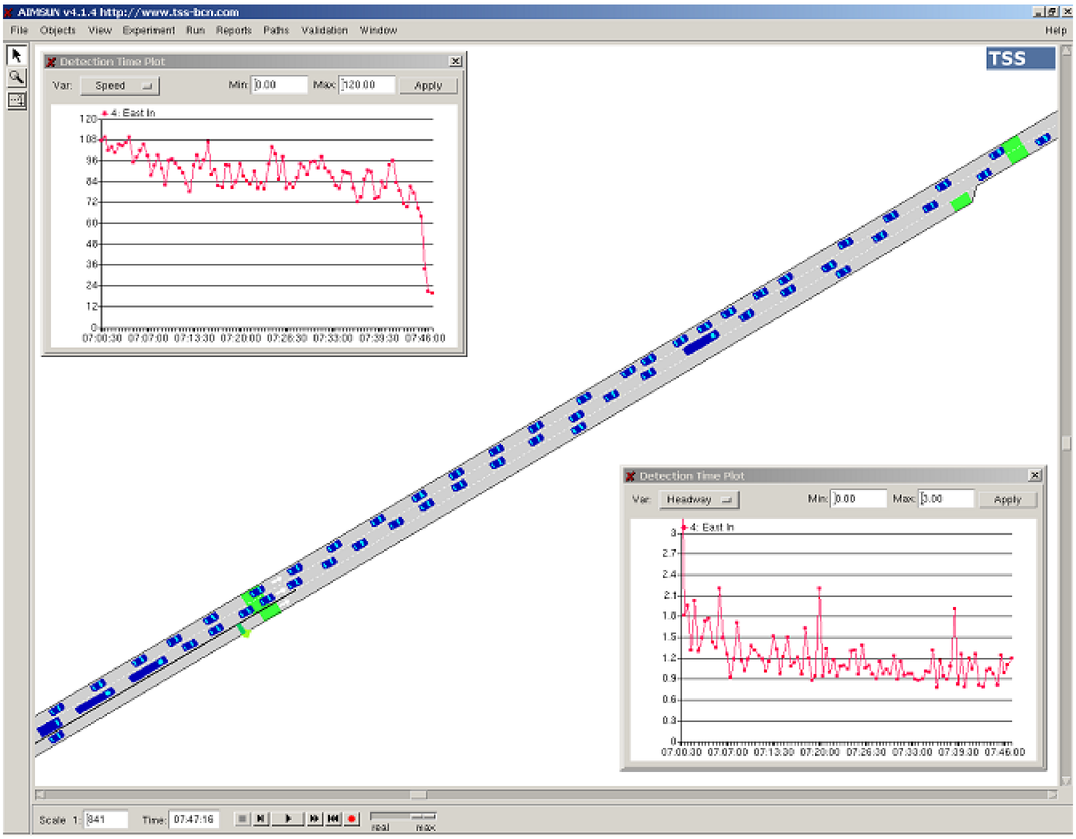

Indicator for microsimulation-based safety evaluation

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Indicator for microsimulation-based safety evaluations

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Abstract

For evaluating ITS (Intelligent Transportation Systems) applications, microsimulation is becoming a more and more useful tool. In the evaluation process, one of the most important steps is the safety analysis. For such work, classical microsimulation outputs give some helpful information which are not sufficient for an accurate analysis in many cases. Nevertheless, the microscopic level of traffic description offers the possibility of knowing the relative position of the vehicles, their speed and deceleration. This paper will explain how a safety indicator can be calculated with these different parameters. This safety indicator is used in a ramp metering case study to illustrate the utility of such output for a safety analysis. This indicator is limited to the rear-end collision probability and gives therefore no information on crossing trajectories conflicts like in junctions.

Keywords

Microsimulation – Safety – Indicators – 3rd Swiss Transport Research Conference – STRC 2003 – Monte Verità

1. Introduction

It is generally agreed that safety analysis play an important role in the implementation and operation of traffic systems. This analysis can be conducted from a preventive as well as from a reactive point of view. The objective of a preventive safety analysis is to identify traffic conditions that are prone to lead to incidents, to determine the relevant factors and to evaluate their importance. This type of preventive analysis can provide indices and indicators which can help traffic engineers to design road infrastructures and implement management strategies which could help reduce the incident likelihood.

