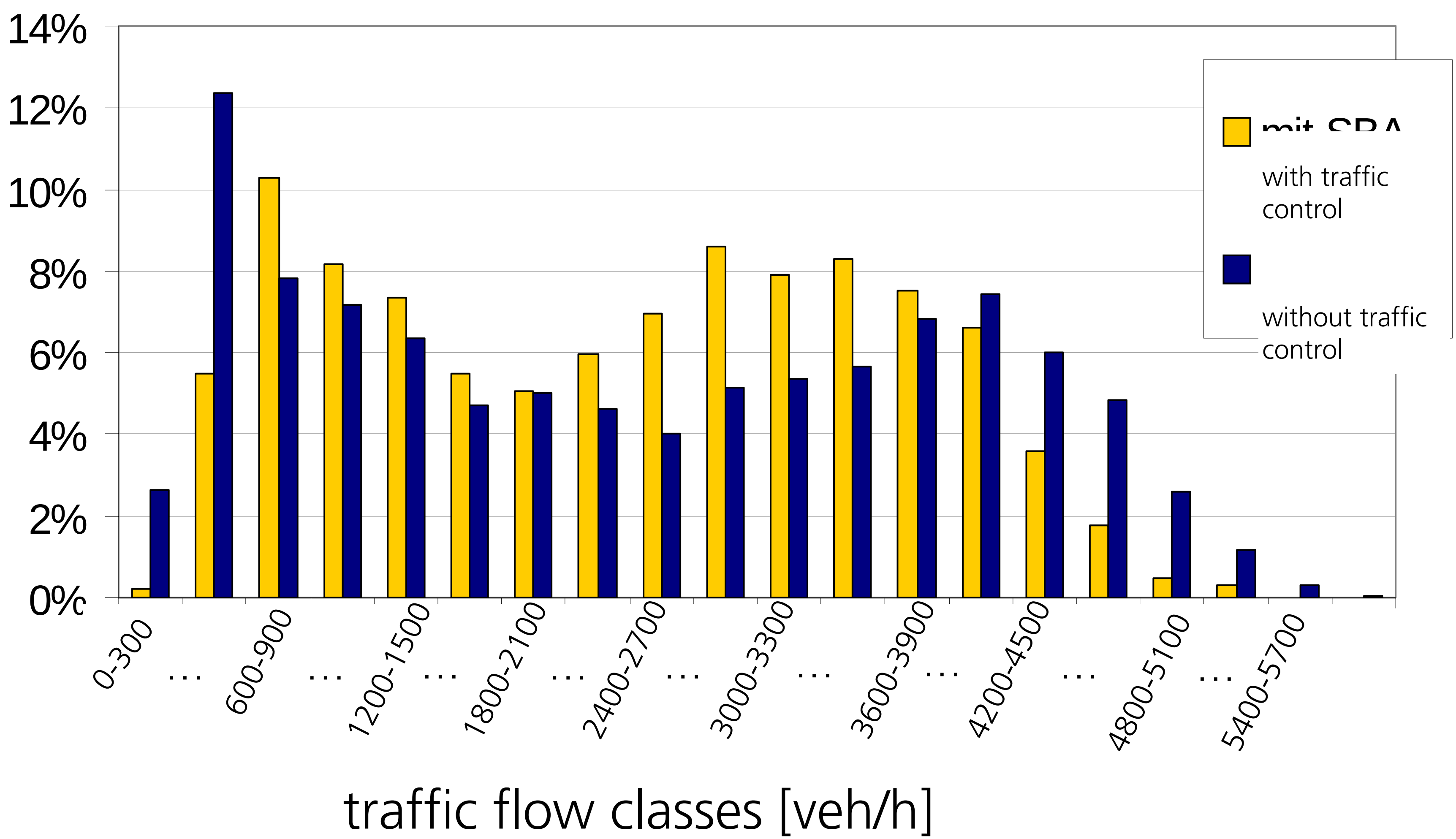
1) speed drop: $\Delta v > 15$ km/h

2) speed after drop: $v_2 < 75$ km/h

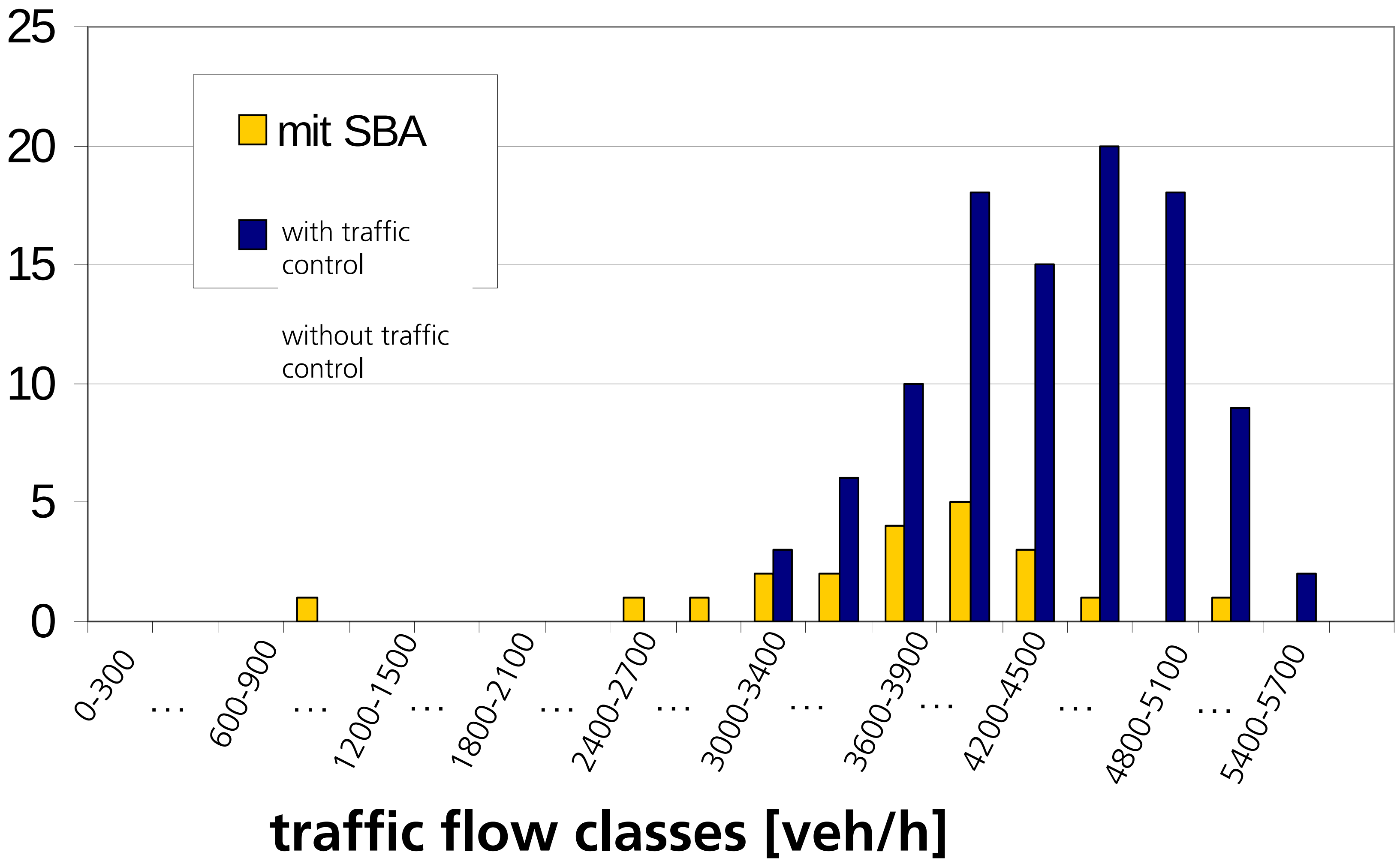
3) minimum traffic flow: $q_1 > 1000$ veh/h

