Executive Summary Report to the Michigan State Legislature and Steering Committee

regarding the

16-ft Wide Mobile Home Study

by

The University of Michigan
Transportation Research Institute

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(Volume 1)

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16. Abstract

This document represents the final reporting of findings from a study of 16-foot wide mobile homes by the University of Michigan Transportation Research Institute on behalf of its sponsors, the Michigan State Legislature and its intermediary steering committee comprised of representatives from the Michigan Department of Transportation, the Michigan Department of Commerce, the Michigan State Police, and the manufactured housing industry. A primary purpose of the study is to evaluate "the mobility, turning ability, and transporting of mobile homes that are more than 14-1/3 feet wide..." as described in Section 10 of Senate Bill No. 142 from the regular session of the 1991 Michigan State Legislature. The study is focused on issues specifically related to differential effects that mobile home width (i.e., 16-ft widths versus 14-ft widths) may have on adjoining traffic and maneuverability. Recommendations are offered regarding safe operation and allowed access to state highways for such vehicles.

The study relies on both *field data,* collected this past October and November on Michigan highways to evaluate driver behavior in the presence of mobile homes, and *computer analysis* to evaluate the low-speed maneuverability of mobile homes as well as their highway-speed dynamic characteristics.

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1.0 Introduction

This Executive Summary (Volume 1) contains the conclusions and recommendations from a study (contained in total in Volume 2) of 16-foot wide mobile homes by the University of Michigan Transportation Research Institute on behalf of its sponsors, the Michigan State Legislature and its intermediary steering committee comprised of representatives from the Michigan Department of Transportation, the Michigan Department of Commerce, the Michigan State Police, and the manufactured housing industry. A primary purpose of the study was to evaluate "the mobility, turning ability, and transporting of mobile homes that are more than 14-1/3 feet wide..." as described in Section 10 of Senate Bill No. 142 from the regular session of 1991. Prior to Senate Bill No. 142, transporting of mobile homes wider than approximately 14 feet was not permitted in Michigan. Under Bill No. 142, mobile homes up to 16-feet in width are allowed by permit to operate for a period of one year. During this period of time, the current study was conducted to help evaluate how wider mobile homes in the state may affect traffic operations and how their increased width may affect their mobility on representative Michigan highways and intersections.

The study is focused on issues specifically related to *differential* effects that mobile home width (i.e., 16-ft widths versus 14-ft widths) may have on adjoining traffic and maneuverability. The study offers recommendations to state agencies regarding safe operation and allowed access to state highways for such vehicles. It should also be noted that in order to properly discriminate differences between 14-ft wide and 16-ft wide tractor/home combinations, a certain fundamental understanding of the basic behavior of this general class of vehicles is required and is accordingly pursued in various portions of the report.

The study relies on both *field data*, collected this past October and November on Michigan highways to evaluate driver behavior in the presence of mobile homes, and *computer analysis* to evaluate the low-speed maneuverability of mobile homes as well as their highway-speed dynamic characteristics. The field data were collected by observers following 13 different mobile homes using surveillance vehicles equipped with video cameras and time measurement equipment designed specifically for measuring certain motion characteristics of the mobile home and adjoining traffic. Results from that work appear primarily in Section 3 of Volume 2. The first portion of Section 3 (Vol. 2) reports on direct in-field measurements by observers (and previously contained in this study's

Interim Report in January). Further analysis of the videotape logs from the same field work are reported in the second portion of Section 3 (Vol. 2) and supplement those findings reported previously.

In Section 4 (Vol. 2), computer analyses are used to examine the low-speed turning and mobility of tractor/home combinations at intersections and freeway exit ramps. Highway speed analyses of how tractor/home combinations are affected by crosswinds and highway cross-slopes are addressed in Section 5 (Vol. 2). Similar analyses related to braking performance issues and weight distribution influences on tractor/home directional stability are examined in Section 6 (Vol. 2). Finally, conclusions and recommendations from the total project work appear in Section 7 (Vol. 2) as well as in Section 2 of this Volume.

Two previous studies [1, 2] conducted twenty years ago by the Michigan Department of State Highways for 12-ft wide and 14-ft wide tractor/home combinations are also noted because of their focus on similar issues. These two studies provide useful background for this discussion and the present concerns of transporting even wider home units on Michigan highways.

