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Do We Use the 'Level of Service' Concept in the Right Way

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1. Introduction:

Worldwide it is recognized that traffic problems are growing exponentially. Traffic problems are the result of traffic volume. This exponential growth of problems is the result of exponential growth of car traffic volumes. Since traffic growth is not a natural law but much more man made it is worthwhile to look on our concept for the calculation of traffic demand. This concept is based on the highway capacity manual level of service principle.

2. HCM-Concept of "level of service":

The service flow rate for level of service "i" is calculated for the prevailing roadway and traffic conditions:

$$
\begin{aligned}
SF_i &= MSF_i \times N \times f_w \times f_{HV} \times f_E \times f_p \\
MSF_i &= c_j \times (v/c)_i \\
SF_i &= c_j \times (v/c)_i \times N \times f_w \times f_{HV} \times f_E \times f_p
\end{aligned}
\qquad (1)
$$

where:

SF_i = service flow rate; the maximum flow rate that can be accommodated by the multilane highway segment under study, in one direction, under prevailing roadway and traffic conditions, while meeting the performance criteria of LOS *i*, in vph;

MSF_i = maximum service flow rate; the maximum rate of flow which can be accommodated by the multilane highway segment under study, per lane, under *ideal conditions*, while meeting the performance criteria of LOS *i*, in pcphpl;

c_j = capacity per lane for a multilane highway with design speed *j*; 2,000 pcphpl for *j* = 70 mph or 60 mph, 1,900 pcphpl for *j* = 50 mph; c_j may be obtained from Table 7-1 as the maximum service flow rate for LOS E;

N = number of lanes in one direction;

$(v/c)_i$ = maximum volume-to-capacity ratio allowable while maintaining the performance characteristics of LOS *i*;

f_w = adjustment factor for lane width and/or lateral clearance restrictions;

f_{HV} = adjustment factor for the presence of heavy vehicles in the traffic stream;

f_E = adjustment factor for the development environment and type of multilane highway; and

f_p = adjustment factor for driver population.

The maximum service flow rate is dependent on the level of service defined. In practice we use the levels A to E but never the level of service F, which describe the socalled unstabil flow conditions. The calculated figure is compared with the traffic volume from the real road section or with traffic flows from forecasting. If we look at figure 1, we can see that level of service situations from A to E encourage traffic flow to grow up. In principle there is only one answer for the question of solving traffic problems: the traffic flow has to grow.

3. Studies on Austrian roads and motorway - effects of self-regulation:

If we look to the traffic growth on roads in Austria (or in an other country) we can observe that the traffic flow is growing faster on motorways than on other roads. The difference is caused by the comfort of driving and the speed (Fig. 2).

But this growth of car traffic can be strongly influenced by other modes (Fig. 3). After the introduction of a Schnellbahnsystem around the city of Vienna the traffic growth on some of the radial roads came to a stop, on some of them we can observe a "negative growth". This leads us to the question whether the level of service concept is applicable only for car traffic or for the other modest too. If it should be applicable for all the other modes we need a uniform scale. The person car (pcu) is not useful if we compare public transport with car traffic. The density, expressed in persons per m^2 would be a usefull unit.

This empirical studies show that the level of service concept as it is in use for the road traffic system might not be right, if we apply it to the whole traffic system. It can create contra-productive effects for the system by becoming the driving force in a self-regulating system. The self regulation system can be studied by methods of automatic control.

4. Critical analysis of HCM-concept.

The traffic system can be described as a dynamic process with the help of the methods of automatic control. Good traffic conditions described by the level of service A, B, C, D and E, produce positive irritations on road users. They encourage the traffic volume to grow. If we would like to study the effect on human behaviour we have to take into account principles of behavioural sciences. If we fix the service flow rate for a certain level of service, we can assume that the irritation to increase the traffic volume is proportional to the traffic volume and the level of service rate (Formula 2)

$$\frac{\delta V}{\delta t} = k \cdot V \qquad (2)$$

The integration of this differential equation gives (3) and (4). This shows that the traffic flow grows exponentially if traffic is handled with the HCM system of LOS. The growth is dependend on the level of service and means the difference between capacity and volume. Since this difference is positive the result is an exponential growth of traffic flow. It is now clear that the exponential growth of traffic problems and the exponential growth of traffic flow is the result of our calculation and decision method based on the LOS concept. It is a systemimmanent cause of traffic problems.

$$\ln V = k \cdot t + c \qquad (3)$$

$$V = c.e^{kt} \quad (4)$$

Formula 3 is also very interesting to explain, if we know that this formula has the form of the well known Weber-Fechners's-Law, which describes the relationship between irritation and sensation. In our case irritation is the car traffic volume and sensation is the reaction of society on this effect. It is nothing else than the LOS concept. The LOS concept is the answer of the question how to solve the problem of increasing traffic flow. This concepts lead to a steady growth of car traffic. So the system is not useful to solve traffic problems in an integrated traffic system, which includes public transport, cyclist and pedestrians too.

