EFFECT OF LONGITUDINAL JOINTS ON VEHICLE POSITIONING

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ABSTRACT

Motorists generally follow the guidance provided by pavement markings, which are normally marked in coincidence with the longitudinal construction joint, when the joints are necessary. At some locations, however, there may be a mismatch between joints and markings, which may lead the motorists to follow joints instead of pavement markings. In the absence of detailed studies on this topic, an effort was made in this study to evaluate the effects of unmatched longitudinal construction joints and pavement markings on the lateral positioning of vehicles. Sites with such characteristics were identified, and detailed data were collected at one of the sites, using video camera techniques to capture movements of vehicles for longer durations. The video tapes were later reduced to extract necessary information. Distance to the centerline of each vehicle, vehicle type, presence of vehicles in the adjacent lane, traffic volume, and vehicle movement were the main data parameters gathered while reducing the data.

Statistical analysis was carried out using Student's t-test to see the differences, if any. Several comparisons were made for various types of vehicles traveling under different weather conditions and vehicles going straight and turning right immediately after passing the location. The analysis results indicated that the distance to the center line of vehicles traveling in the target lane was statistically different from the expected lateral positioning of the vehicles if they were not affected by the joints.

Based on the analysis of field data, drivers' lateral position seems to be affected by unmatched joints and pavement markings. It might be advisable to make efforts to avoid such occurrences.

INTRODUCTION

Drivers rely on a complex series of visual cues to safely navigate the roads. Longitudinal lines, transverse lines, arrows, words, symbol markings, and special markings constitute different types of pavement markings that guide the motorists in positioning the vehicles on the roads. Longitudinal lines, such as center lines, lane lines, and edge lines, delineate vehicular paths of travel along the roadway by marking the center of road, lanes of travel, and edges of the pavement, respectively. Pavement edge lines provide a visual guide in confining vehicles to a travel lane. Several factors, such as speed, traffic composition, weather conditions, lighting conditions, roadway geometric design features, drivers' physical condition, and personal attributes, may also have an influence on the lateral position of vehicles.

In situations where the pavement is wider than the paving machine, longitudinal construction joints occur. The construction joints are also induced by sawing to prevent random cracking. Pavement markings are normally expected to be marked in coincidence with the longitudinal construction joints. In some circumstances, however, markings do not exactly match with the construction joints. Under these situations, motorists may follow either the joints or the markings as their guiding marks for travel.

The study described in this paper has been primarily conducted to evaluate the effects of unmatched pavement markings and longitudinal construction joints on lateral position of vehicles, both under the daytime and nighttime conditions. The research team undertook the activity of an extensive field study to identify the sites having such characteristics. Detailed field data were collected, and analysis was carried out based on data collected at one site that met the requirements. A questionnaire was also sent to transportation professionals and engineers of the state of Kansas and across the country to solicit their opinions on the unmatched joints and pavement markings. In addition to evaluating the effects of mismatched joints and pavement markings on the lateral position of vehicles, this study was also conducted to provide transportation agencies with guidelines on the placement of longitudinal joints on the pavement.

LITERATURE REVIEW

Even though not much information is currently available on the research carried out on unmatched joints and pavement markings, some studies have been conducted to evaluate the effects of pavement edge lines on lateral position of vehicles. One such investigation was performed by the Missouri State Highway Department in 1969 to study the effect of pavement edge lines on the lateral position of vehicles on rural two-lane highways with widths between 20 ft and 24 ft. (*1*). Vehicle placement was measured using an electronic placement tape with a 20-pen graphic recorder. The main finding was that vehicles generally tended to move closer to the centerline under free-flow conditions after applying the edge lines. In 1971, Hassan confirmed the results of the previous study by utilizing a mechanical traffic counter to measure the vehicles' lateral placement on two one-mile sections that were 18 ft and 24 ft wide in Maryland (*2*). The analysis found that, with edge lines, vehicle position was closer to the centerline of the roadway on both sections.

A research study was conducted by Steyvers and De Waard in the Netherlands in 2000 using video recording equipment to observe vehicles' position changes before and after edge line markings on four narrow rural roadways with pavement widths between 13.5 ft and 14.8 ft (*3*). It was observed that drivers took a more central position after the edge line markings were incorporated on the road.