A typical use of microscopic traffic simulation is evaluating traffic systems, namely those involving ITS applications. Given the relevance of safety in traffic systems, it becomes obvious that safety analysis should be an important issue in an ITS application evaluation process. The implementation of an ITS application cannot be justified only by the increase in performance of a network if it implies a decrease in user safety. Therefore, the knowledge of the safety level is crucial for making good decisions. However, safety analysis also has an indirect impact on the evaluation process. Indeed, if the network safety level decreases, the number of accidents rises. The presence of new accidents will create congestions and thus a decrease in network performance. The safety and performance evaluations are directly linked, the first having an important influence on the second. In microscopic simulation based evaluation, this phenomenon becomes critical. Indeed, most of the currently existing microscopic traffic simulators are based on the family of car-following, lane changing and gap acceptance models to model the vehicle's behavior (Gabbard (1991)). That makes of microscopic traffic simulation an "perfect world" where no incidents can occur, as far as the basic modeling hypothesis in the underlying car-following models is that vehicles should keep a "safety to stop distance" (Gerlough and Huber (1975), Mahut (2000)). Hence, a decrease in safety doesn't imply a decrease in network performance as it must do. This particular aspect of the microscopic simulation increases the need of a safety analysis tool providing useful micro-simulation safety indicators to be used in the evaluation processes.

In the literature, few articles have dealt with this particular area in microsimulation. Among them are the work of Archer (2000) which has demonstrated the potential of micro-simulation for safety assessments. Minderhoud & Bovy (2001) have presented a first safety indicator but which was only based on the time to collision (TTC) parameter. Finally, Kosonen & Ree (2000) have introduced the SINDI project and proposed an indicator combining the TTC and the speed for a non-constant reaction time simulator (HUTSIM).

This lack of efficient safety indicators has provided the motivation for the research presented in this paper. The research has been carried out with the microscopic traffic simulator AIMSUN (Barcelo & all. (1995),(1998),(1999)) embedded in the GETRAM software environment for traffic modelling and analysis, (TSS (2002)). The paper is structured as follows: Section 2 presents the development of a different approach to get a micro-simulation safety indicator. Section 3 explains how this indicator can be calculated during a simulation process. Section 4 describes its testing on a site in the peripheral motorway of Lausanne in Switzerland. Finally, Section 5 contains the conclusions of this paper.

2. Approach

As explained in the introduction, microsimulation models prevent all type of collision between vehicles. In the particular case of linear conflicts, which is the topic of this paper, the car-following model is in charge of avoiding collision situations. Microsimulation software has its own car-following model, an improved version evolved from the seminal Gipps model (Gipps (1981)), in the case of AIMSUN, but all models are generally based on an important behavioural parameter: the driver's reaction time. Depending on the software, the reaction time can be a global parameter for all the vehicles (including their drivers) or differentiated for each class of vehicle and it can be a deterministic value or a stochastic one (following a distribution rule). But the reaction time of a particular vehicle remains constant during all the simulation. In every case, the car-following model controls the acceleration and deceleration and consequently the headway of the follower vehicle depending on its reaction time. Obviously, the less a vehicle's reaction time is, the less its minimum acceptable headway is.

If this approach offers an excellent approximation of the traffic flows and the relative position of the vehicles, it doesn't permit to extract potential collision situation from the simulation process as they exist in reality. The main reason is that, in the simulation, the headway between two vehicles is in accordance to the reaction time of the follower, but in real world this accordance is not always guaranteed. The big difference between the model and the real behaviour of drivers is that in reality the reaction time is always changing and is not constant during a travel. The reaction time and, consequently, the concentration of the driver are permanently influenced by his state of tiredness, a phone call, a dialog with other passengers, a look in another direction, etc.

As the behaviour model approximates with a satisfactory accuracy the vehicle's movements, the reaction time, which is obtained after the calibration process, represents then the average of the reaction times of the vehicles in reality. Better said, it represents the average of the reaction times the drivers believe they have! A lot of standards fix limits or standard values for reaction time in the field of road transport. Usually, a standard reaction time represents a maximum limit that only few drivers exceed and only during some limited moments of their journey. This standard reaction time is generally used in road geometry studies and planning. For example, the Swiss standards have adopted 2 seconds as standard reaction time which is divided in a physiological reaction period and a mechanical one (Bühlmann & all. (1991)).

