# Interim 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

Report No. UMTRI-91-49

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December 20, 1991

**Technical Report Documentation Page**

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| UMTRI-91-49 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| Interim Report to the Michigan State Legislature and Steering Committee Regarding the 16-ft Wide Mobile Home Study | December 20, 1991 |
| | 6. Performing Organization Code |
| 7. Author(s)<br>C. MacAdam and F. Streff | 8. Performing Organization Report No.<br>UMTRI-91-49 |
| 9. Performing Organization Name and Address<br>The University of Michigan<br>Transportation Research Institute<br>2901 Baxter Road, Ann Arbor, Michigan 48109 | 10. Work Unit No. (TRAIS)<br><br>11. Contract or Grant No.<br>MDOT 91-1291 |
| 12. Sponsoring Agency Name and Address<br>Michigan Department of Transportation<br>Lansing, Michigan | 13. Type of Report and Period Covered<br>Interim<br>9/12/91 - 12/20/91<br><br>14. Sponsoring Agency Code |

15. Supplementary Notes

16. Abstract


This document represents an interim reporting of findings from an on-going 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 mobile home 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 1991. 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 ultimately will make recommendations to state agencies regarding safe operation and allowed access to state highways for such vehicles.


| 17. Key Words | 18. Distribution Statement |
|---|---|
| mobile home, offtracking, encroachment, highway design, wide load, vehicle width, modular home, highway use, maneuverability, traffic, mobility | No restrictions |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 44 | |

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# 1.0 Introduction

This document represents an interim reporting of findings from an on-going 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 mobile home 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 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 is being 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 ultimately will make recommendations to state agencies regarding safe operation and allowed access to state highways for such vehicles.

As will be described in the following sections of the report, the study is relying 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. Processing of all the field data is still incomplete. However, major portions of that work have been completed and those results appear in Section 3.0. The computer analysis work has only recently begun and certain results applicable to low-speed turning and mobility appear in Section 4.0.

The current study was begun on September 12, 1991 and is scheduled to conclude on May 15, 1992 with a final report submitted to the the state legislature and the steering committee at that time.

## 2.0 Overview of Work Completed To Date by Project Task

This section of the Interim Report provides an overview of the various project tasks and their current status. Prior to the brief discussion of each of the project tasks, a general description of the basic vehicle configuration in question, which may prove helpful in subsequent sections of the report, is first presented.

### General Description of the Vehicle and Its Transport Along Highways

In Figure 2-1 the basic geometry of a 16-ft wide home unit and towing tractor is described. The overall length of the combination vehicle is 95 feet with the home unit length of 79 feet constituting the major element. In general, the homes observed to date have normally been equipped with either 4 or 5 axle sets depending upon the weight of the home. Home weights seem to range in the vicinity of 10 to 20 thousand pounds depending upon the particular design and degree of interior finishing by the manufacturer prior to shipment. Typically the towing tractor has a 10-foot wheelbase and is equipped with a "stinger-type" ball joint hitch for hauling the home unit.

Transporting of 16-ft wide homes requires the kind of vehicle positioning on the highway as depicted in Figure 2-2. The tractor/home combination vehicle is required to utilize most of the shoulder area in order to maintain some clearance margin for adjoining traffic on the highway side of the home. In practice, this idealized view is difficult to maintain and some wandering of the combination vehicle does occur causing intermittent encroachments by the home unit outside of its designated 12-ft lane.

Figures 2-3 through 2-5 help to further illustrate how lane width and shoulder characteristics on freeways and two-lane highways affect the wheel placements of both 14-ft wide and 16-ft wide homes. The wheel/axle assemblies used in transporting all such homes provide a maximum spread of 9.5 feet as noted in these figures. Consequently, the shoulder-side wheels on the mobile home are required to track along different portions of the shoulder area — depending upon the lane width, shoulder width, and lateral positioning of the vehicle by the tractor driver.

In the final project report in May, the initial results described in this interim report will be further analyzed to help assess the influence of lane width variability and shoulder characteristics. State trunkline data will also be used to help extend that discussion to other highway characteristics not directly observed in the field study.