The authors would like to thank and acknowledge all the members of the steering committee who provided helpful guidance, suggestions, and technical assistance throughout the course of this study. The committee chairman, Mr. Richard Kuzma of MDOT, was especially helpful and acted as the primary liaison person with the research team at UMTRI. Mr. John Kanillopoolos from MDOT provided many useful suggestions and technical assistance related to highway design and geometrics. Thanks also to the Michigan State Police representatives, Insp. Bill Mohr and Sgt. Eric Johnson, and to their colleagues at the Coldwater and Grass Lake Weigh Stations for conducting axle load measurements on 26 tractor/home combinations. The Michigan Manufactured Housing representative, Mr. Tim DeWitt, likewise provided much appreciated assistance in obtaining basic design information on the home units examined in the study. Thanks also to Mr. Steve Zamiara of the Michigan Department of Commerce and to Mr. Dave Morena of the Federal Highway Administration for their helpful comments and suggestions. Lastly, the assistance of John Koch and Mike Campbell of UMTRI is acknowledged for their help in instrumenting the surveillance vehicles and collecting field data.

The funding for this study was provided by the Michigan Department of Transportation, the Federal Highway Administration, and the Michigan Department of Commerce.

2.0 Conclusions and Recommendations

—•— *Conclusions* —•—

The conclusions seen here summarize the basic findings described in Sections 2 through 6 of Volume 2. (Those conclusions for which home width per se plays a significant role are explicitly noted. Those conclusions that do not identify home width explicitly as a factor may be applied to homes of all widths, i.e., 14-ft, 16-ft, and 18-ft wide units.) Recommendations appear in the section immediately following the conclusions.

The results obtained from the field study observation data indicate that:

- During passing events on multilane divided highways, 16-foot wide tractor/home units encroached into the passing lane more than 14-foot wide units on average. Specifically, 16-foot wide units were observed encroaching an average 40.3% of the time for each passing event, while 14-foot wide units were observed encroaching an average of only 20.5 % of the time for each passing event.

- On multilane divided highways no significant relationship was found between the shoulder encroachment behavior of passing vehicles and the width of the tractor/home unit being passed.

- Passing vehicles (on multilane divided highways) were found to encroach onto the shoulder nearly two-thirds of the time regardless of the width of the tractor/home unit being passed.

- On two-lane, undivided roadways, drivers approaching an oncoming 16-foot wide tractor/home unit were more likely to use the shoulder than were drivers approaching 14-foot wide units. Approximately 57% of oncoming drivers used the shoulder when approaching a 16-foot wide unit; only 32% of drivers used the shoulder when approaching an oncoming 14-foot wide unit.

- The collected data also show that tractor/home units of both widths regularly travel in excess of the maximum speed specified on their travel permits. The 16-foot wide units were found to be travelling at almost the same average speeds as the 14-foot wide units.

- The field data collected under this study were focused almost exclusively on home shipments that entered the state from manufacturers and were travelling to dealer sites. No data were collected for home shipments that originated at in-state dealers and travelled to the final site locations of the homes. Consequently, the data reported here do reflect the more idealized travel portion of home shipments in the state that make use of higher quality freeways and roads. Even under these more ideal travel conditions, the data collected under this study still display a significant amount of time and miles spent on two-lane undivided highways. It should likewise be noted that the second portion of most deliveries (dealer to site) rely to an even greater extent on two-lane undivided secondary highways and county roads.

Videotape analyses from the field study completed since the Interim Report indicate that:

- 16-foot wide homes encroach into the left adjacent lane more often than do 14-foot homes.

- 16-foot homes use the right shoulder a greater proportion of the time than do 14-foot homes.

- Homes of both widths are more likely to encroach into the left adjoining lane when travelling on roadways with 11-foot lanes than on roadways with 12-foot lanes.

- Encroachment into the left adjacent lane is related to the condition of the right shoulder such that the poorer the condition of the right shoulder, the more time homes spend encroaching in the left adjacent lane.

- Homes of both widths spend less time using the right shoulder when that shoulder is in poor condition. This is the probable reason greater left adjacent lane encroachments were observed for roadways with right shoulders in poor condition.

- Homes of both widths are more likely to spend time encroaching into the left adjacent lane on two-lane roadways than multilane divided highways.

- Both cars and trucks are more likely to use the shoulder when passing 16-foot wide homes than when passing 14-foot wides, and trucks are even more likely to use the shoulder when passing than are cars.