The definition of the standard reaction time implies that the potential of collision becomes significant if the headway between two vehicles is below this value. In fact, this statement is only valid if both vehicles are driving with the same speed and have the same deceleration capacity, which is rarely the case. More precisely, the approach to determine the crash potential between to vehicles (a follower and a leader) is to respond to the following question:

If the follower vehicle's reaction time is equal to the standard time reaction (2 seconds in the Swiss case) and the leader vehicle breaks with its maximum deceleration capacity, will a crash occur?

Obviously, the importance of this "hypothetical" crash will be proportional to the difference of speed between both vehicles at collision time (first impact) but also to the speed of the follower vehicle at collision time (potential impacts with other cars or lateral obstacles after the first impact).

3. The "unsafety" density parameter

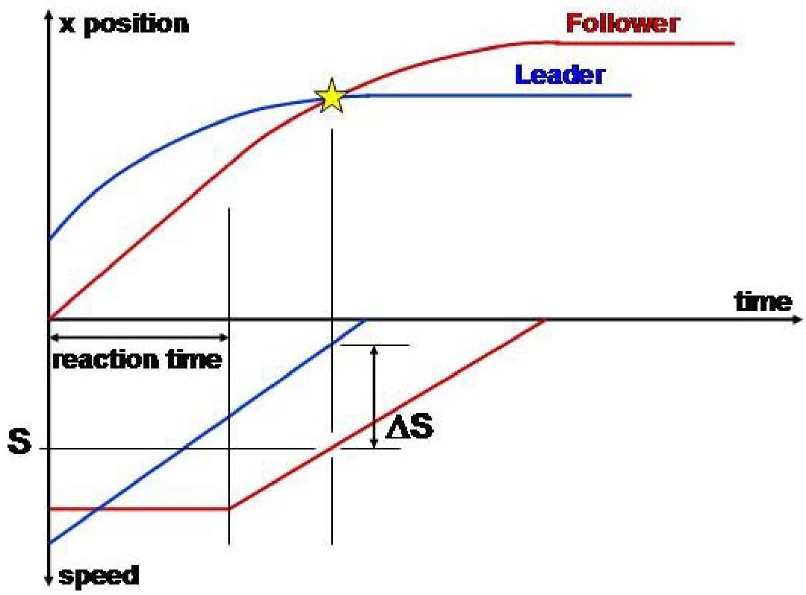
The application of this approach during a microsimulation process is:

During each simulation step, the position, the speed and the maximum breaking capacity of a particular vehicle is known and can be obtained. The same parameters can be obtained for its leader vehicle. The two following hypotheses are taking into account:

- Follower vehicle's reaction time = standard reaction time (2 seconds for the Swiss case)
- Leader vehicle breaks with its maximum braking capacity

With this information and by applying the basic dynamic rules, it's possible to determine if the "hypothetical" crash will occur or not. If it occurs, the speed of the follower vehicle **S** and the difference of speed Δ**S** at collision time can be calculated as shown in figure 1.

Figure 1 DS and S can be calculated applying the basic dynamic rules



As explained in the previous chapter, the importance of this "hypothetical" crash is proportional to **S** and Δ**S**. An "unsafety" parameter could then be defined as the multiplication of both parameters. But this value represents the maximum importance possible. But the real deceleration of the leader vehicle can be obtained (if it is decelerating). So, this maximum value must be multiplied by the ratio **R_d** between the deceleration of the leader vehicle and its maximum deceleration capacity. The "unsafety" parameter can then be defined as:

$$unsafety \quad = \quad \Delta S \cdot S \cdot R_d \quad (1)$$

This parameter determines the level of "unsafety" in the relation between two consecutive vehicles on the road for a determined simulation step. If the "hypothetical" crash doesn't occur or the leader vehicle isn't breaking, the value of the "unsafety" parameter is zero.