# Figure 2-1. Description of the Mobile Home and Towing Tractor Combination

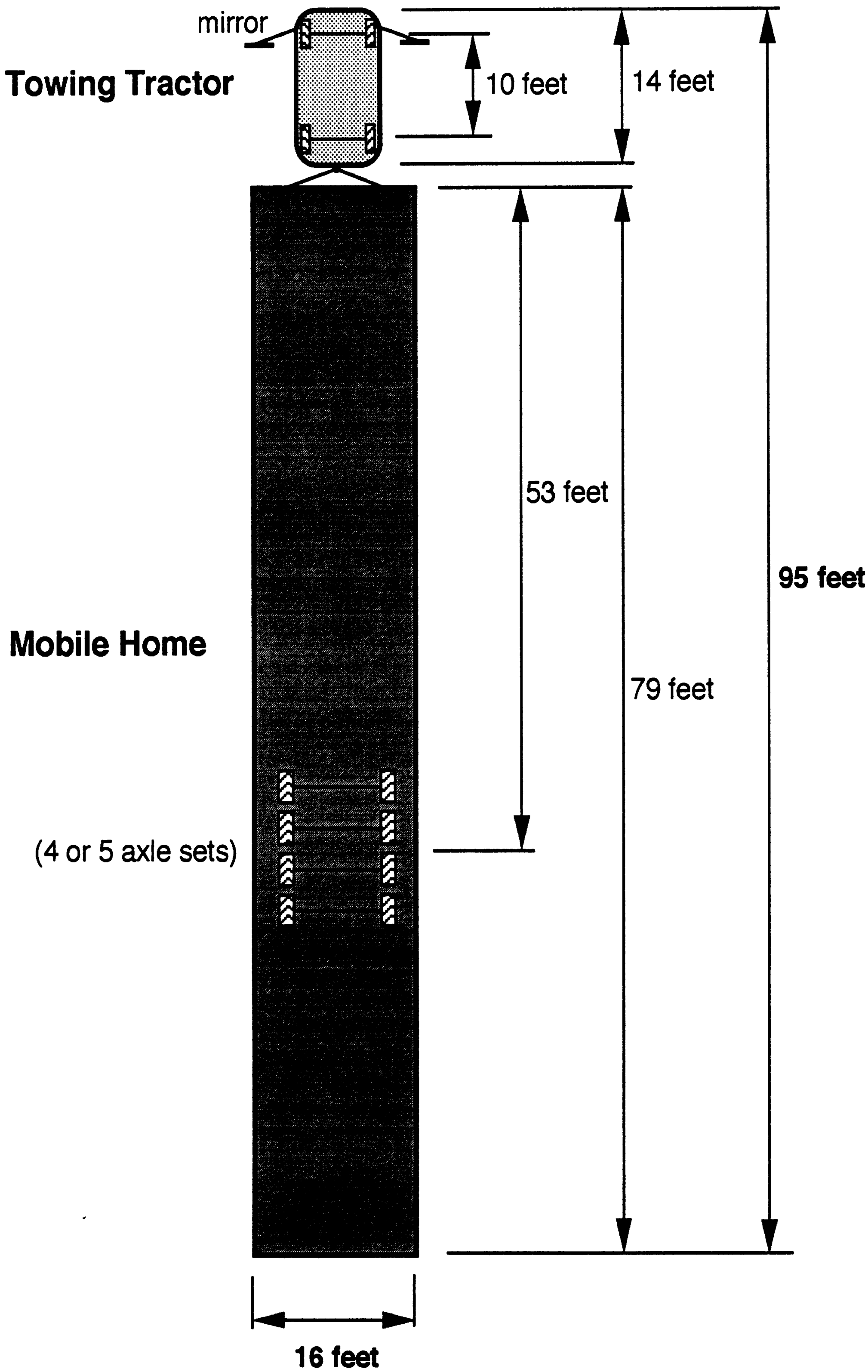