result: breakdown y/n at q_1

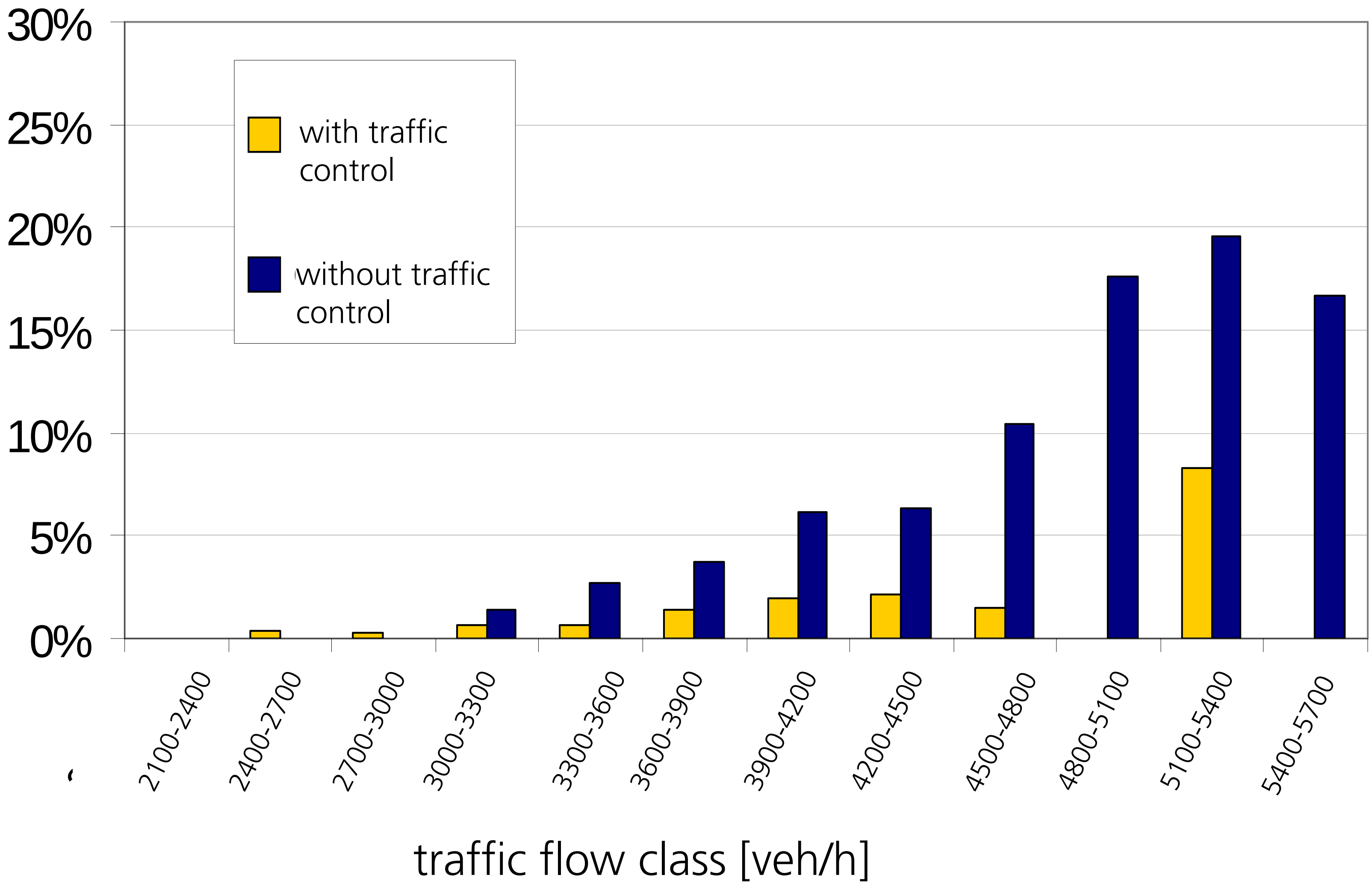
temporal ratio of different traffic flow classes (%)
zeitlicher Anteil der Verkehrsstärke-Klassen [%]