Sun et al. conducted a study in Louisiana to evaluate the effects of pavement edge lines on lateral position of vehicles (*4*). After thoroughly experimenting with and evaluating several data collection methods, Sun et al.'s research team used air-switch devices (also known as road tubes) for collecting large number of samples as this method was found to be more reliable, less intrusive, and easier to setup in the field. Three traffic counters were used, each connected with at least two tubes for collecting the data. The tubes were fixed in such a manner that the data for vehicles with their right tires touching the one ft section of roadway next to the pavement edge, vehicles with their right tires touching the roadway section between one and two ft from the roadway section, number of vehicles crossing the center line, hourly volume, and operating speed of vehicles were obtained. The data were collected at a total of ten sites on Louisiana rural two-lane highways for at least 24 hours before and after implementation of edge lines. It has been found that with the implementation of edge lines the vehicles followed a more centralized path, which indicates that there is an effect of pavement edge lines on the lateral position of vehicles.

Another study has been conducted in Tyler, Texas to compare the edge-line effects on speed, lateral position, and human perception (*5*). Three two-lane roads with lane widths of 9, 10, and 11 ft were selected for collecting the data and carrying out the analysis. The lateral position of vehicles before and after the edge line treatments were observed under both the categories of stationary observation design and test driving design. On applying the edge line, drivers traveling on the 9 ft lane width highways moved their vehicles closer to the roadway edge, with greatest movement on curved sections. While driving on 10 ft lane width highways, the drivers tended to move slightly towards the center of the road. While traveling on the 11 ft wide lanes, the drivers moved slightly closer to the centerline under all lighting conditions. These results indicate that as the lane width increases the drivers tend to be closer to the centerline under all lighting conditions upon the implementation of edge lines.

In summary, the majority of past studies confirm that there is a significant impact of the pavement edge lines on the lateral position of vehicles.

METHODOLOGY

The methodology section includes the details on field study carried out and the method used for reducing the data. Details of the surveys conducted are not discussed in this paper.

Field Study

The site is a four lane road having two lanes in each direction. The widths of two lanes of the road which were of primary concern were measured as 12.40 ft and 11.85 ft respectively. Longitudinal construction joints were observed to be located at distances of 5.00 and 12.80 ft from the right curb on the section of the road which was considered for analysis. A new lane was added to facilitate the movement of vehicles to and from the railroad station, located closer to the site, shown in the Figure 1 by an arrow mark. With the addition of a new lane, a mismatch between longitudinal construction joints and pavement markings was observed. The movements of vehicles were recorded for longer durations along the section of the road which had unmatched joints and pavement markings. The data recorded were then extracted from the video tapes in the laboratory.