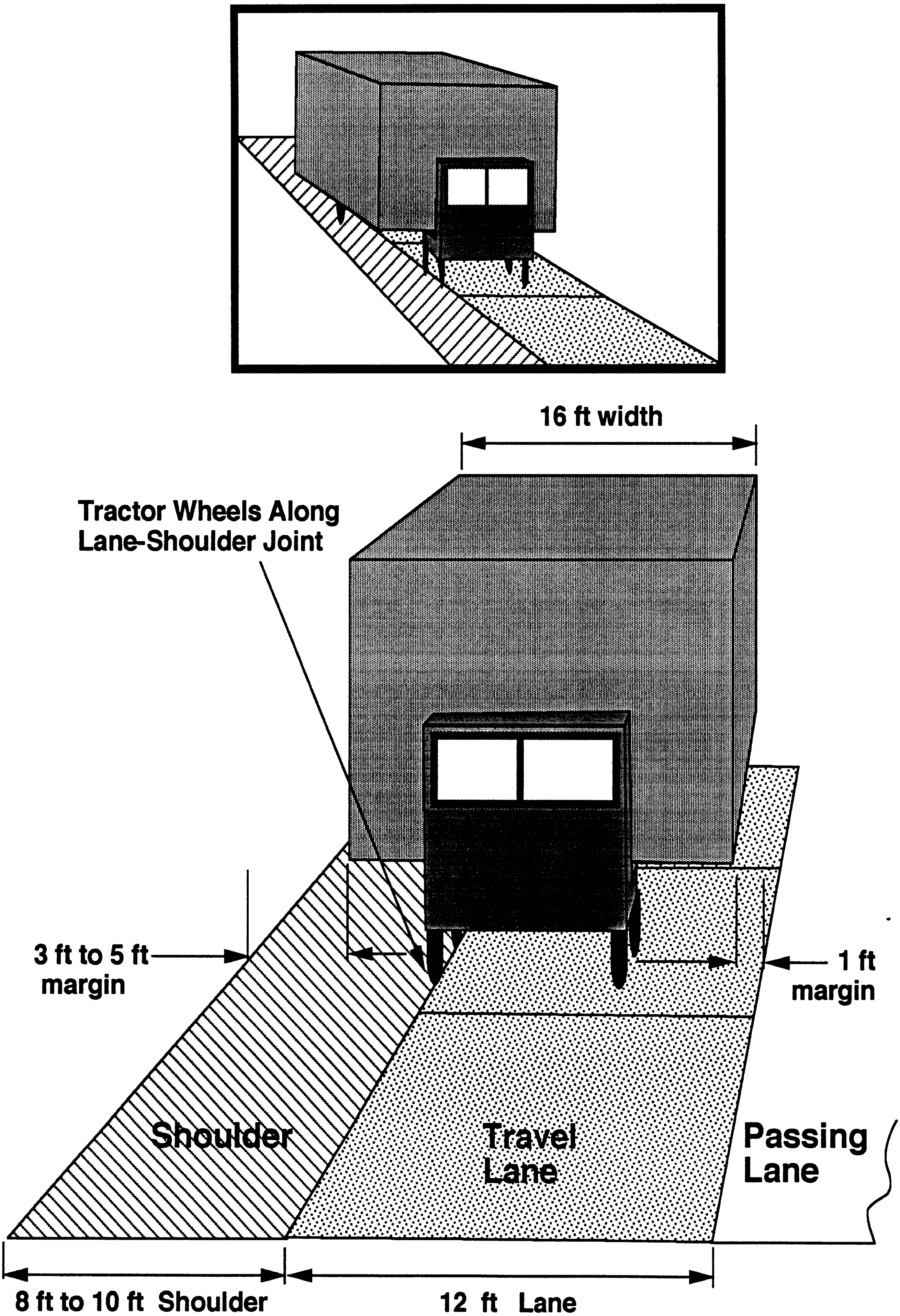
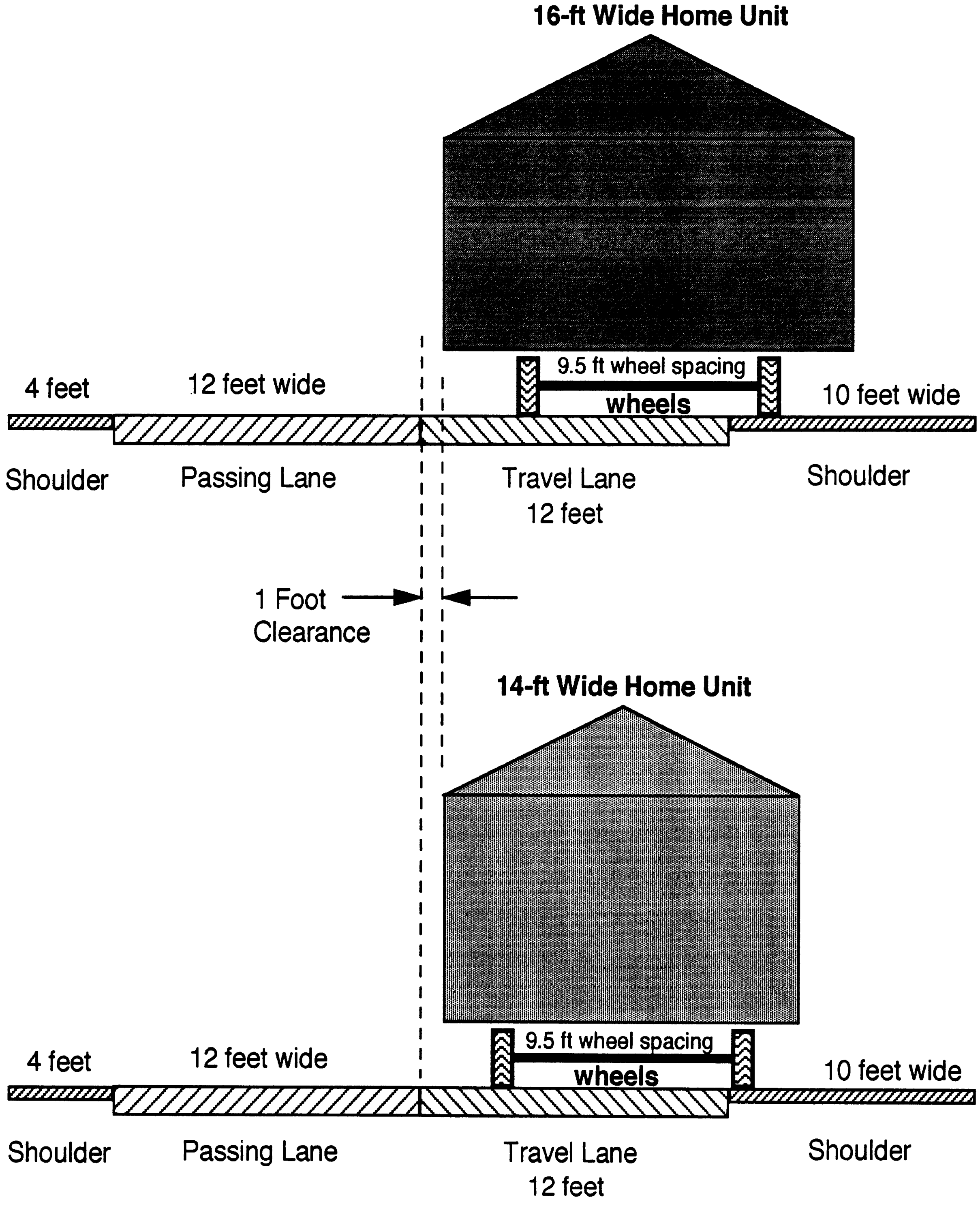