But this parameter doesn't give a global situation of the safety in a network or part of it. For that purpose, an "unsafety" density parameter must be calculated. It will be done for each link of the microsimulation model network and for each aggregation period as follows:

$$unsafety\ density \quad = \quad \frac{\sum_{s=1}^{S_t} \sum_{v=1}^{V_t} unsafety_{v,s} \cdot d}{T \cdot L} \quad (2)$$

Where:

V_t = nb of vehicles in the link

S_t = nb of simulation steps within aggregation period

d = simulation step duration [s]

T = aggregation period duration [s]

L = section length [m]

The "unsafety" density (UD) parameter allows to compare the safety level between different links of the network, and to observe its evolution from one time period to another. But the most significant is that it permits comparison between different simulation scenarios and can therefore be the principal indicator to use in a safety assessment process.

4. Case study

The UD parameter was used within the framework of an evaluation study of a ramp metering implementation on one of the Lausanne (Switzerland) by-pass junctions. In this section of the by-pass, frequent congestion problems are reported during peak hours. The traffic flow on this section increases dramatically in some few kilometers by an important traffic input coming from Morges-West (first entrance) and Morges-East (second entrance) junctions. Generally, congestions appear in the second entrance area. A validation process has been conducted for this section demonstrating a good correlation between the UD evolution (for the current situation) and the accident reports provided by the police for this particular area.

A microsimulation-based performance evaluation shows that the implementation of a ramp metering on the second entrance permits to limit the length of the congestion queue and, consequently, the duration of the congestion. At the safety assessment level, clear conclusions are more difficult to get. Indeed, typical microsimulation outputs give two contradictory results:

- Presence of the ramp metering decreases the duration of congestion => decrease in accidents potential => increase in user safety
- The ramp metering strategy implies important variations of speed in the junction area and on the on-ramp => increase in accidents potential => decrease in user safety

Without safety indicators, it's difficult to get a global balance between these two conclusions, but the application of the UD parameter allows it.

Figure 2 shows the one hour average UD for each section of the microsimulation model. The case with ramp metering (RM) is compared to the one without. In both cases, the UD before the first entrance is close to zero because the normal flow allows regular headways and a fluid traffic without important breaking manoeuvres. Between both entrances, the UD is much more important in the case without RM, because the back of the queue moves back close to the first entrance and because the congestion duration is more important. In the case with RM, the safety problem due to congestion appears only after section ID 35. The phenomenon of speed variations in the second entrance area in the case with RM is confirmed by a UD level more important. However, from a global point of view, this graphic permits to say that the case with RM is a safer scenario.