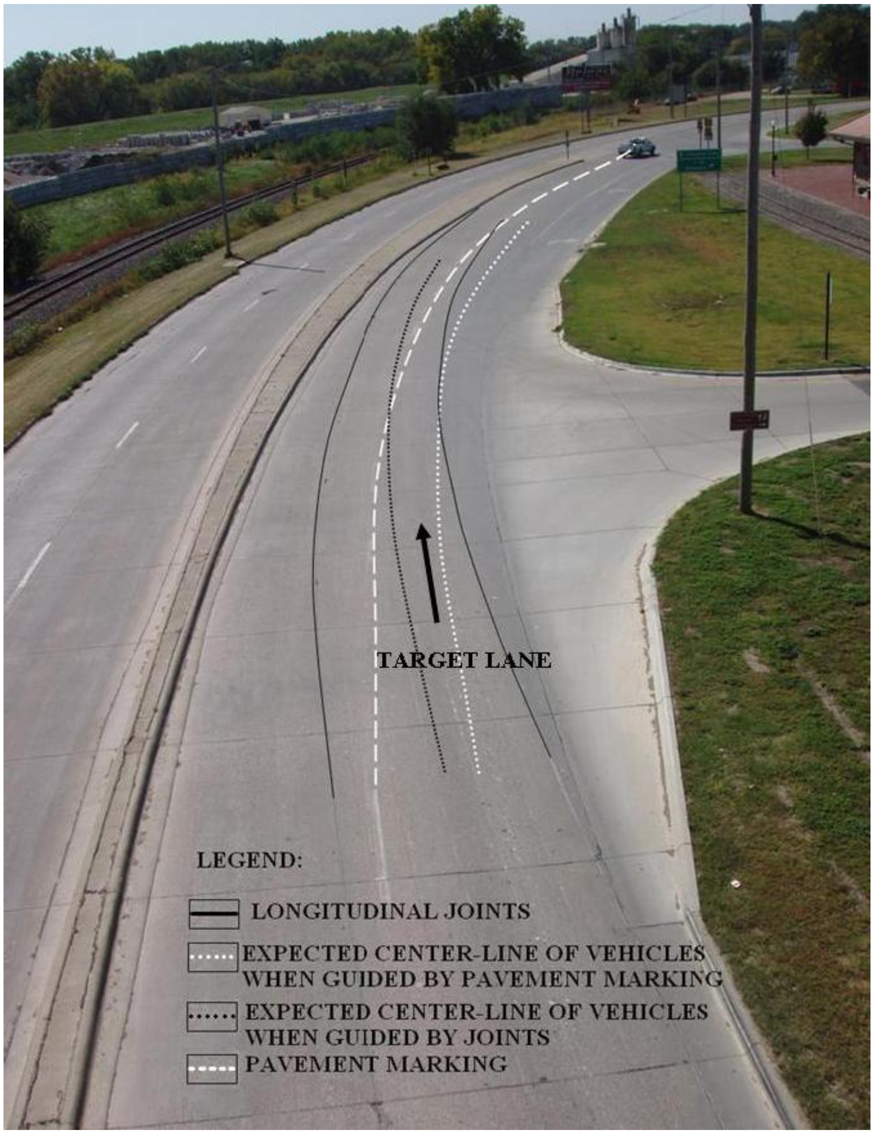

FIGURE 1 Photograph of the data collection site.

Method of Data Reduction

The total width of the two lanes of the road was measured as 24.25 ft. Longitudinal joints were observed to be starting from a specific point along the curve, which were found to be positioned diagonally along the section of the road. The starting point of the unmatched joints and pavement markings across the width of the curve was chosen while reducing the data. The movements of the vehicles along this section of the road were observed. A simple method was adopted for extracting the data from the video tapes. A paper-scale, whose measurements were in the units of divisions of inches was set up on the television screen, such that the zero value (beginning point of measurement) started at the right curb of the road, and the final division was at the end of the left lane. The reference point along the curve which was used in the data extraction process is shown in the Figure 2.