- Cars are more likely to use the shoulder when passing homes on roadways with 11-foot lanes than on those with 12-foot wide lanes. In general, vehicles were more

likely to use the shoulder when passing 16-foot wide homes than 14-foot wide homes independent of lane width. Insufficient data exist to determine if the use of shoulders for trucks follows the same pattern.

- Shoulder use of cars passing homes increases as the shoulder conditions improve. In general, vehicles were more likely to use the shoulder when passing 16-foot wide homes than 14-foot wide homes for all shoulder conditions. Insufficient data exist to determine if the use of shoulders for trucks follows the same pattern.

- Both cars and trucks were more likely to travel on the shoulder when approaching homes on two-lane undivided roadways (in the oncoming direction) than when passing on multilane divided highways (travelling in the same direction). Trucks were more likely than cars to use the shoulder when passing on both road types. In general, vehicles were more likely to use the shoulder when passing 16-foot wide homes than 14-foot wide homes when travelling on either multilane divided or two-lane undivided roadways.

- The results indicating increased shoulder use by vehicles passing tractor/home combinations suggest that the safety of these passing vehicles is likely degraded. This safety degradation is based on the fact that passing vehicles are more likely to use the shoulders, thus reducing the margin of error available to the passing vehicles. In addition, shoulder surface conditions are generally poorer than surface conditions of the normal travel lanes and can lead to increased control difficulty for the passing vehicles.

- It may sometimes be argued that because there is a lack of accident data demonstrating a clear relationship between manufactured home transport and accident experience that there is no safety degradation resulting from the movement of homes. This is not necessarily true if accidents, or near-accidents, involving vehicles in the vicinity of home units do occur and are indirectly influenced by their presence (e.g., traffic congestion, visibility restrictions, etc.). Degradation in safety margins can still occur even if it does not lead to specific, measurable, and well defined crash events that are ultimately recorded in the accident record.

The low-speed turning analyses described in Volume 2 indicate that:

- Both 14-ft, 16-ft wide, and 18-ft wide tractor/home units require considerably greater turning width at intersections (an additional 9 feet or more) than many other highway vehicles —including several types of large combination vehicles (doubles and triples).

14-ft wide by 80-ft long home units require approximately 35 feet of swept path width in turning through a normal right-hand intersection; 16-ft wide homes require 37 feet; and 18-ft wide units about 39 feet .

- Mobile home *width* is nearly as important a factor as *length* in contributing to the amount of space required by such vehicles when turning at intersections. Approximately half of the required turning space is due to the length of such vehicles; the other half of required turning space is attributable to their width.

- Curb clearance levels at turning intersections are diminished by approximately three feet when the home width is increased from 14-ft to 16-ft, and diminished by approximately six feet when the home width is increased from 14-ft to 18-ft.

- Minimum curb radii need to be increased approximately 7 feet for every 2 feet of additional home width in order to provide a comparable level of curb clearance.

- The more restrictive intersections likely encountered by tractor/home combinations in Michigan need to be at least 47 feet in radius for 14-ft wide homes, 53 feet in radius for 16-ft wide homes, and 60 feet in radius for 18-ft wide homes. These curb radii provide 1) minimal curb clearances while conducting 90-degree right-hand turns, and 2) avoid undesirable initial offsets by homes into oncoming traffic. (Curb radii less than these levels require tractor/home combinations to encroach, prior to the start of the turn, into oncoming traffic lanes in order to complete the turn with no curb-side conflicts.)

- Overhang or swing-out behavior exhibited by the outside rear-end of mobile homes during tight turning, as occurs at intersections, is particularly large (2 feet or more) when compared with overhang of conventional highway vehicles. A 16-foot wide home would increase this swing-out encroachment motion by an additional 1-foot margin beyond that seen for a 14-foot wide home; an 18-ft wide would increase this encroachment motion by an additional 2 feet over 14-ft wide homes.

- Encroachments into oncoming (or opposing) traffic lanes is the primary means available to tractor/home combination drivers for performing turns at more restrictive intersections (those existing intersections with smaller than required curb radii and not originally designed to accommodate vehicles of this size). The amount of required encroachment increases significantly with home width.