Figure 1 One hour average UD for each of the microsimulation model's sections

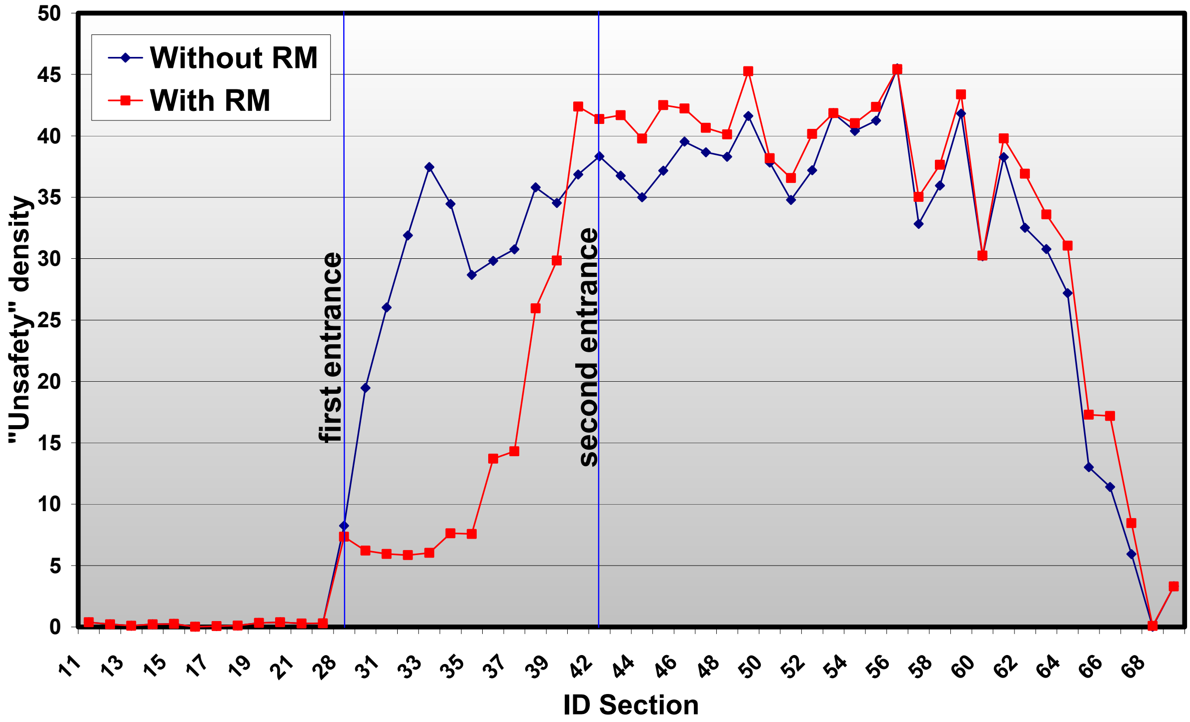
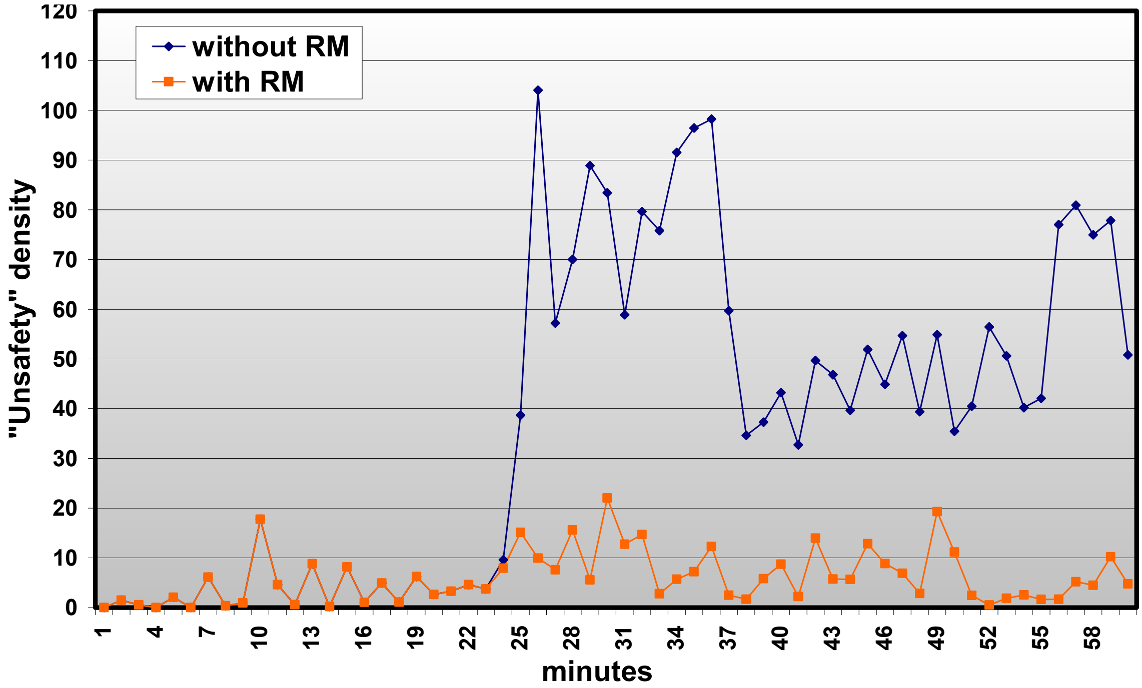


