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1. Motivation

To manage any kind of system, it is essential to understand the internal processes and limitations to avoid a collapse. Water, gas and energy supply are good examples. These systems have to be monitored constantly to ensure an undisrupted service for all users, even during high demand (e.g. increase of electricity usage during summer times). What is well known in such fields, is still quite a new approach for managing traffic networks. While we understand the traffic flow process, and often are able to find solutions for local bottlenecks, the more global view of a system for network wide strategic decisions is less explored.

This paper explores the demand, Tokyo Metropolitan Expressway has to handle, using ETC-OD data. About three million vehicle records have been extracted from trips on Wednesdays in September 2006. The choice for Wednesdays is based on literature¹⁾⁻³⁾, where it is commonly stated that Wednesdays can be referred to as “normal” days without any influences from the weekend (i.e. high demand in evenings, more spread peak hours). The demand is generated by 186 on-ramps, from which 78 ramps generate a substantial input from more than 100 vehicles per hour with the maximum inflow of a single ramp being about 1800 vehicles per hour.

During the study period, the Tokyo Metropolitan Expressway carried 665.000 to 721.000 vehicles with ETC on board units per day. That means that the demand variation, considering the whole network, is less than 10%. The value itself might not be surprising, but the fact that only 18% of the vehicles are regular users is, and raises the question who the majority of drivers are every day, why the demand remains relatively constant and what the implications for traffic management on the expressway are.

To answer these questions we will first take a closer look at the data, to determine the facts on volumes, traffic sources, and traffic composition.

2. Temporal and Spatial Demand Analysis

As mentioned before, the actual daily traffic demand on the Tokyo Metropolitan Expressway does not vary significantly. Figure 1 shows the network wide demand for four Wednesdays in September 2006. The figure shows for each day a morning and evening peak, with

the evening peak being a bit more spread over time. Especially the morning peak's shape is fairly regular and just shows some overall increase at the end of the month. One should remember that with the low percentage of regular users, this single observation can lead to wrong assumptions about the total network.

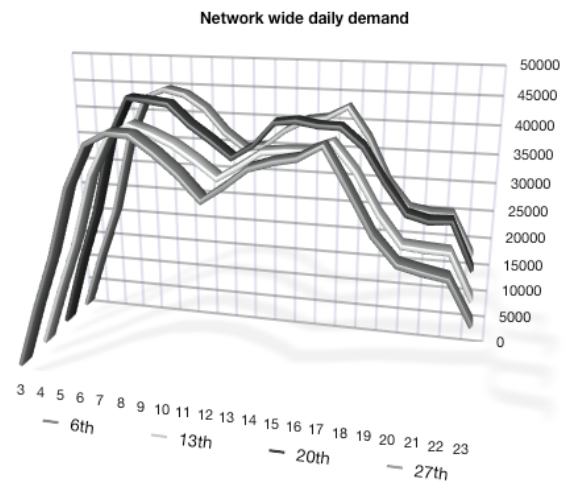


Figure 1: Daily network wide traffic demand

If we focus on one of the most used on-ramps to enter the Tokyo Metropolitan Expressway (Takaido) the traffic demand 6 a.m. can vary from around 350 vehicles/hour up to 2050 vehicles/hour. Figure 2 shows the demand for the same four Wednesdays as the total demand.

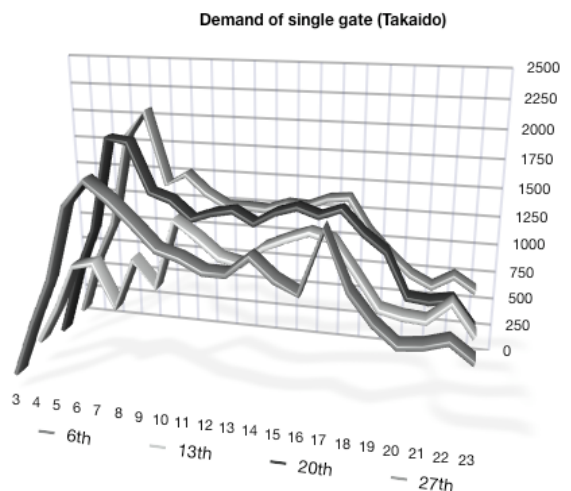


Figure 2: Daily traffic demand from Takaido on-ramp

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However, this is not a constant behavior throughout the network. Other on-ramps have a quite stable demand profile (see Figure 3). Comparing both on-ramps, one can also clearly determine that the Takaido ramp has more traffic in the morning, while the Kawaguchi on-ramp has a more significant evening peak.