- A tractor/home unit that is just barely able to turn through a given intersection with minimal clearance, will require an additional 4 feet of offset (towards or into oncoming traffic lanes) in order to also turn through the same intersection with minimal clearance if its width is increased by 2 feet. This magnification, or doubling, of required space deriving from increased home width is significant, since all of the additional space required by the tractor/home combination (4 feet in this case) is obtained by offsetting the tractor/home combination towards oncoming traffic lanes. (A comparable 18-ft wide home would require an initial offset of 8 feet toward oncoming traffic lanes.)

- Most freeway exit ramps under low speed turning conditions do not provide special clearance problems for 14-ft wide and 16-ft wide tractor/home combinations. However, 18-ft wide homes will require the tractor driver to steer along an outer (larger radii) path on many ramps in order to provide additional clearance along the inner shoulder for the home. (On a 300-ft radius turning ramp, with the tractor centered in the turning lane, the wheel sets under an 80-ft long home unit will offtrack towards the inside of the curve approximately 6 feet at speeds less than 8 mph.)

The computer analyses of highway-speed conditions presented in Volume 2 indicate that:

- For tractor/home combinations operating at speeds of 45 mph under idealized (steady and non-varying) crosswinds of 25 mph, the rear-end of 80-ft long home units will offtrack laterally about 1 foot. These results are largely independent of width, though wider (and thereby heavier) home units do exhibit approximately 5% less offtracking (0.5 inches) per 2 feet of additional home width under these conditions.

- The same analyses indicate that when realistic crosswind profiles that include natural, random-like variations are accounted for as well, the level of peak lateral offtracking exhibited by the same set of tractor/home combinations increases from 1 foot to approximately 1.5 feet.

- Increasing vehicle speed from 45 mph to 55 mph (22%) increases the crosswind offtracking amount by an additional 13%.

- Home units that are 20% lighter than the average home unit examined here, will also show increases of 20% in crosswind offtracking levels.

- The random-like and variable component of natural crosswinds is an important characteristic that acts as an on-going excitation of the tractor/home combination system

and that acts to amplify lateral space demands (versus more idealized, non-varying crosswind disturbances).

- The influence of most highway cross-slopes on offtracking of tractor/home combinations while travelling in a straight-line direction is small and largely independent of width. A highway having a 2% cross-slope induces about 0.22 feet of offtracking at the end of an 80-ft long home unit.

- Superelevated highway curves (freeway connectors with operating speeds of 45-55 mph), require less than a foot of additional lateral space to accommodate tractor/home combination offtracking tendencies along such curves. (Along a 1270-ft radius curve with 6.7% superelevation, the wheel sets under an 80-ft long home unit will offtrack towards the inside of the curve nearly 1 foot at a speed of 45 mph, and approximately 0.5 feet at a speed of 55 mph.)

The braking performance and hitch load analyses seen in Volume 2 indicate that:

- The braking capabilities of most tractor/home combinations are dependent primarily upon the towing tractor for stopping power. Since the tractor unit constitutes only 35% or so of the total combination vehicle weight, the braking ability of such vehicles is notably poor. Consequently, a strong disparity exists between the stopping capability of tractor/home combinations and most other highway vehicles.

- From speeds of 45 mph on dry high-friction pavements, approximately 200 feet of stopping distance is required for tractor/home combinations. Passenger cars typically require half this stopping distance from the same speed. Heavy trucks require about two-thirds this distance.

- From speeds of 55 mph on dry pavement, more than 300 feet of stopping distance is required for tractor/home combinations. Again, passenger cars typically require less than half this stopping distance and heavy trucks about two-thirds this distance.

- Slightly longer stopping distances are required for wider homes because of their increased weight.

- Over-braking by the tractor driver (inadvertent or emergency-induced) will typically result in an unstable jackknife response. This undesirable tendency further reduces the margin for error and controllability for the tractor driver during braking conditions.

- Tractor/home oscillatory behavior (or sway) at highway speeds is very sensitive to the hitch load percentage (percentage of home weight carried by the tractor at the hitch location). A normal or design value of 24% provides good damping and prevents unwanted oscillatory behavior. Reducing the hitch load percentage to a level of 12% can produce unstable oscillatory responses. Hitch load percentages in the vicinity of 18% produce moderate amounts of oscillatory behavior.

- Increasing vehicle speeds from 45 mph to 55 mph results in less system damping and increases the likelihood of oscillatory behavior, particularly when hitch load percentages fall below 20%.

- Wider and longer home units exhibit slightly less damping (or slightly greater oscillatory behavior) than shorter and narrower home units for the same speed conditions and hitch load percentages.