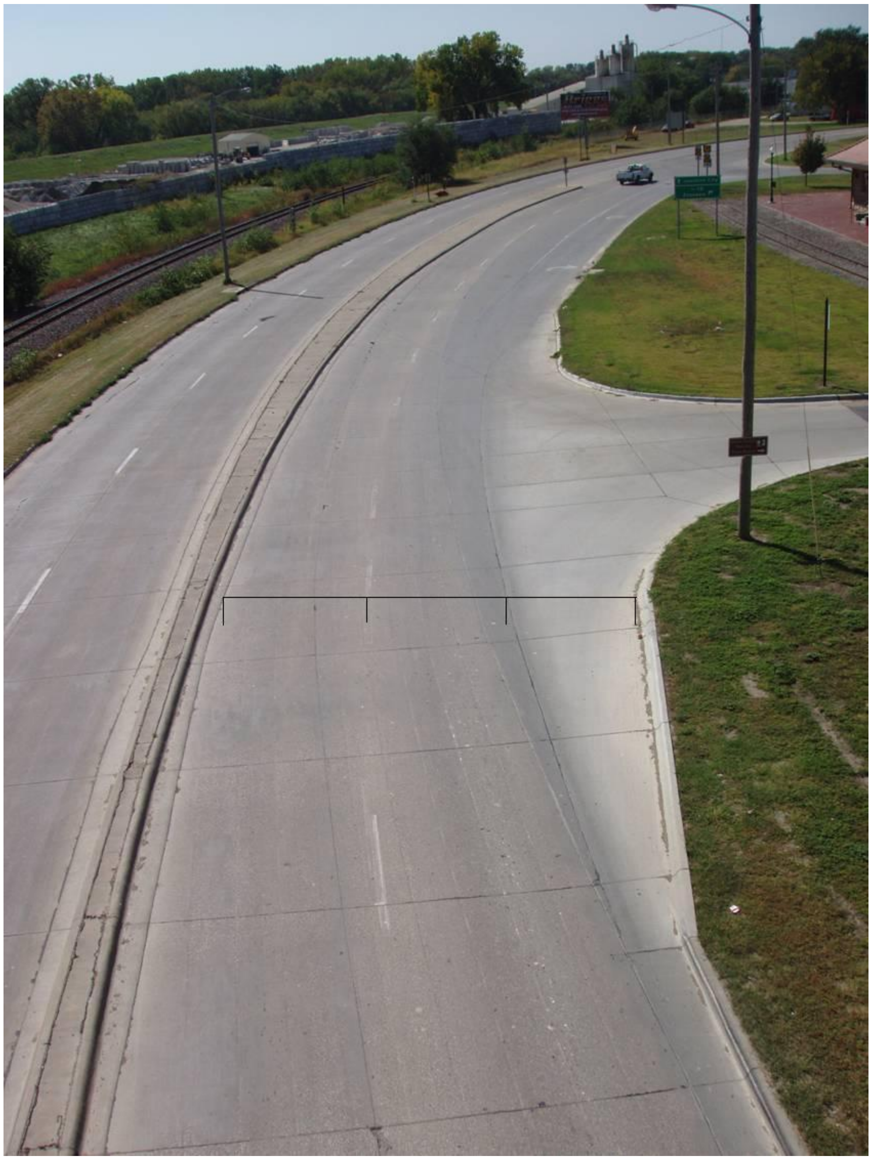

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FIGURE 2 Reference points for data reduction

The distance to the right lateral side of the vehicle traveling in the target lane from the right curb of the road was measured. For all vehicles, a similar method was adopted. The widths of the vehicles were also calculated. Thereby, the distance to the centerline of vehicles from the right curb was computed. These distances were then converted to the real-world dimensions with the help of Excel spread sheets by applying the corresponding scale factor. In addition to the distance to the right lateral side of the vehicle in the target lane, other details such as the type of vehicle, whether there was a vehicle traveling in the adjacent lane, and the movement of the vehicle right after passing the location (i.e. right turn on to the ramp vs. straight) were extracted from the video tapes. Also recorded was the weather condition at the time of the data collection to see whether it affects driver performance.

Data related to a total of 14,050 vehicles was extracted from the video tapes. Vehicles were classified on the basis of weather conditions and movement. Vehicles traveling under good and bad weather, i.e., rainy, snowy, and wet pavement conditions were observed. From the data extracted using the video tapes, 8,518 and 5,532 vehicles were observed to be traveling under good and bad weather conditions, respectively. Vehicles that were going straight and those making a right turn immediately after the portion of the road that had unmatched joints and pavement markings have been observed as 8,714 and 5,336 vehicles, respectively.

DATA ANALYSIS

The Anderson-Darling test was performed to check whether the data satisfied the assumptions of normality. A histogram was also plotted for verifying the same. As the data satisfied the assumption of normal distribution, t-tests were applied for comparing the means. Statistical Analysis Software (SAS) was used for performing the t-tests. For comparing the mean distance to the centerline of travel of the vehicles to a hypothetical value, a one sample t-test was applied. For comparing the means of two groups of data, classified on the basis of weather conditions and movement independent group t-test was applied.

Initially, the entire dataset of 14,050 vehicles extracted from the video tapes was analyzed by one sample t-test using SAS software. If the vehicles are assumed to be guided by the pavement markings alone, the expected position of the centerline of the vehicles from the right curb of the road should have been located at 6.2 ft, which is half the width of the target lane, and which is the distance to the centerline of the target lane. The distance to the centerline of vehicles was used as the variable, and a one-sample t-test was applied with a null hypothesis: The mean distance to the centerline of travel of the vehicles is equal to 6.20 ft and the alternative hypothesis: The mean distance is not equal to 6.20 ft. The value of the t-statistic was obtained as 63.72. As the *p*-value reported in the output was less than 0.05, with 95% confidence, it was said that the mean distance to the centerline of the vehicles from the right curb of the road was significantly different from 6.20 ft It implied that the null hypothesis could be rejected. The *t*-values and *p*-values corresponding to the *t*-tests are reported in Table 1.