absolut number of traffic breakdowns



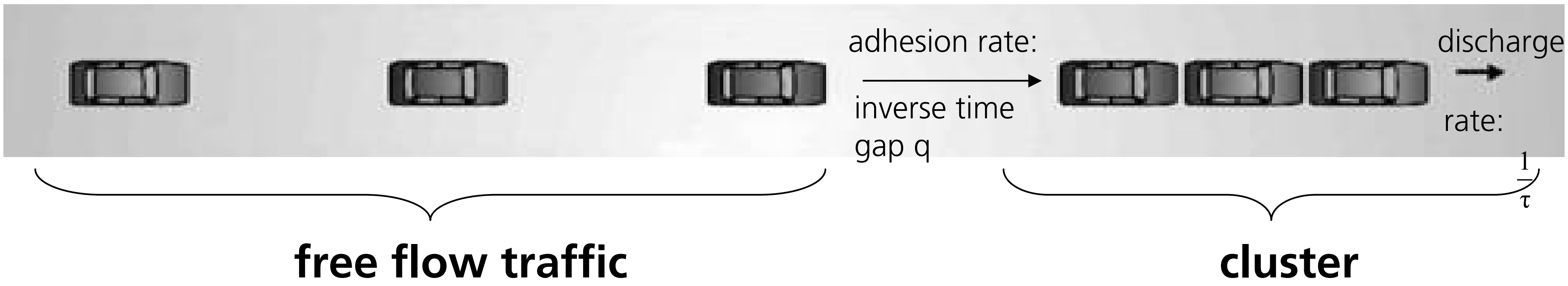
probability of traffic breakdown



Approximation for the breakdown probability function for a two lane section

Source: Kühne, R.; Anstett, N.: New Methods for Determining Critical Sections on Freeways, Transportation Research Board, 1997

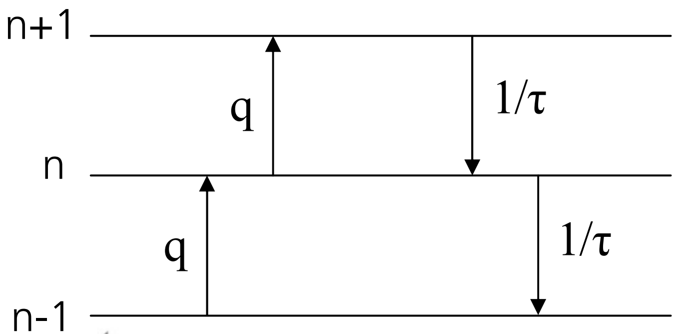
decomposition into free flow and congested traffic



number of vehicles within the cluster: n

minimum cluster size: n_{esc}

balance



$$\dot{P}(n,t) = +q\,P(n-1,t) - q\,P(n,t) + \frac{1}{\tau}\,P(n+1,t) - \frac{1}{\tau}\,P(n,t)$$

Taylor expansion

$$P(n\pm1,t) \approx P(n,t) \pm \partial_n P(n,t) + \frac{1}{2}\partial_n^2 P(n,t)$$

into balance equation gives
Fokker Planck equation

$$P(n,t) = -(q-\frac{1}{\tau})\partial_n P(n,t) + \frac{1}{2}(\overset{\approx \frac{1}{\tau}}{\cancel{q}} + \frac{1}{\tau})\partial_n^2 P(n,t)$$

dim. less variables (~supressed)

$$x = \frac{n}{n_{esc}} \qquad \tilde{t} = \frac{1}{\tau n_{esc}^2} \qquad \beta = (\tau q - 1)\, n_{esc}$$