- Housing manufacturer design guidelines (described in Volume 2) are reasonable rules to follow in providing for adequate hitch load percentages and the number of axles on home units. The "2/3 rule" regarding axle locations results in a 24% hitch load percentage, provided the home unit has its weight uniformly distributed along its length.

— • — *Recommendations* — • —

The following recommendations, in general, identify tractor/home combinations operating along two-lane undivided highways as the primary focus of concern. The concern is especially magnified along such routes that have narrow and/or deteriorating shoulders, particularly for oversize homes wider than 14 feet. This scenario frequently results in tractor/home units encroaching across undivided highway centerlines into oncoming traffic lanes. This is not normally viewed as a reasonable method of ordinary transport practice for highway vehicles. Consequently, current transport of 16-ft wide homes along two-lane highways with particularly narrow shoulder widths is not supported by this study until shoulder width upgrades along these highway sections are undertaken. An interim/transitional period of operation for 16-ft wide homes is suggested as a possible temporary solution for permitting 16-ft wide transports to continue to operate during any shoulder reconstruction period. The study does not support a status quo position that permits continued indefinite access by oversize 16-ft wide homes to those two-lane undivided highways having limited width capacities.

In general, divided multilane freeway operations in rural, low traffic density areas with wide shoulders do not present a significant problem for transporting 14-ft or 16-ft wide homes. However, these same vehicles must ultimately access narrower secondary roadways. In doing so, their mobility is restricted and their presence reduces the normally accepted vehicle-to-vehicle spacing expected by other highway users. Accordingly, the aforementioned concerns regarding tractor/home combinations operating along two-lane undivided highways will still frequently apply in many cases.

The specific recommendations based upon the findings and observations of this study are that:

Highway Shoulder Upgrades

- If the State determines that it is in its interest to allow the movement of 16-ft wide homes over the highway, paved shoulder widths along two-lane undivided highways likely to be used by tractor/home combinations in Michigan, and not currently meeting recommended minimum widths (indicated below), should be upgraded to those recommended widths. In addition, gravel areas adjoining those paved shoulders should meet comparable width requirements to provide sufficient clearance for lateral overhang of the home. This recommendation is based upon consideration of

cumulative lateral space requirements that account for home width, crosswind influences, highway cross-slope effects, driver steering uncertainties, and minimal buffer zones of 1 foot along both sides of the home unit, such that home encroachments across highway centerlines and into oncoming traffic lanes are avoided.

— For home widths of 14 feet, the minimum cleared width (consisting of the travel lane, the paved shoulder width, and the adjoining gravel width) should be at least 18 feet of which the total paved surface portion (travel lane and paved shoulder area) is at least 16 feet.

— For home widths of 16 feet, the minimum cleared width should be at least 20 feet of which the total paved surface portion (travel lane and paved shoulder area) is at least 17 feet.

— For home widths of 18 feet, the minimum cleared width should be at least 22 feet of which the total paved surface portion (travel lane and paved shoulder area) is at least 18 feet. (If the wheel track for 18-ft wide homes exceeds 9' 6", an additional 1 foot of shoulder pavement is recommended.)

These recommended minimum paved surface widths (lane + shoulder) suggest that for two-lane highways with lane widths of 12 feet, the paved shoulder should be at least 4 feet wide to accommodate 14-ft wide homes, 5 feet wide to accommodate 16-ft wide homes, and 6 feet wide to accommodate 18-ft wide homes. (Eleven-foot wide travel lanes would increase these recommended paved shoulder widths by 1 foot.)

[These recommendations are based upon a simple formula for estimating the minimum cleared width (i.e., travel lane, paved shoulder, and additional gravel width) given by, $C = W + 4.25$, where W is the width of the home unit and C is the minimum cleared width. The 4.25 (feet) value is used to account for the combined effects of crosswind influences (1.5 feet), highway cross-slopes (0.25 feet), normal driver steering uncertainty (at least 0.5 feet), and 1 foot buffer margins along both sides of the home unit (2 feet).]

- The recommended upgrades do affect shoulder design and strength issues. Such upgrades would need to strengthen affected shoulder areas (by increasing pavement depths) in order to handle the increased loads regularly being carried along such routes.

- For those two-lane highway segments requiring shoulder widening, a transitional time period will exist prior to completion of the recommended shoulder widening construction. During this transitional period, an additional lead escort vehicle (preferably from a police agency) should be provided at these specific route sections to slow down and warn oncoming traffic of likely encroachments across the centerline by the home unit.