5. How can the level of service concept be used as a tool for the control of traffic development in an integrated system:

(3) and (4) describe the basic behaviour of man in an artificial environment. First of all we have to look for a common unit. For person transport the common unit is the man and not a car. The key element to control the traffic system is the irritation of traffic system user. Traffic system users choose always that part of the traffic system which has the greatest positive irritation for them and they try to prevent that parts which has a lower or a negative irritation to them. To bring car drivers to public transport use, public transport has to have a greater positive irritations than the car. Kenworthy and Newman have shown that in the city center the situation is rather worse for car users, but the specific energy consumption per capita as well as the air pollution per capita is the lowest one. Fig. 2 and 3 is the result of the relative strong negative irritation for car users compared to other modes. Speed reduction, parking fees, red waves for traffic signals are some of the tools to reduce the positive irritation for car drivers.

But the question is, how we can influence and control the car traffic outside built up areas ? Instead of changing the environment by building always more new roads, the traffic engineer has to become aware that his main business in the future has to be the right organisation of traffic flows on the existing road network. He has to control the traffic flow and not only to extend the infrastructure. By organizing the traffic system in such a way as it is planned with a certain level of service we must use the bottom side of the diagram figure 1 and we have to define the LOS-concept on the F-side. This levels of service are FA to FE. FA is the very low level of service with very low speeds and a limited traffic flow ratio.

The question is how we can control the traffic ? The traffic flow follow first the upper side of the diagram, with low density and high speeds, but if traffic volume is exceeding a certain level of service, the situation has to jump from the upper to the bottom part of the diagram, to prevent a further growth of traffic. This can be done (at least) in two ways.

1. By using a kind of signal-system-control. If somebody trys to enter into a section with more traffic than accepted, has to wait for such a long time that he get the travel speed for the level of service FE. Car drivers have now the possibility to learn from the system how they have to use it.

The system can be handled by automatic traffic counts together with an access control system. It can be also be handled by systems like PROMETHEUS via satellite and so on.

2. A much more simpler sysem is the introduction of market economy into the system. If the car drivers drive on the circumstqances which are not planned (there is to much car traffic on the way) they pay twice, three times, x-times more compared to the desired situation. Under this circumstances traffic users will very easy learn to handle the system in a right way. The occupancy rate will increase and the number of cars will decrease very soon. We can easily keep the level of service we want. In this case the traffic system is not influenced directly but in fact indirectly by travel costs which increase rapidly if traffic flow exceed the planned level of service.

This examples show that this concept fits exactly into the existing system of market economy. But since this system fits into market economy it is also obvious that the prevailing level of service concept is not in line with the principles of market economy. Therefore it is no doubt, why it produces always new problems and an exponential growth of traffic flow and traffic problems.

6. Conclusion:

Observation in practice shows that the traffic growth can be influenced by many effects. The simple concept of level of service which has been developed in the Highway Capacity Manual has only one answer to the steady traffic growth - it is the extension of road infrastructure. But there are much more answers possible taking into account the whole traffic system. We can solve car traffic problems also with the help of public transport, pedestrians and cycles. The theoretical analysis of the LOS-concept with the view of automatic control shows that the exponential traffic flow growth as well as the exponential increase of traffic problem are the logical consequences of the application of the level of service concept. The theoretical analysis gives us a better understanding about the mechanismus in the traffic system. The diagrams from the empirical studies from Kenworthy and Newman can be supported by theoretical analysis. The balance of the development of the different traffic modes can only be reached if the level of service F is included into the mechanism. Therefore it is necessary to introduce a system with a level of service FA to FE to be able to guarantee levels A to E.