$$\dot{P}(x,t) = (\partial_x \Phi' + \partial_x^2) P(x,t)$$

with potential

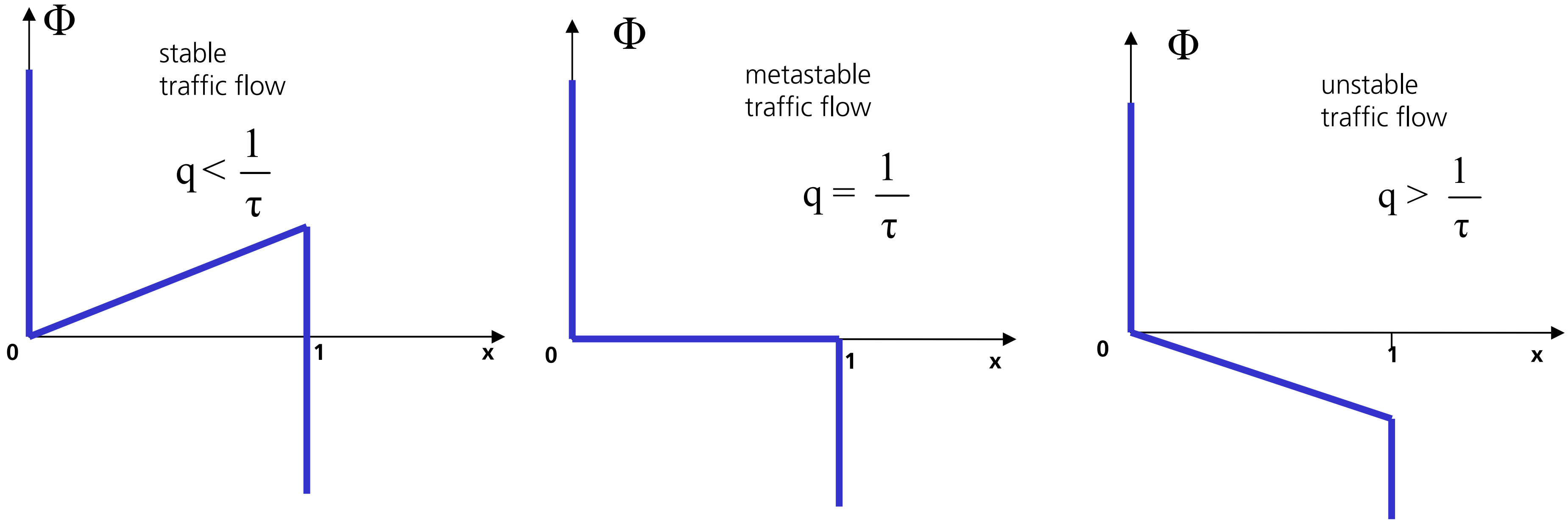
$$\Phi = -2\beta x \qquad 0 < x < 1$$

traffic state dynamics

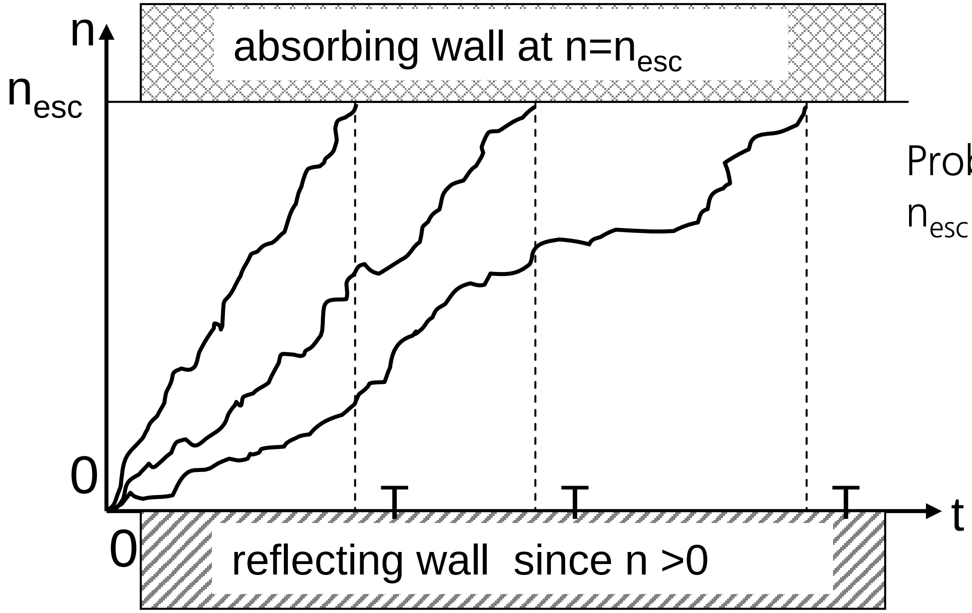
$$\dot{x} = -\Phi' + \Gamma(t)$$

$\Gamma(t)$ = fluctuating force

$$<\Gamma(t)> = 0 \qquad <\Gamma(t)\,\Gamma(t')> 2\delta(t-t')$$



First passage time



Probability of state n anywhere between 0 and n_{esc} at time t when started with n=0 at time t=0:

$$W(t) = \int_0^{n_{esc}} \left(P(n,t|0,0)\right) dn$$

Drop of probability of state n anywhere between 0 and n_{esc}

$$-\frac{dW(t)}{dt} = -\int_0^{n_{esc}} \dot{P}(n,t|0,0)dn$$

≡ probability that state exceedes $n=n_{esc}$:

$$\mathcal{P}(t) = -\int_0^{n_{esc}} \dot{P}(n,t|0,0)dn$$

Inserting Fokker Planck equation: $\dot{P}(n,t|0,0) + \partial_n j(n,t|0,0) = 0$

$$\sim> \mathcal{P}(t) = -\int_0^{n_{esc}} \dot{P}(n,t|0,0)dn = j(n,t|0,0)\Big|_0^{n_{esc}} = j(n_{esc},t|0,0)$$

separation $P(x,t) = e^{-\frac{\Phi(x)}{2}} e^{-\lambda t} \varphi(x)$ gives $(-\partial_x^2 + \beta^2)\varphi_\nu(x) = \lambda_\nu \varphi_\nu(x)$ with $(-\beta + \partial_x)\varphi(0) = 0$

$$\varphi(1) = 0$$

ground state $\varphi_0 = \begin{cases} N_0 \sin k_0 (x-1) \\ N_0 \sinh \kappa_0 (x-1) \end{cases}$ $\lambda_0 = \begin{cases} k_0^2 + \beta^2 \\ -\kappa_0^2 + \beta^2 \end{cases}$ $N_0^2 = \dfrac{2}{1+\beta/\lambda_0}$ $\beta > -1$, $N_0^2 = \dfrac{2}{-1-\beta/\lambda_0}$ $\beta < -1$