- Use of an additional lead escort vehicle (police or otherwise), itself, in lieu of the accompanying shoulder widening effort recommended above, is not suggested as an alternate long term solution along such routes, particularly for homes wider than 14 feet. Such escort activities by police agencies are only being identified as one possible method for improving the safety along such routes under a well defined short-term arrangement.

Highway Intersections

- Curb radii at intersection turns along routes of tractor/home combinations should generally be increased to at least 60 feet to provide sufficient curb clearance and avoidance of encroachments by home units into oncoming traffic lanes at the start of intersection turning maneuvers. Design values for specific intersection geometries could be based upon the information contained in Volume 2.

- Traffic control and stoppage is recommended for those restricted intersections that require encroachments by home units into oncoming traffic lanes from their initial turning position. Cross-road traffic will always be stopped and cleared in any event to allow the tractor/home to complete its turn into the lanes of oncoming cross traffic. However, additional assistance is likely required at many restricted intersections in order to not only control the cross-road traffic, but to stop and control the following and opposing traffic as well at the start of intersection turns. Traffic control under these circumstances should be exercised by an agency having the proper authority.

Tractor/Home Braking Performance

- Addition of brakes to all axles (as opposed to one or two) on the home unit is strongly recommended to improve the braking performance of most tractor/home combinations. This will also help to alleviate the braking demand upon the tractor unit and help to better stabilize the combination vehicle during emergency stops. Jackknifing tendencies

will likewise be reduced. This raises the question of how to best accomplish this because of existing federal regulations and/or interstate commerce issues.

- Because of the limited stopping capability of existing tractor/home combinations and their tendency to jackknife under emergency braking, sufficient space should be provided between the lead escort vehicle and the towing tractor. This lead buffer zone should be maintained free of traffic with highly visible signing located on the back of the lead escort vehicle and the front of the tractor to warn adjacent vehicles out of this zone. For freeway travel at speeds of 45 mph, the length of this buffer zone should be at least 250 feet. At lower speeds of 25 mph, the buffer zone should be maintained clear of traffic for a distance of 150 feet. (These recommended clearance distances reflect a perception and reaction time of 2.5 seconds for the tractor driver and the stopping ability of tractor/home combinations relative to passenger cars.)

- The lead escort vehicle, in cooperation with the tractor driver, should maintain reasonable lead distances ahead of the tractor/home combination so as to discourage other traffic from wandering into the lead buffer zone. Lead distances should not exceed 500 feet on the freeway and 200 feet along slower 25 mph routes having additional traffic.

- Slippery surface conditions further aggravate the braking capabilities of tractor/home combinations and travel should not be allowed during snow/ice conditions.

Speed Limits and Enforcement

- Because of the limited stopping ability of tractor/home combinations, maximum speeds for such vehicles should be limited to 45 mph on freeways. (At freeway speeds of 55 mph, the recommended buffer zone would have to grow to a distance of nearly 400 feet and could not be easily maintained free of other traffic by the lead escort vehicle.) On two-lane undivided highways, where sight distances are limited and travel conditions are less ideal, the current speed limit of 35 mph should be maintained.

- Enhanced enforcement of speed limits for tractor/home combinations is recommended. Field observations of average tractor/home combination travel speeds in this study indicated routine violation of allowed limits on their permits. Based upon the braking performance disparities that exist between tractor/home combinations and other highway vehicles, more vigorous enforcement of speeding is recommended. Computer-based analyses also indicate that greater oscillatory behavior and

considerably greater stopping distances are exhibited by these vehicles as speeds increase. Responsibility for safe operation of the units rests largely on the tractor operators and their employers. Speed regulation possibilities to consider by companies or individuals responsible for shipping these homes could include: A) installing automated data recorders on all tractors used to ship homes with the data from these recorders being sent to MDOT to ensure compliance, or B) providing an equivalent method to guarantee compliance. MDOT should be empowered to withhold shipping permits from those companies or individuals that have an excessive record of speed limit violation.

Tractor/Home Transport Practice

- Design practice for home units that result in approximately a 24% hitch load percentage is supported. The axle placement rule noted in Volume 2 that locates the axle-set centerline two-thirds behind the front of the home is an example. In all cases, hitch load percentages should be maintained in the 20% to 30% range. Side-to-side (sway) oscillations begin to develop in tractor/home combinations when hitch load percentages fall below the 20% level, thereby requiring additional lateral space and increasing the chances of lateral encroachments.