There are different ways to control the traffic system in practice. One of them is traffic regulation by electronic equipments, the second way is the introduction of an economy market. If traffic flow is increasing the threshold of a given LOS travel costs are increasing. If we introduce this kind of automatic control mechanism into our traffic system, the road user can very easily and quickly learn how to behave in and handle the system, how to prevent bottlenecks, how to prevent congestions and so on. If we don't introduced this system and continue to use the level of service concept as it has been done in the last decades we will produce even more traffic problems in the future than in the past. We have to bring learning-principles into the traffic system by better understanding the level of service concept as a tool for controlling the whole traffic system.

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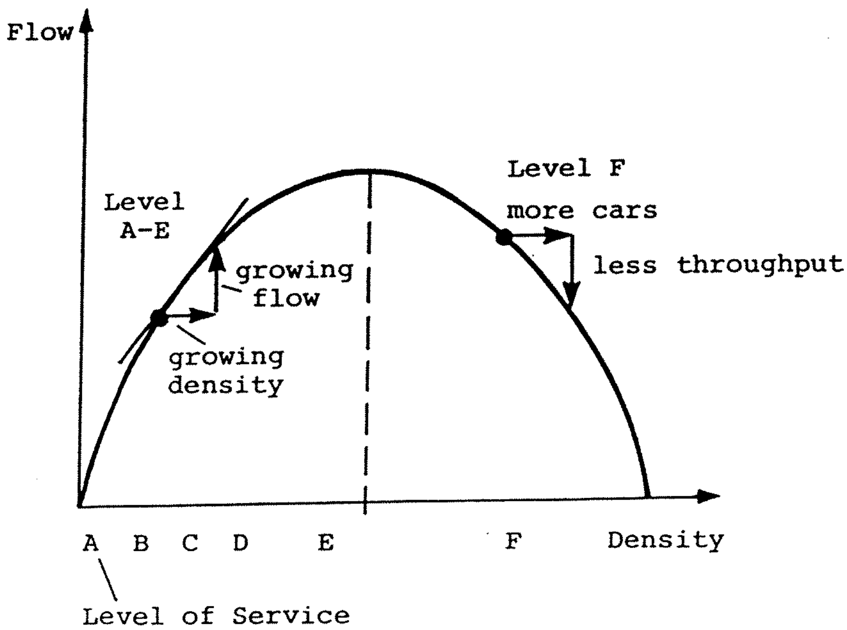
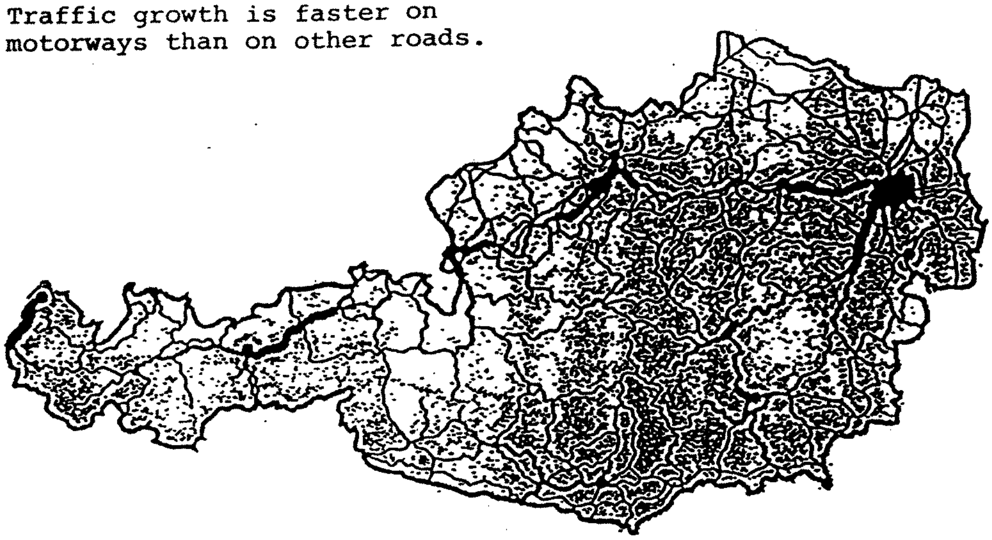

Flow
Level
A-E
growing
flow
growing
density
Level F
more cars
less throughput
A B C D E F
Density
Level of Service

Fig.1

Car-Traffic growth from 1970-1990

Traffic growth is faster on
motorways than on other roads.