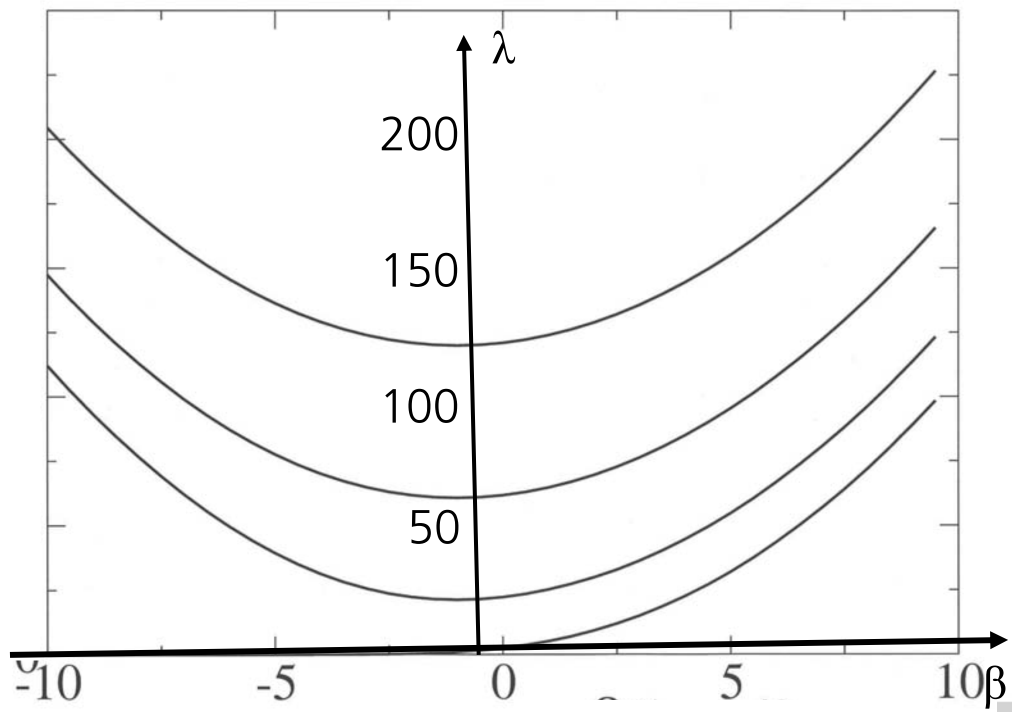
excited states $\varphi_\nu = N_\nu \sin k_\nu (x-1)$ $\lambda_\nu = k_\nu^2 + \beta^2$ $N_\nu^2 = \dfrac{2}{1+\beta/\lambda_\nu}$ $\nu = 1,2,....$

eigenvalues

$k_0 \cot k_0 = -\beta$ $\beta > -1$

$\kappa_0 \coth \kappa_0 = -\beta$ $\beta < -1$

$k_\nu \cot k_\nu = -\beta$ $\nu = 1,2,....$

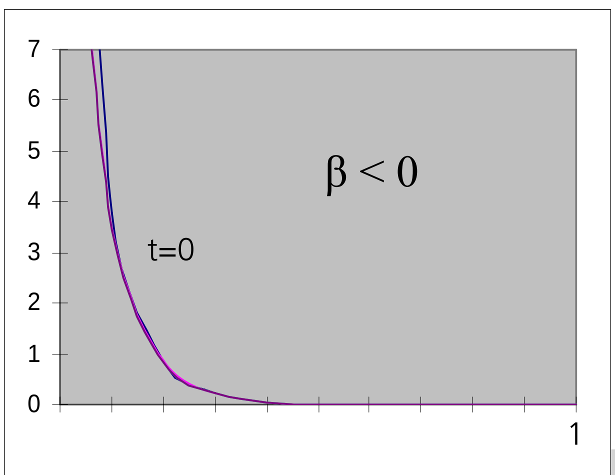


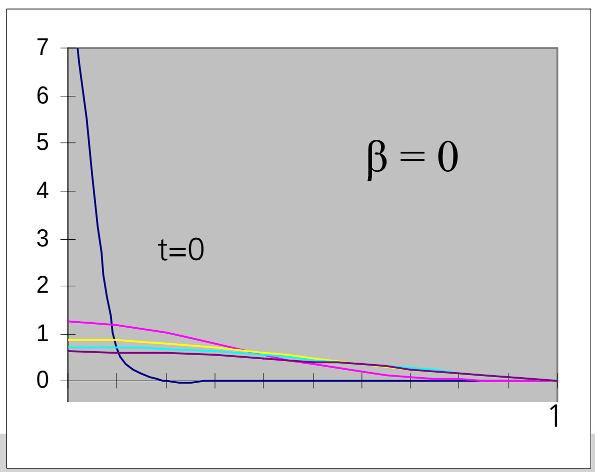
time development of probability distribution