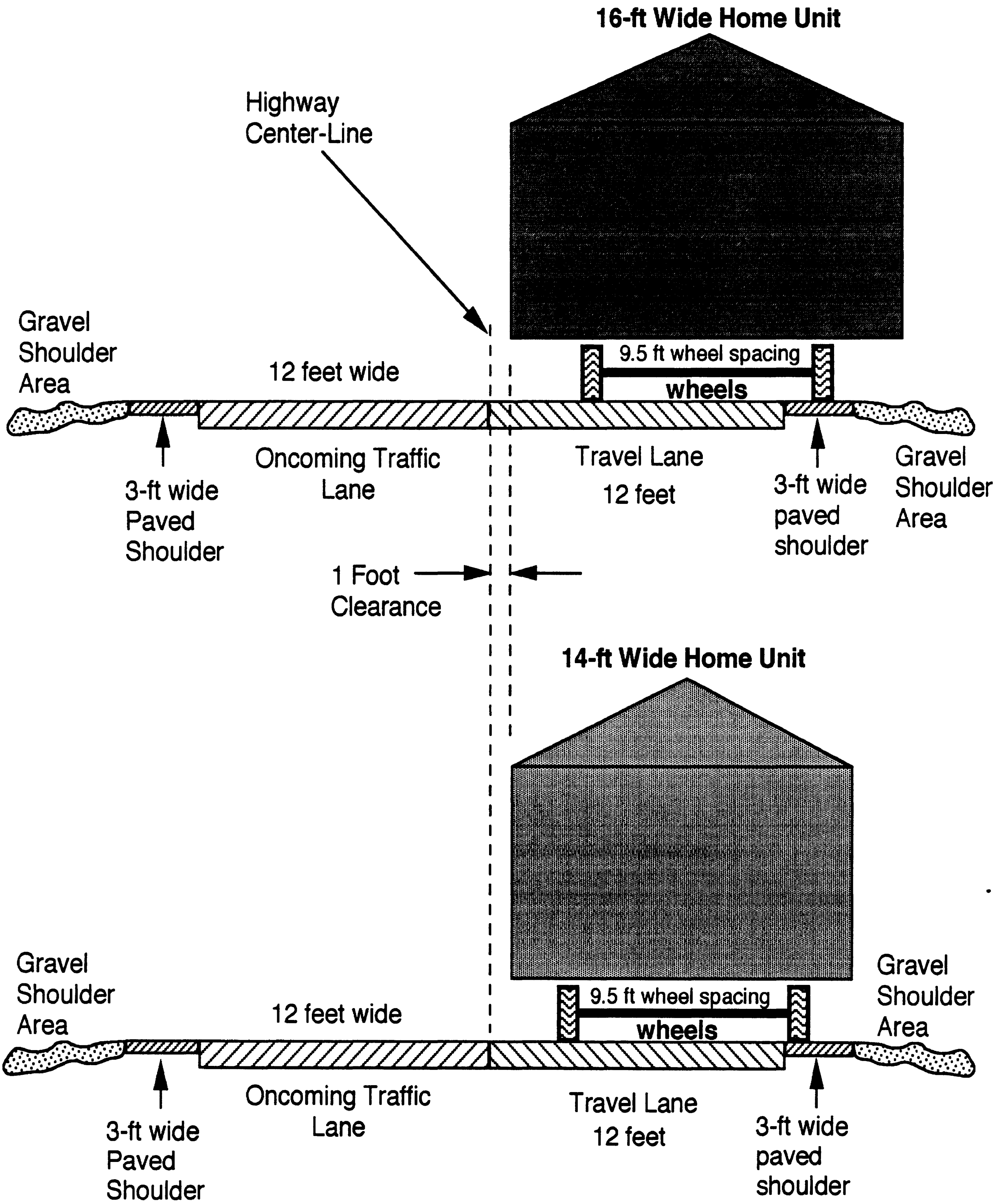
Figure 2-2. Freeway Transport of 16-ft-Wide Mobile Homes