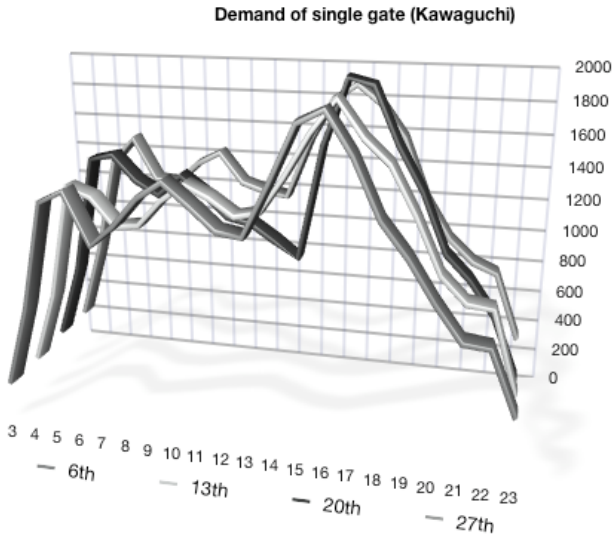


Figure 3: Daily traffic demand from Kawaguchi on-ramp

With the presence of typical commuting patterns on the one hand, but heavily fluctuating traffic demand on the other hand, we will now explore how the network is used.

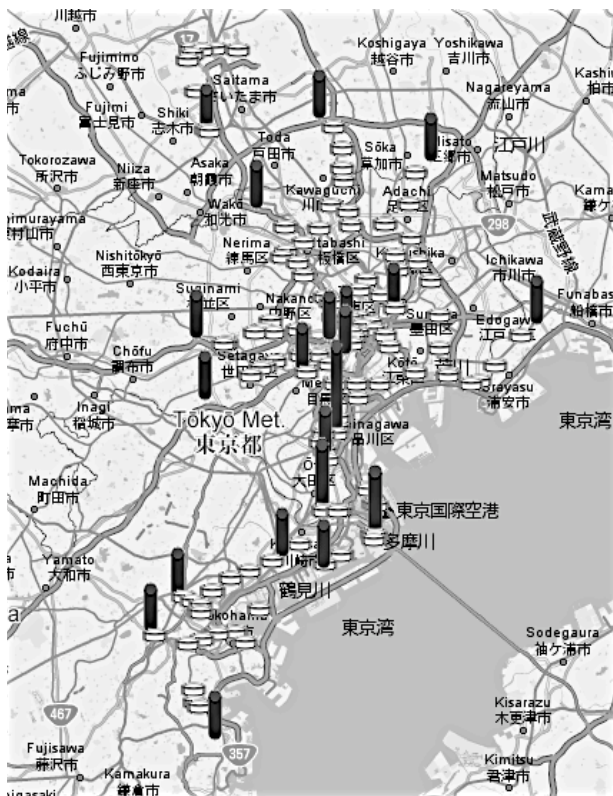


Figure 4: Heavy user traffic demand

First, we focus on the demand from vehicles that enter the Tokyo Metropolitan Expressway at least six times during these four days for a similar trip. Similar trips here is used to define a trip that compares to a commute back and forth.

As shown in Figure 4, the heavy users are mainly from the outside of the Tokyo Metropolitan Expressway area, connecting from other Expressways.