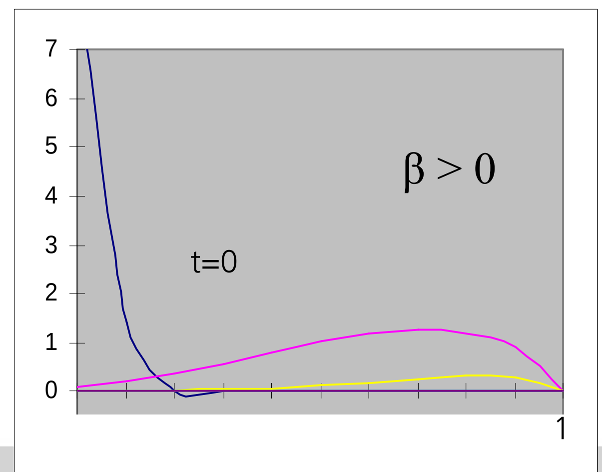
$$P(x,t)\,|\,0,0)| = \delta(x)$$

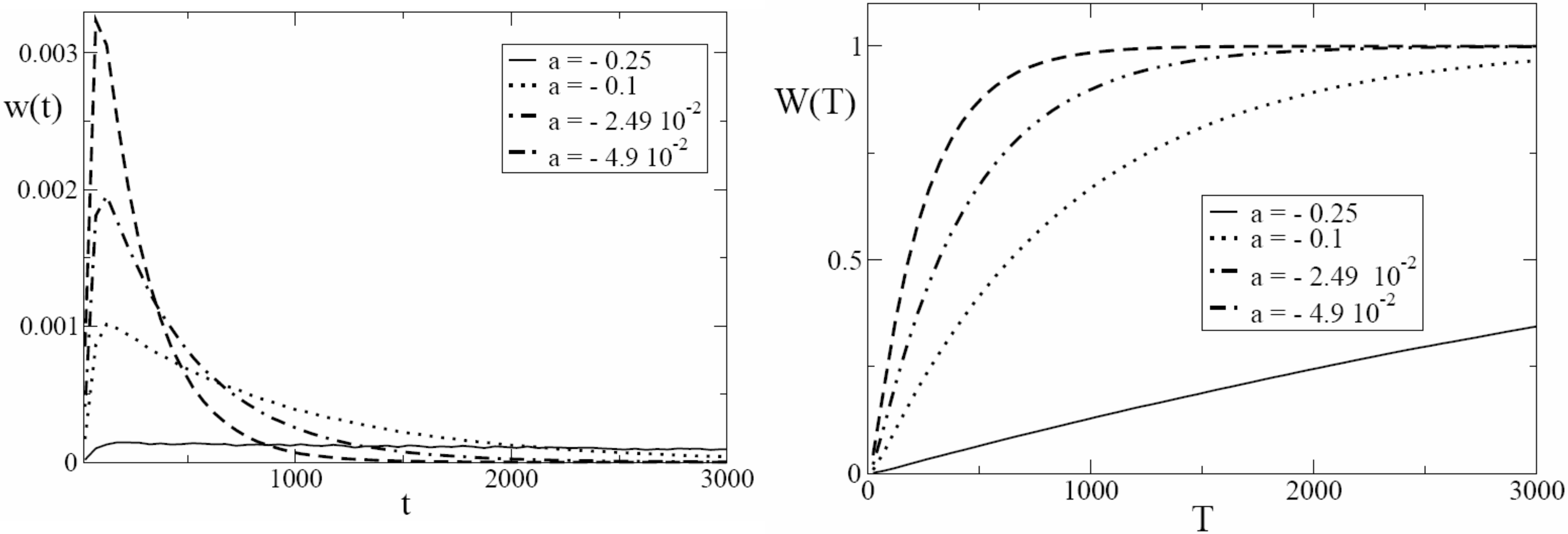
$$P(x,t\,|\,0,0)| = e^{\frac{-\Phi(x)}{2} + \frac{\Phi(0)}{2}} \sum_{\nu} \varphi_{\nu}(x)\ \varphi_{\nu}(0)\ e^{-\lambda_{\nu} t}$$

$$= \begin{cases} \dfrac{e^{\frac{-x^2}{4t} + \beta x - \beta^2 t}}{\sqrt{4\pi t}} - \dfrac{e^{-\frac{(x-2)^2}{4t} + \beta x - \beta^2 t}}{\sqrt{4\pi t}} & \beta > -1 \\ e^{\beta x} N_{\nu}^{2} \sinh\kappa_{\nu}(x-1)\ \sinh(-\kappa_{\nu})\ e^{-\lambda_0 t} + \quad \% & \beta < -1 \end{cases}$$







