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Volume I - Final Technical Report
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16. Abstract

An extensive study of the dynamic performance of multitrailer vehicles, and the influence of double-drawbar dollies (C-dollies) on that performance is reported. Six vehicle configurations (five double-trailer combinations and one triple) are considered. The performance of the six vehicles is examined using a matrix of seven different converter dollies (an A-dolly and 6 C-dollies) and 15 different vehicle parametric variations (e.g., center-of-gravity height, tire-cornering stiffness, roll stiffness, etc.). The performance quality of the vehicles is judged using measures such as rearward amplification, yaw-damping ratio, static rollover stability, offtracking, and dynamic-load-transfer ratio.

The results from over 2800 computer simulation runs are used in a statistical regression analysis to produce simple methods for predicting performance numerics for A-trains based on vehicle parameters easily obtained in the field. Performance improvement factors for C-dollies are also developed. Recommendations for minimum performance standards and for C-dolly specifications are also reported.

An economic analysis comparing A-dollies and C-dollies is presented. This analysis is based on data from a field survey and the literature and includes purchase, start-up, operational, and accident cost considerations.

The report also includes the ancillary performance issue of backing ability.

Extensive appendices are included in Vol II. Vol III is a Technical Summary.

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VOLUME I: FINAL TECHNICAL REPORT

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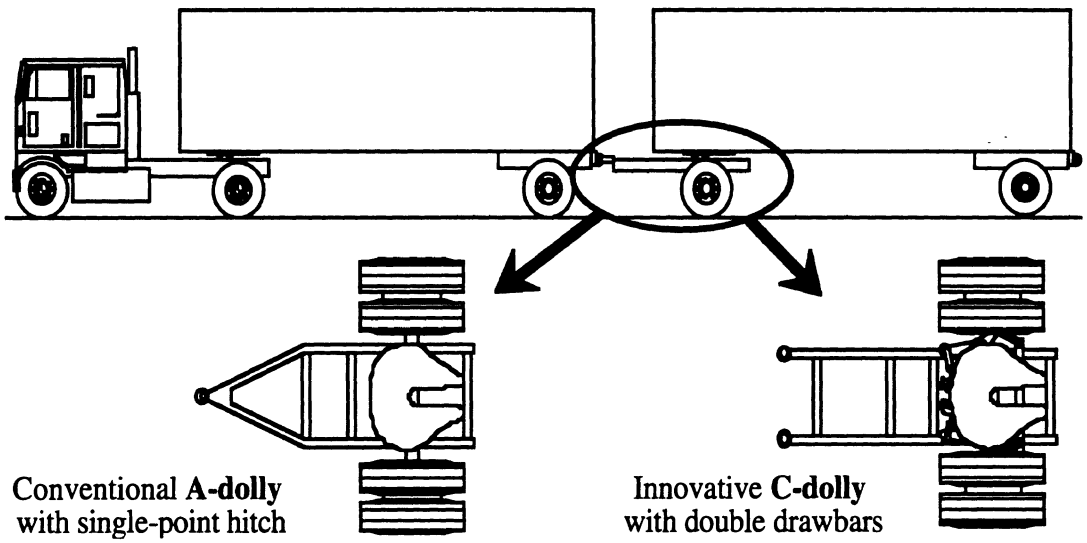
TECHNICAL SUMMARY

This research project has sought to establish a practical method for specifying innovative converter dollies (so-called C-dollies) for use in coupling the trailers of double- and triple-trailer truck combinations. Across the U.S. today, such truck combinations are virtually always equipped with the conventional A-dolly. This type of coupling device is known to allow undesirable forms of dynamic instability during emergency evasive maneuvering. The problem occurs during evasive maneuvering when the rearmost trailer of the vehicle may respond in a very exaggerated fashion, possibly resulting in a rollover. This behavior has been compared to "cracking the whip" and is referred to technically as rearward amplification. The C-dolly is attractive for its ability to reduce rearward amplification substantially, thereby increasing the safe maneuvering capability of the whole vehicle. This study has quantified the improvement in dynamic performance attainable with C-dollies. It has also evaluated the tradeoff between operating costs and safety benefits that might derive from the widespread use of this type of coupling equipment.