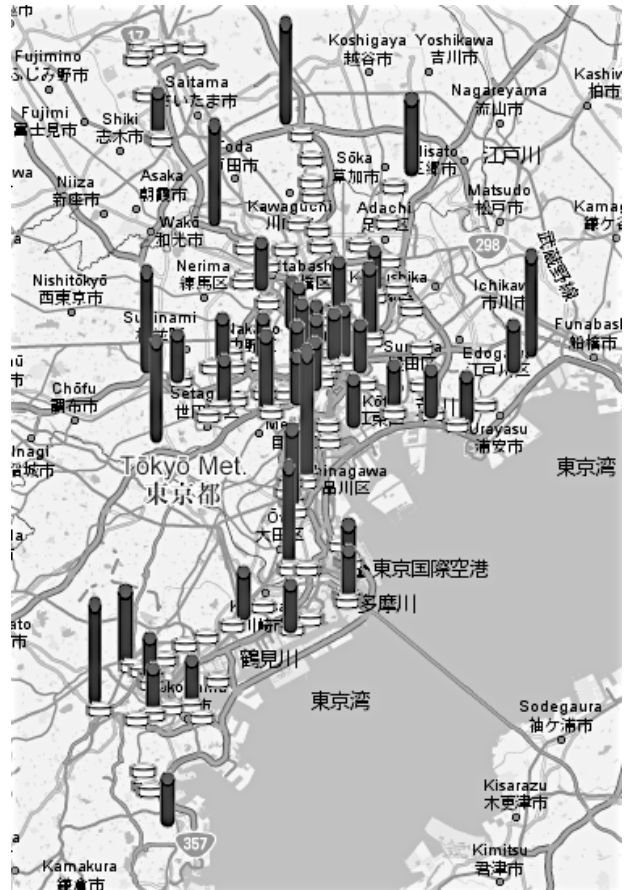


Figure 5: Other user traffic demand

The other traffic demand which is composed mainly of vehicles that just enter once the network in the study period is shown in Figure 5.

This 'random' traffic can also be found coming from connecting Expressways, but additionally is the major demand source in the central and business districts of the area. In other words, the Tokyo Metropolitan Expressway is the daily gateway for over half a Million 'visitors' to Tokyo.

When we look at the vehicle usage, we can state, that among the heavy users the ratio between private and commercial vehicles is about even (see Figure 6). Considering all traffic, the private vehicles have the bigger share, which leads to the conclusion that the random traffic is mainly due to private used vehicles.

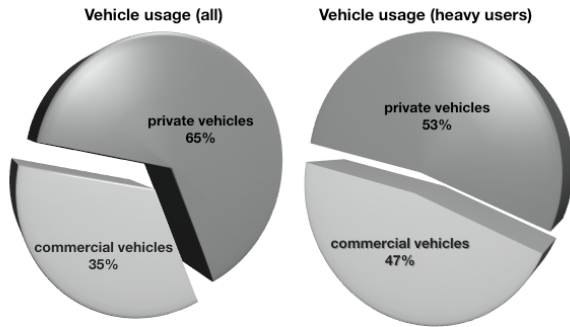


Figure 6: Vehicle usage

Private used vehicle here means that it has a white number plate. That means that company cars are also counting as private cars, since they are just distinguished by the number plate.

Figure 7 breaks down the vehicle types a bit more. This makes clear that the commercial vehicles are almost entirely trucks, since the percentages are almost equal. Commercially used passenger cars, such as taxis, seem not to play any significant role.

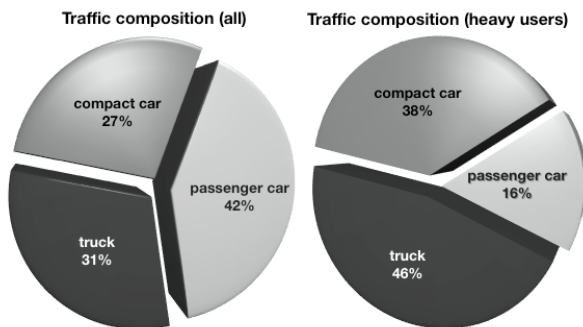


Figure 7: Traffic composition

This knowledge about the traffic demand leaves the question about the implications for traffic operation in such a network.

Usually, the average demand of commuting traffic with a clear morning and evening peak is the foundation for traffic operations, taking into account the typical fluctuations. This seems to be difficult when the majority of the demand is from vehicles that use the network only sporadically. This issue we will discuss further in the next paragraph.

3. Implications for traffic operations

As mentioned, traffic operations is based on regular patterns and observed fluctuations. Such patterns are

usually taken at bottlenecks and not at entry point to the network. So instead of focusing on the entry demand we took a look at the inner circular road which is a weak link of the network, since most traffic has to pass it partially during the journey.