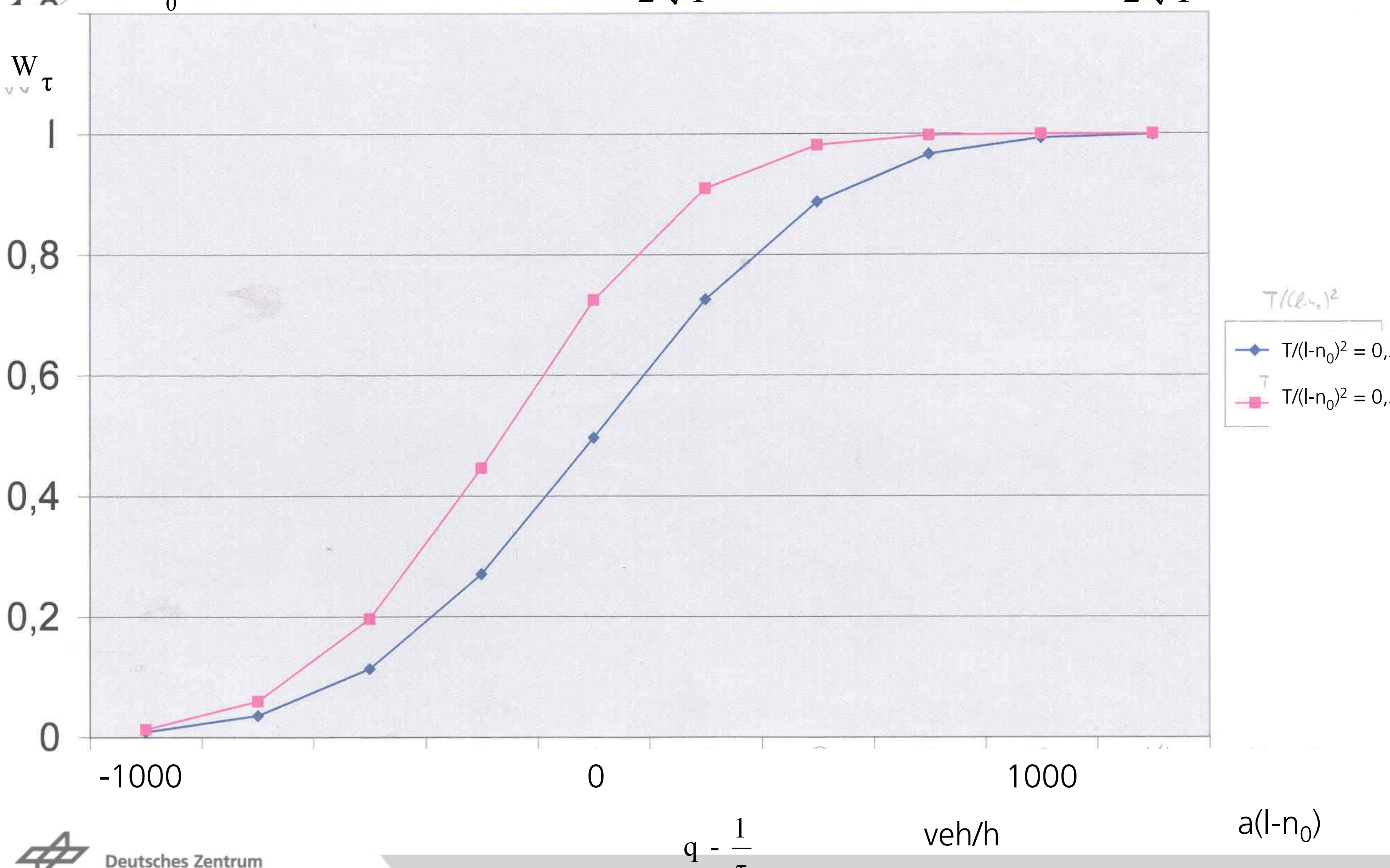


First passage time distribution (left: density; right: cumulative distribution) as probabilistic interpretation of observing a traffic breakdown during a time interval (t,t+dt) or during the observation time 0…T

Source: R. Kühne, R. Mahnke, J. Hinkel: Modelling the Effects of Corridor Control Systems on Road Capacity; ISHC Yokohama Juli 2006

cummulative breakdown probability

$$W(T) = 1 - \int_0^1 dx\, P(x,T|0,0) = \frac{1}{2}\left(1 - \operatorname{erf}\left(\frac{1}{2\sqrt{T}} - \beta\sqrt{T}\right)\right) + \frac{e^{2\beta}}{2}\left(1 - \operatorname{erf}\left(\frac{1}{2\sqrt{T}} + \beta\sqrt{T}\right)\right)$$



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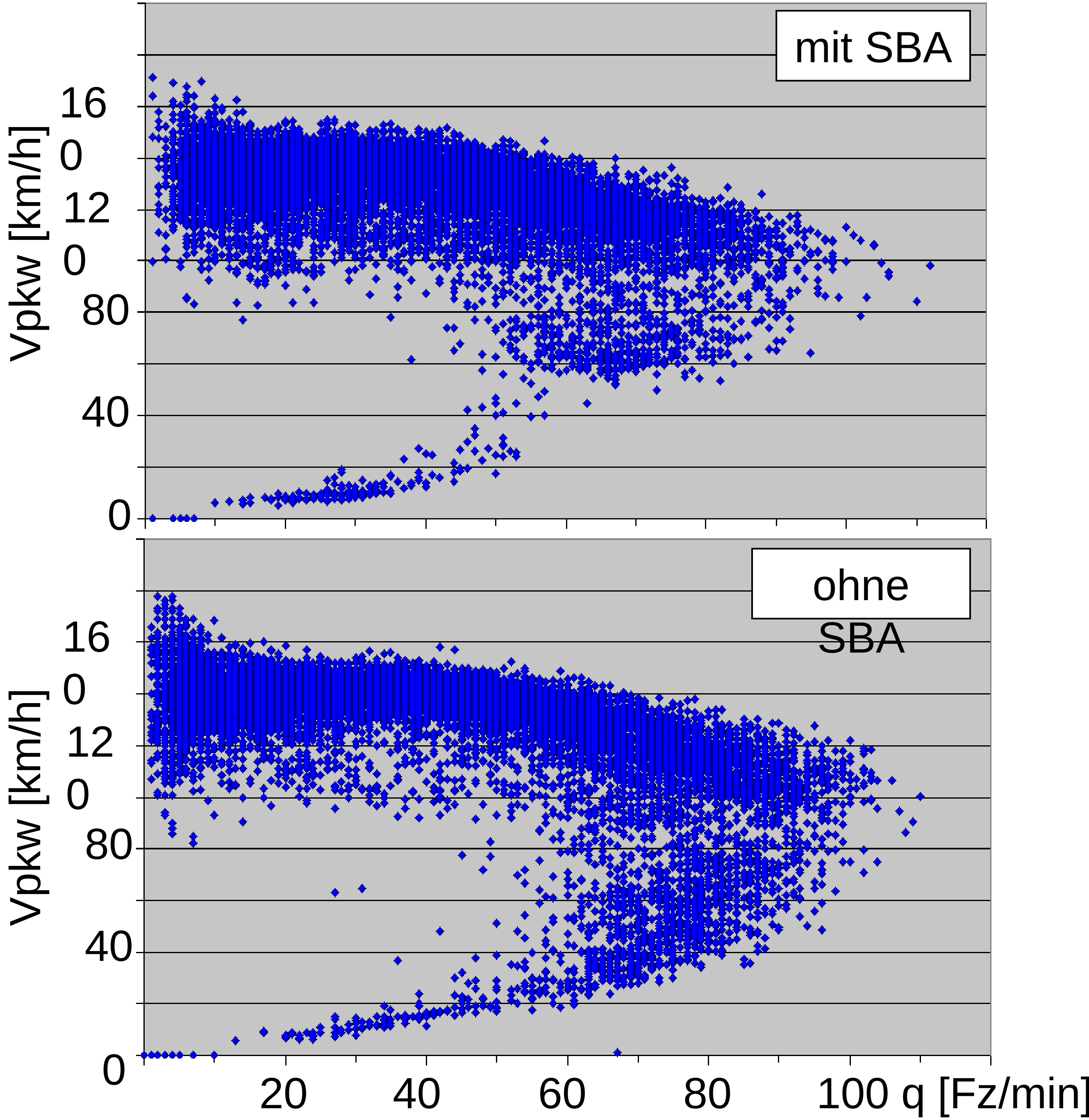
Beispiel einer Streckenbeeinflussungsanlage