- The 6000 lb per axle (maximum) rule for determining the number of axles to use on home units, also described in Volume 2, is likewise supported and recommended.

Existing Permit Practice

- Existing permit rules regarding time of day restrictions, urban area restrictions, escort practices, seasonal restrictions, and designated routing by knowledgeable state authorities is supported.

- A uniform height limitation on home units (e.g., 13' 6" , or, some equivalent) number should be determined based upon a survey of bridge height clearances and similar limitations along the routes designated for all tractor/home combinations.

Bridge Crossings

- Traffic control and stoppage is recommended at bridge crossings having widths less than 30 feet for 14-ft wide homes, 34 feet for 16-ft wide homes, and 38 feet for 18-ft wide homes.

Escort Vehicles and Driver Training

- Given the longer stopping distances required by tractor/home units, it is important that escort vehicles work in close cooperation with the tractor/home units to control traffic travelling in close proximity to the homes. The role escort vehicles play in traffic control is critical such that specific, detailed, and approved training programs should be developed and enforced for any and all drivers of tractor/home escorts. Of critical importance in this training is the need to ensure that a clear lane of movement is available to the tractor/home unit for any lane change or other maneuvers that involve the tractor/home unit changing direction or speed. It is also important that escort vehicle drivers be advised of the dangers associated with both leading the tractor/home unit too closely or allowing other vehicles to get between the front of the tractor/home unit and the lead escort. The tractor/home unit requires longer distances to stop and complete other maneuvers, and it is the role of the escorts to assure that proper distances are maintained between the tractor/home unit and other vehicles. Escort training programs may be able to be "piggy-backed" onto existing specialized driving courses. Such piggy-backing would reduce costs of training and may in fact enhance more general knowledge and skills of escort team drivers to maximize their ability to escort manufactured housing units. To ensure escort drivers do complete authorized courses, it is recommended that escort drivers be certified through some official process and that only certified drivers be permitted to escort home units.

  It is probably true that proper escort vehicle behavior may frustrate the inexperienced and generally uninformed public, especially because proper escort behavior may involve impeding the planned passing behavior of other vehicles. However, this frustration may be mitigated by a thorough public information and education program to inform the general driving public about the dangers associated with improper passing, following, and lead distances when driving around the tractor/home units.

Public Information & Education Programs

- Because the general driving public is likely unaware of the maneuvering limitations of tractor/home units and the importance of maintaining a safe following, leading, and passing distance when travelling near these vehicles, a comprehensive PI&E effort is recommended. This PI&E effort should be concentrated during the beginning of peak delivery periods, but should continue throughout periods when tractor/home units are travelling on the roadways.

- A comprehensive PI&E strategy involving all media (print and broadcast) should be employed to reach the broadest possible audience in those areas most affected by home shipments. This may include special educational posters at rest areas, developing informational articles for newspapers to print periodically, developing public service announcements for radio and television, and other forms of media. These PI&E materials should stress that it is as important, if not more so, for the general driving public to drive carefully and cautiously around tractor/home units than for the tractor/home unit drivers. A special emphasis of the PI&E campaign should be to instruct drivers not to try to "beat" the escort vehicles. The escorts are there to protect the area around the tractor/home unit to ensure safe transportation for both the home and those driving in the proximity of the home. This special emphasis should also stress the importance of not getting between the escort vehicles and the tractor/home unit. This is especially true for vehicles that may want to duck between the tractor/home unit and the lead escort vehicle. This area (between the tractor/home unit and lead escort) is there as a buffer zone providing the tractor/home unit additional space in which to complete stops safely.

Urban Freeways and Multilane Undivided Highways

- Although this study did not gather much data along urban freeways and multilane undivided highways, it was apparent that under such congested traffic conditions, tractor/home combinations introduce more complicated traffic situations and potential for conflicts. Accordingly, the study recommends continued support of existing geographical and time-of-day restrictions on tractor/home combinations along urban freeways and multilane highways.

- Along more rural multilane undivided highways, shoulder quality and width seemed to vary to a much greater extent than on interstate freeways. Under these travel conditions, encroachments by the home into the passing lane are likely to be more frequent. Consequently, greater vigilance and control of surrounding traffic by the escort vehicles should be emphasized under these circumstances.

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