The fundamental conclusion of this study is that, from a dynamic performance point of view, the self-steering C-dolly[1] is unequivocally superior to the conventional A-dolly when



The two styles of converter dollies

[1] Most C-dollies include a mechanism to allow steering of the dolly wheels. Self-steering styles allow steering through castering but with some restraint that tends to keep the wheels on center. Other styles control steering as a function of trailer articulation.

certain minimum specifications for the C-dolly are met. Conversely, from the economic point of view of the truck operator, it is equally clear that potential savings from reduced accident experience are generally not adequate to compensate fully for the additional expenses associated with using the heavier and more expensive C-dolly.

The detailed results of the study show that among all of the more common types of multitrailer truck combinations in service, some are in distinct need of the performance improvement that C-dollies can provide, while others do not appear to warrant such hardware. One important result of this study is the development of very simple methods for predicting the relevant dynamic performance qualities of truck combinations when equipped with A-dollies and the performance improvements that can be expected through the use of C-dollies. These elements, along with recommended minimum performance standards, provide a means for judging individual vehicle configurations to determine whether or not they are appropriate candidates for C-dolly use. The overall research effort, together with results from a prior FHWA study and extensive work conducted for the Roads and Transportation Association of Canada, has established a substantive basis for C-dolly specifications.

No full-scale vehicle testing was conducted for this study. Rather, analysis of the statistical accident record, field survey work, and a large computerized sensitivity study of vehicle dynamic behavior served as the primary research methods. A variety of individual topics were investigated and are briefly discussed below.

- The **safety benefit** of C-dollies, in terms of reduced accident costs, was inferred by considering a hypothetical future state in which C-dollies would become universal in double-trailer operations. Per this premise, the analysis showed that 13 percent to 40 percent of the rollovers now experienced by these vehicles could be prevented with C-dollies. This would result in an accident cost savings equal to approximately $0.01 per dolly-mile of operation.

- The **operating costs** of C-dollies were examined with the aid of survey data obtained from 30 cooperating trucking companies. These data, when employed in an economic model covering ten years of operation, showed that the net operating costs (including the above safety benefit) increase by about $0.029 per dolly-mile as a result of using C-dollies. Eighty-five percent of this incremental cost was due to the higher weight of the C-dolly and the resulting loss of payload capacity. Consequently, an incentive increase in legal weight allowances of as little as 1000 pounds could more than offset the increased cost of using C-dollies. Greater weight allowance incentives might be a very effective means of promoting the broad use of C-dollies.

- **Vehicle performance,** as a function of vehicle configuration and dolly parameters, was examined in terms of rearward amplification, roll stability, offtracking, ability to

back up, and total strength demands on the dolly. The results of this extensive simulation work support the following:

- Double- and triple-trailer truck combination can be prequalified using *simple predictor* formulas developed in this study. When baseline performance levels for the vehicle equipped with A-dollies are less than specified levels, operation with C-dollies would be advised.

- Among the primary types of C-dolly designs, the *controlled-steering* C-dolly was found to be generally lower in performance than another version called the *self-steering* C-dolly. Thus, among current designs, the self-steering type of dolly is recommended whenever a C-dolly is warranted.

- One property of the self-steering C-dolly was seen to transcend all others in importance for ensuring good stability characteristics. This property addresses the level of tire side forces that can be sustained before the initiation of self steering. The minimum level of this characteristic specified in the study would ensure that the dolly tires normally run straight ahead and, therefore, will provide an adequate level of dynamic stability, while still allowing self steering when the vehicle conducts very tight turns, such as at intersections.

- A number of secondary properties of the dolly also warranted specification. These included the tongue length, the torsional strength of the dolly frame, and the strength of the dolly's pintle hitch connections. An additional specification on the torsional *stiffness* of the dolly structure is explicitly not recommended, even though some stability improvements accrue from high values of this property. The stiffness issue seems best left up to the dolly designer since arbitrarily high values imposed by specification would carry the penalty of fatigue damage to the coupled trailers, as well as a higher weight penalty for the dolly.