TABLE 1 Details of the t-test Based on the Type of Vehicle

Description	Sample Size	Mean (ft)	Std. Dev. (ft)	*t*-value	*p*-value (*)
All vehicles	14,050	7.06	1.61	63.72	<0.0001
Passenger cars	5,878	6.36	1.44	8.36	<0.0001
Vans	4,055	7.42	1.49	51.85	<0.0001
Pick-ups	3,352	7.55	1.48	52.92	<0.0001
Heavy vehicles	765	8.50	1.61	39.55	<0.0001

*** $p<0.05$ (significant)**

In addition to the mean and standard deviation values obtained from the data, the expected mean and the quartile values are also provided for a general idea on the distribution of vehicles across the lane. From the values in Table 2, it can be concluded that the mean (observed mean) differed from the actual mean. Except for the entire dataset (all vehicles) and passenger cars, the expected mean distance to the centerline of vehicles across the width of the road was not within the quartile values.

TABLE 2 Mean, Standard Deviation and Quartile Values for the Data

Description	Sample Size	Mean (ft)	Std. Dev. (ft)	Expected Mean (ft)	Lower Quartile (ft)	Upper Quartile (ft)
All vehicles	14,050	7.06	1.61	6.20	5.69	8.08
Passenger cars	5,878	6.36	1.44	6.20	4.88	7.31
Vans	4,055	7.42	1.49	6.20	6.47	8.08
Pick-ups	3,352	7.55	1.48	6.20	6.85	8.47
Heavy vehicles	765	8.50	1.61	6.20	7.27	9.70

For comparing the mean distances of the vehicles under good and bad weather conditions, an independent group t-test was applied under the null hypothesis: The mean distance to the centerline of travel of the vehicles under normal weather condition is equal to that of the mean value under adverse weather and the alternative hypothesis: The null is not true. As the *p*-value corresponding to the *t*-test was less than 0.05, the null hypothesis, that the mean distance to the centerline of the vehicles under good weather is the same as that of the bad weather was rejected. Hence, with 95% confidence, the mean distance to the centerline of vehicles under good weather conditions is different to that of vehicles under bad weather conditions.

The details of the t-test, i.e., the mean and standard deviation of vehicles traveling under different weather conditions, are reported in Table 3. In addition to the mean and standard deviation, the *p*-values corresponding to the independent t-tests, along with the *F*-statistic and t-statistic values, are also reported. Since the *p*-value corresponding to the *F*- statistic for different vehicles under good and bad weather conditions was found to be less than 0.0001, the method of unequal variance was used for analyzing the data.

TABLE 3 Details of the t-test for the Data Classified on the Basis of Weather Conditions

Description	Weather Condition	Sample Size	Mean (ft)	Std. Dev. (ft)	***F*-test**		***t*-test**	
					***F* value**	**Pr.>*F***	***t*-value**	**Pr.>*t***
All vehicles	Bad	5,532	6.76	1.37	1.57	<0.0001	19.62	<0.0001
	Good	8,518	7.27	1.72				
Passenger cars	Bad	2,290	6.10	1.23	1.55	<0.0001	11.70	<0.0001
	Good	3,588	6.52	1.53				
Vans	Bad	1,773	7.10	1.26	1.62	<0.0001	12.47	<0.0001
	Good	2,282	7.66	1.61				
Pick-ups	Bad	1,210	7.21	1.26	1.69	<0.0001	11.09	<0.0001
	Good	2,142	7.75	1.62				
Heavy vehicles	Bad	258	8.13	1.27	1.82	<0.0001	5.47	<0.0001
	Good	507	8.79	1.71				

*** *p*<0.05 (significant)**

The independent group t-test was also applied to the vehicles classified on the basis of movement, and the results are presented in Table 4. Since the *p*-value associated with the *F*-statistic was greater than 0.05, the method of equal variance was used for analyzing the data. The *p*-value corresponding to independent group *t*-test applied for the data of heavy vehicles tested on the basis of movement was found to be greater than 0.05 which implies that the result is not statistically significant. The other t-tests applied on the data classified on the basis of movement were found to be statistically significant.