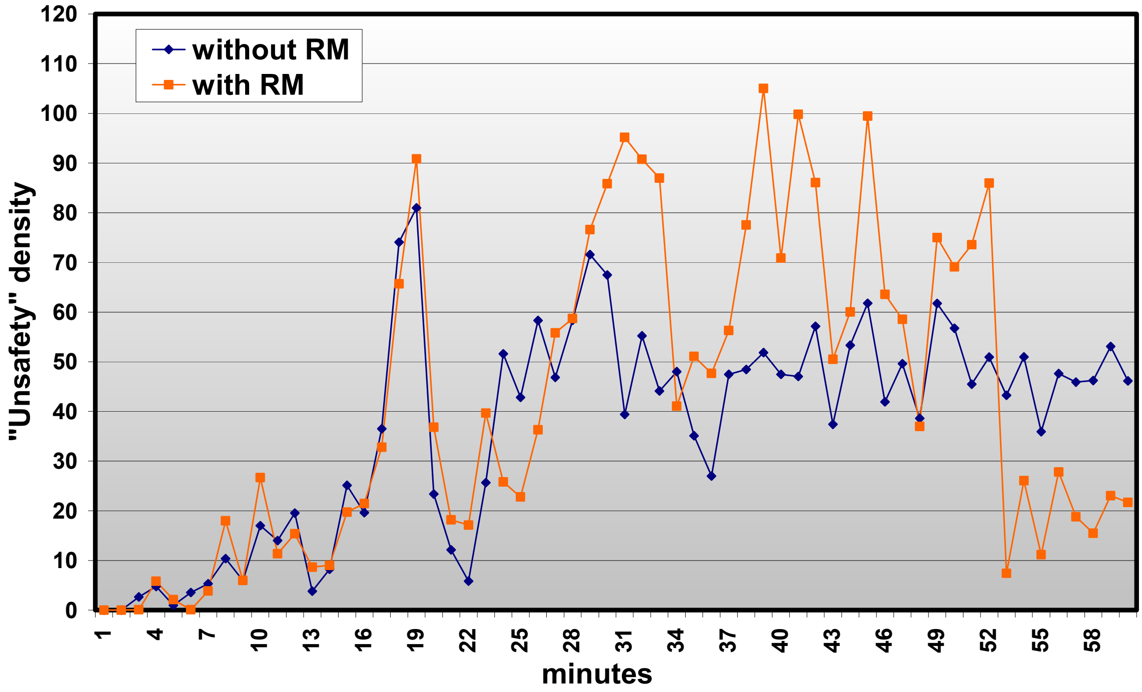
Figure 3 and 4 illustrate more accurately both phenomena. The first one (figure 3) shows the evolution of the UD in section ID 35 (between both entrances) during the simulation process. In the case without RM, the back of the queue enters in the section at minute 25 and stays until minute 38 before entering in the up-stream section. The very important UD level during this period is due to the fact that vehicles entering the queue have to brake very strongly and the risk of a crash is very high. Between minute 38 and 55, the section is under a completely congested regime with a medium UD level due to the "jerked" movement of the cars. After minute 55, the back of the queue is coming back from the upstream section. In the case with RM, the congestion doesn't reach this section and the UD level is the typical one for an important but fluid traffic flow.

Figure 2 Evolution of the UD on a section (ID 35) between both entrances during the simulation process



The second one (figure 4) shows the evolution of the UD in section ID 43, just in the second entrance area. For both cases, the congestion appears on minute 18. As from this time, the evolution differs. In the case without RM, the traffic flow enters in a totally congested regime with a similar UD level as observed in the previous graphic. In the case with RM, the important variation of speed due to the ramp metering strategy implies a higher level of UD. But after minute 52, the congestion period is finished (which is not the case without ramp metering) and the UD comes back to a "normal" level.

Figure 3 Evolution of the UD on a the entrance area section (ID 43) during the simulation process



5. Conclusions

The "unsafety" density parameter is an important indicator for safety assessment and gives more accurate information than typical microsimulation outputs. It allows, among other things, to highlight the difference in safety level between a fluid and a "jerked" traffic flow situation, which cannot be shown by using traditional macroscopic outputs like speed, flow or occupancy. The "unsafety" density parameter is based on the direct interaction between pairs of vehicles, which is the most appropriate for treating safety problems.

However, some limitations must be taken into account. The value of this parameter doesn't really have a sense in itself and must be used only for comparison purposes. The "unsafety" density parameter takes into account only potential rear-end collision and is therefore particularly planned for highways network assessments. If the model calibration is always very important in microsimulation studies, it becomes still more significant when the "unsafety" density parameter is used. Indeed, its accuracy is directly dependent on the quality of the driver's behavioural parameters.

The ramp metering case study has shown how useful was the use of the safety indicator but it could also by applied for the evaluation of applications like Intelligent Speed Adaptation, Variable Speed Limitation Signs and so on. However, some further research has to be done to improve the correlation between the value of the "unsafety" parameter and the real gravity of "hypothetical" crash. Some more validation test should also be done.

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