Figure 8 shows the detector count on the inner circular road of the Tokyo Metropolitan Expressway.

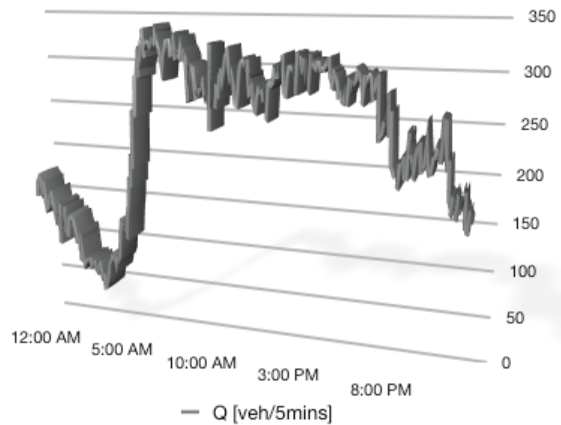


Figure 8: Inner circular route traffic load

The traffic volume pattern is very steady during the study period, in contrast to the demand. This implicates that even though the demand is not steady with a major random component, that the traffic flow on the other hand is quite stable. After a steep volume increase in the morning, the traffic volume remains high until the evening. There is no significant morning and evening peak.

This means, that independent from the highly variable demand, traffic operations can be based on a fairly stable pattern of traffic volumes over the day. It raises of course the question of why the link volume from detectors is stable when the demand from the ETC-OD data shows such high fluctuations.

However, the volume of about 300 vehicles per five minutes is equal to 1800 vehicles per hour and lane, so that we can assume that the network runs on a volume close to capacity.

With the traffic volume close to capacity it is vital to steer and control the traffic in the most possible efficient way. This however is not trivial, when not knowing more details about the actual demand.

The daily throughput of the network seems to be self regulating by the capacity and traffic information provided to the road users regulates the 'random' demand, so that the overall situation when just looked at the volumes is stable. Traffic operations under these circumstances require detailed information and flow inspection if one wants to relief the traffic situation.

4. Conclusions

In this paper, we used ETC-OD data to get more insight into the demand of the Tokyo Metropolitan Expressway, to better understand how the system operates.

The first interesting finding was that even though the daily traffic volume of the Expressway is fairly stable, that the demand can vary significantly. A closer look on the demand showed that just a very small percentage of road users, are so called 'heavy users' which use the expressway on a nearly daily bases. The major part of the users are vehicles that enter the Expressway only on a monthly or even less frequent basis. We found that heavy users are mainly using the on-ramps on the outer part of the Expressway, while the 'random traffic' is spread over the whole network and especially in the business areas in and around Tokyo.

Since the 'random' part of the traffic demand is found to be private owned vehicles, it is certain to say that driving services and taxi companies have no influence. The high portion of trucks among the commuters is probably due to delivery services and close by transports of goods.

One possible reason for the high randomness would have been transport vehicles on long transport chains, passing Tokyo in longer turns then the study period. However, the indication for this is not clear and the difference between commuting trucks and the number of trucks overall is not significant enough.

The high percentage of passenger cars in the 'random' traffic is more possible due to business travel and company services that are carried out using vehicles, not registered as commercial vehicles (i.e. green number plates).

The second interesting finding is that the detector based volume counts on the inner circular road of the Tokyo

Metropolitan Expressway were very stable during the study period. This lead to the idea that the network is self regulating the demand. With the traffic information provided at the on-ramps of the Expressway, the network fills quickly up and remains at capacity level, but it does not completely collapses. However, additional measure would be necessary to operate the Expressway optimal.

We have seen clearly that ETC-OD data contains more valuable information than pure detector data. The knowledge of the source and destination of vehicles can be used for more specific control measures, since more information allows a more detailed reaction.

Future work should fuse historical ETC-OD data, with realtime ETC entrance data and detector counts. The historical OD pattern can help to forecast the actual traffic demand, or even individual travel patterns can be identified and used to forecast movement in the network.

This study has shown that aggregated information can be misinterpreted easily since details are hidden. Engineers keep improving algorithms and models to deal with these uncertainties, but in the future our systems will detect more and more individual information and research should already begin to create the frameworks and environments to fuse these sources for the benefit of traffic control.

5. Acknowledgment

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