TABLE 4 Details of the t-test for the Data Classified on the Basis of Movement

Description	Movement	Sample Size	Mean (ft)	Std. Dev. (ft)	*F*-test		*t*-test	
					F value	Pr.>*F*	*t*-value	Pr.>*t*
All vehicles	Right Straight	5,336 8,714	6.90 7.16	1.61 1.60	1.02	0.34	9.40	<0.0001
Passenger cars	Right Straight	2,221 3,657	6.14 6.49	1.44 1.42	1.02	0.52	9.10	<0.0001
Vans	Right Straight	1,503 2,552	7.16 7.47	1.45 1.51	1.07	0.12	6.07	<0.0001
Pick-ups	Right Straight	1,295 2,057	7.42 7.64	1.46 1.49	1.04	0.46	4.21	<0.0001
Heavy vehicles	Right Straight	317 448	8.58 8.44	1.48 1.69	1.30	0.01	1.19	0.2455

*** *p*<0.05 (significant)**

For checking the effects due to the ambient traffic characteristics, i.e. due to the vehicles in the adjacent lane, independent group t-test was applied. The data of vehicles in the target lane, having vehicles in the adjacent lane was compared to the data without any vehicles in the adjacent lane and results are reported in the Table 5.

TABLE 5 Details of the t-test for the Data Classified on the Basis of Vehicles in the Adjacent Lane

Description	Vehicles in Adjacent Lane	Sample Size	Mean (ft)	Std. Dev. (ft)	*F*-test		*t*-test	
					F value	Pr.>*F*	*t*-value	Pr.>*t*
All vehicles	No Yes	12,591 1,459	7.11 6.70	1.61 1.53	1.11	0.0072	9.47	<0.0001
Passenger cars	No Yes	5,286 592	6.40 5.96	1.44 1.36	1.12	0.0620	7.12	<0.0001
Vans	No Yes	3,663 392	7.46 7.01	1.50 1.36	1.22	0.0100	6.13	<0.0001
Pick-ups	No Yes	2,976 376	7.60 7.20	1.48 1.41	1.11	0.1972	4.83	<0.0001
Heavy vehicles	No Yes	666 99	8.57 8.04	1.62 1.46	1.23	0.1976	3.04	0.0024

*** *p*<0.05 (significant)**

All the results were found to be statistically significant, implying that the difference between the mean distance to the centerline of travel of the vehicles with and without any vehicles in the adjacent lane was statistically significant. From the test results, it may be concluded that the ambient traffic characteristics may have an effect on the lateral position of vehicles traveling in the target lane.

LIMITATIONS

Observations were recorded during the daytime and nighttime conditions for comparing the data. While reducing the data, necessary information could not be extracted during the nighttime conditions as the vehicles and their positions were not visible on the screen. This was one of the limitations of the study. It should be noted that detailed data collection was limited to just one site because of the difficulty in identifying more sites with similar characteristics. This research needs to be expanded by identifying and collecting data from sites with similar characteristics to make the findings more reliable. The details on the regular drivers and non-regular drivers were also not considered. Probably this information could be helpful in getting useful information.

The speed variation of vehicles was difficult to obtain from the video tapes recorded. Future research can be done in this context.

CONCLUSIONS

If the lateral position of vehicles is assumed to be guided by the pavement markings alone, the mean distance to the centerline of travel should have been located at 6.20 ft. The average value of the distance to the centerline of vehicles calculated from the data recorded was equal to 7.06 ft. Since the longitudinal joints were located at 5 and 12.80 ft away from the right curb of the pavement, the drivers may have followed the joints instead of the markings.

The results of the t-tests applied for the data classified on the basis of weather conditions, movement and vehicles in the adjacent lane were found to be statistically significant, except for the heavy vehicles tested on the basis of movement. It indicates that there was a difference between the mean distances to the centerline of travel for the vehicles under different conditions.

The analysis of field data implies that the mismatched longitudinal construction joints and pavement markings seem to have an effect on the lateral position of vehicles. There could be a possibility for the drivers to confuse the joints for the pavement markings and be guided by them, which may create some safety problems. The standard specifications of 35 states have provisions concerning the unmatched joints and pavement markings. Some states do not have any information regarding the positioning of longitudinal construction joints with respect to pavement markings. It would be better if the standard specifications of all the states had provisions pertaining to the mismatch.

Based on analysis of field data, it may be concluded that the unmatched longitudinal construction joints and pavement markings may have an effect on the lateral position of vehicles.

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