[Quelle: Engl, H. und F. Lämmel, Highway Deutschland, 1996]

Comparison of two q –v Diagrams from 5 minutes intervals



[A9 München – Holledau, Zeitraum 27.07.-09.08.2000, d.h. 20160 Messwerte]

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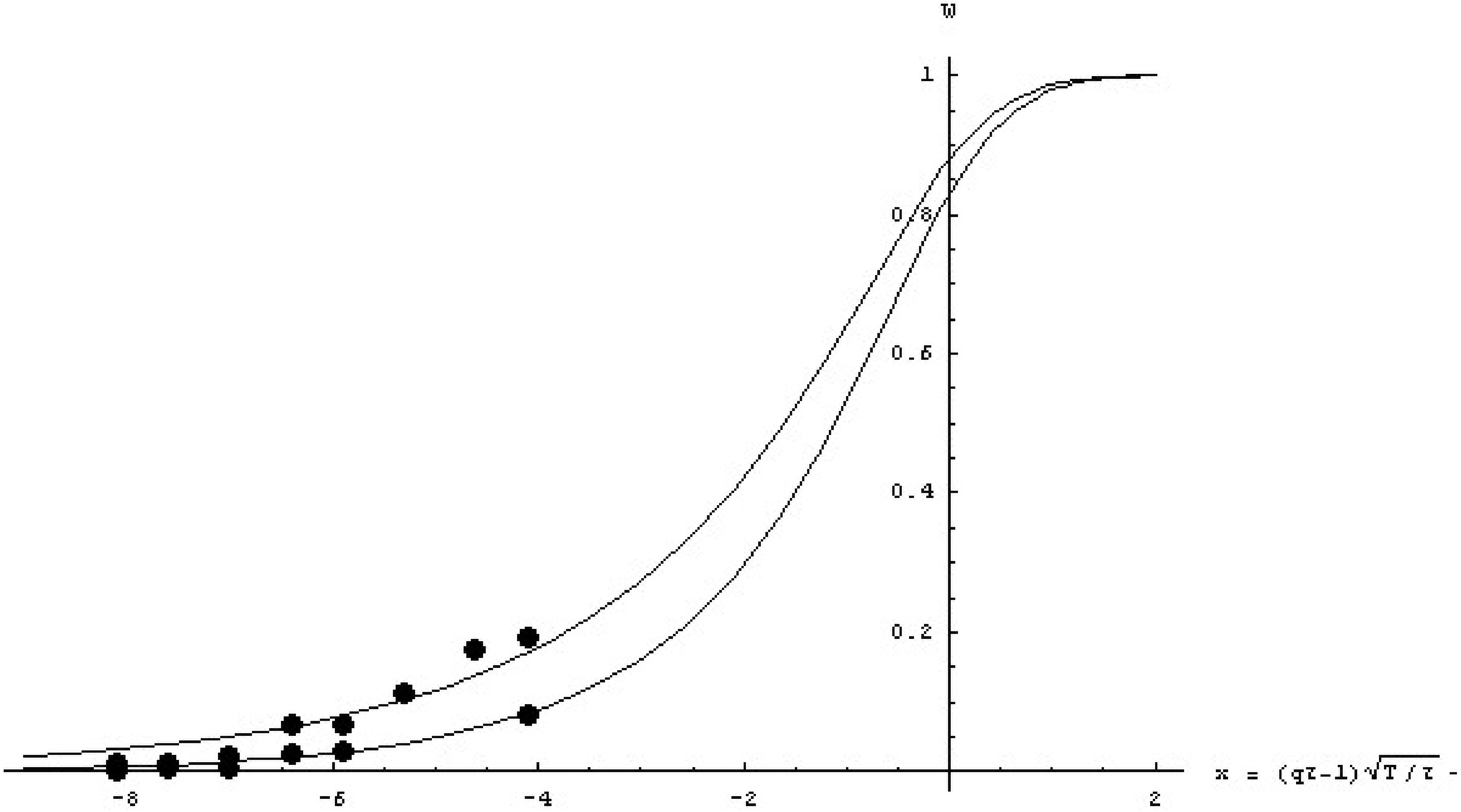

Cummulative breakdown probability distribution as function of the traffic volume q as control parameters for different critical cluster sizes m modelling the influence of traffic control measures on the breakdown probability

Source: R. Kühne, R. Mahnke, J. Hinkel: Modelling the Effects of Corridor Control Systems on Road Capacity; ISHC Yokohama Juli 2006