1970



1990

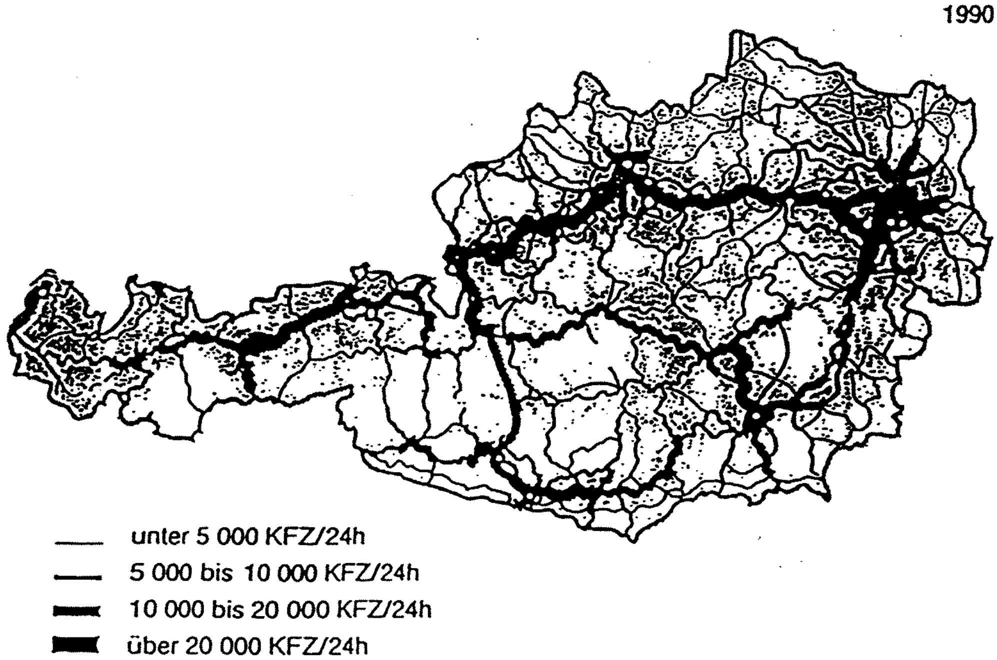


Fig. 2

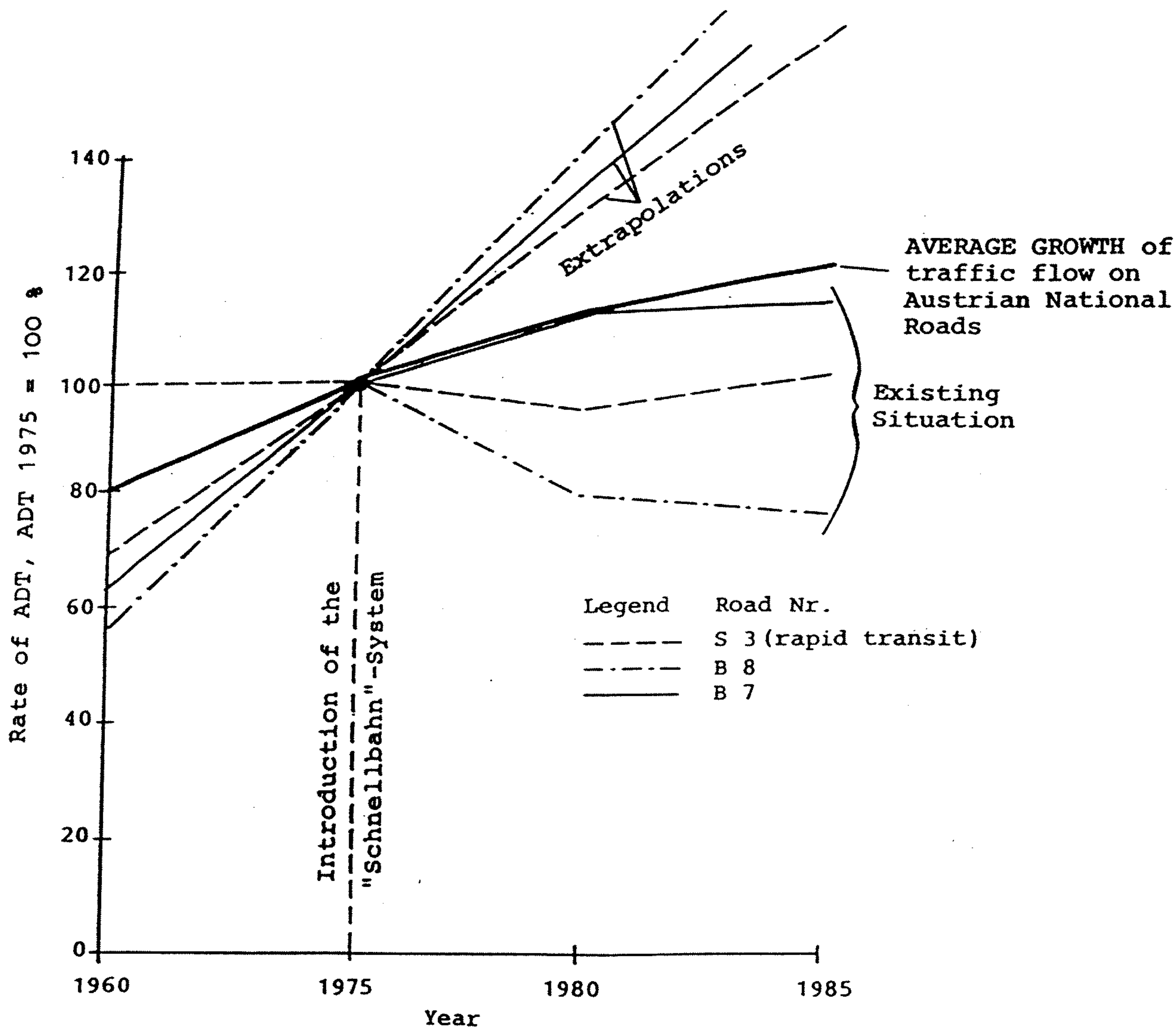


Fig. 3 : Development of traffic growth parallel to the rapid transit (Schnellbahn).

Source: Institut für Verkehrsplanung und Verkehrstechnik. Daten aus: STEIERWALD, G.; et al: "Automatische Straßenverkehrszählung - Jahresbericht 1985". <u>Bundesministerium für Wirtschaftliche Angelegenheiten. Bundesstraßenverwaltung.</u> Wien, 1986.

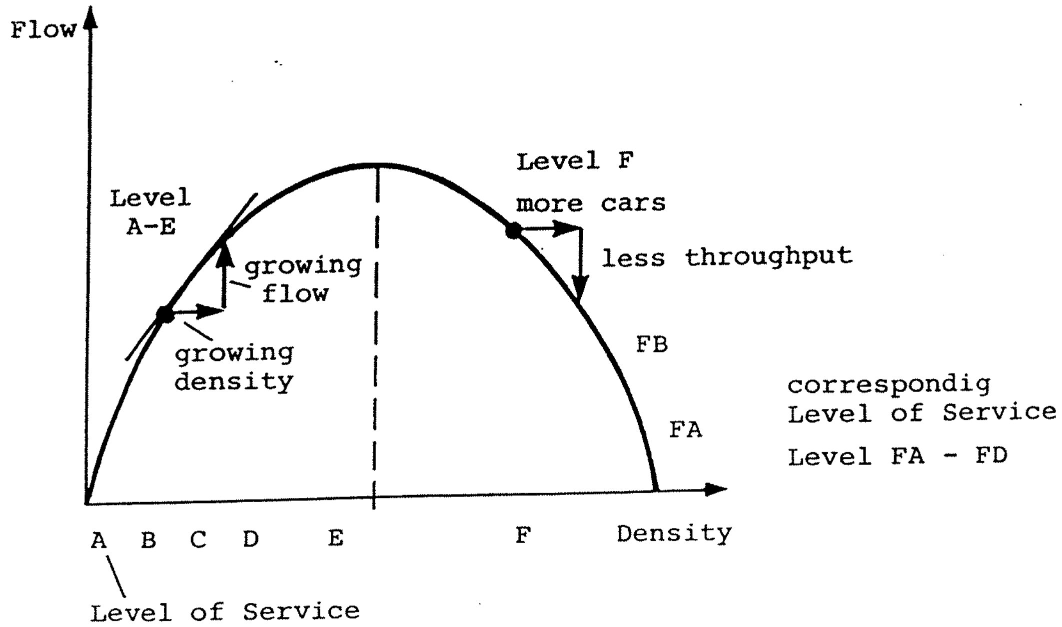

Flow
Level
A-E
growing
flow
growing
density
Level F
more cars
less throughput
FB
FA
correspondig
Level of Service
Level FA - FD
A B C D E F
Density
Level of Service

Fig. 4