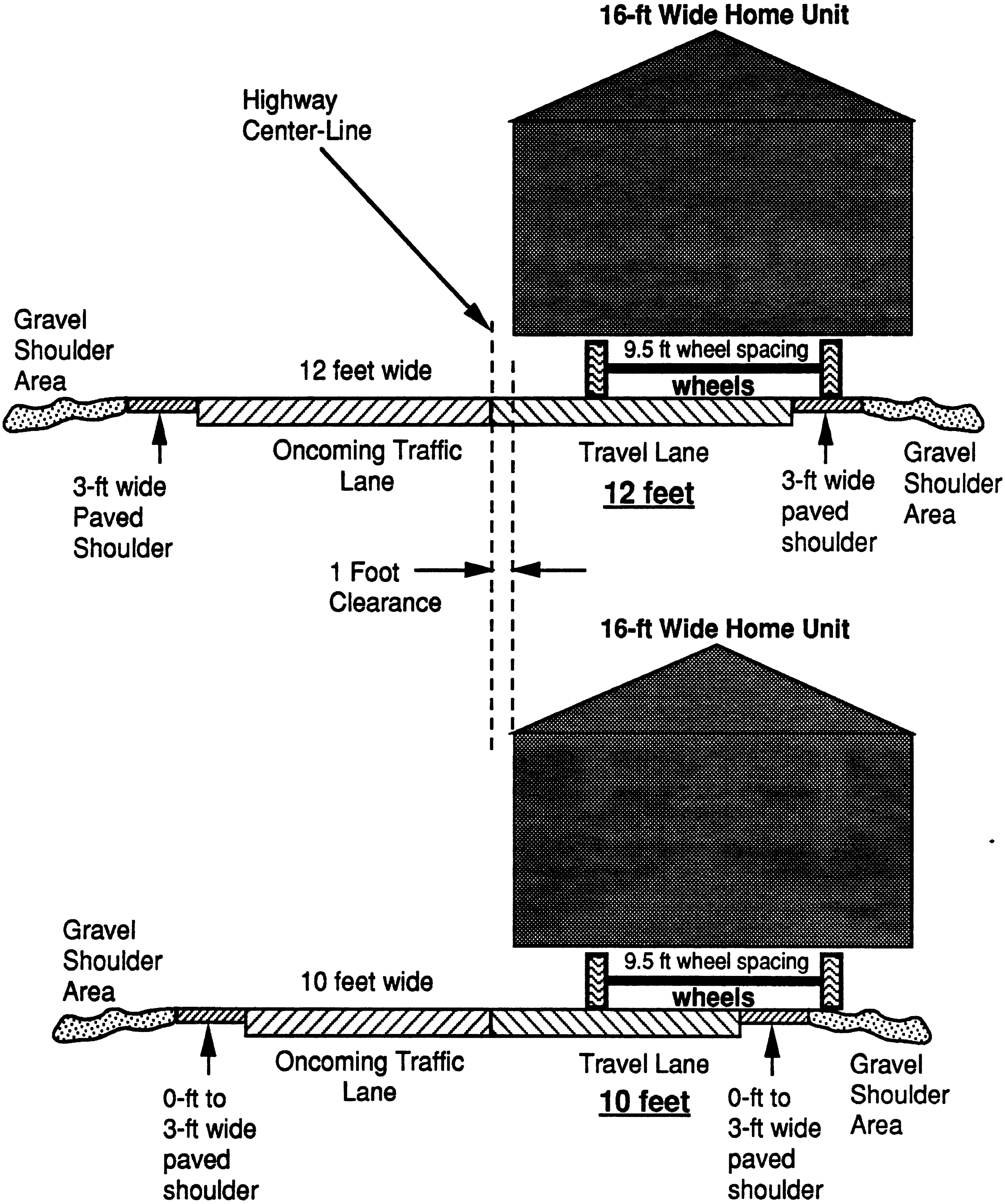
# Figure 2-3. Wheel Placement on *Freeway* for 14-ft and 16-ft Wide Homes (View from Rear)



# Figure 2-4. Wheel Placement on *Two-Lane Highway* for 14-ft and 16-ft Wide Homes (View from Rear)



# Figure 2-5. Influence of Lane Width on Wheel Placement on Shoulder for *Two-Lane Highways* (View from Rear)



## Project Task Descriptions and Current Status

The total project is comprised of 5 tasks. The tasks are divided according to the nature of the work being performed as noted in the following listing:

Task 1: Preparation for Data Collection (Coordination with State Agencies and Mobile Home Manufacturers)

Task 2: Observations and Data Collection of Mobile Home - Traffic Interactions

Task 3: Offtracking Analyses (Low-Speed Maneuvering and Highway-Speed Disturbances)

Task 4: Data Reduction and Interpretation of Video Recordings

Task 5: Reports and Recommendations

In Figure 2-6 a task schedule chart is seen which summarizes the current status of the project and the planned versus completed work in each task. A brief overview of each task and its current status follows.

### *Task 1: Preparation for Data Collection (Coordination with State Agencies and Mobile Home Manufacturers)*

The primary purpose of this task was to permit the research team to develop procedures, gather basic information on vehicles, and arrange for test equipment prior to collecting field data. It also provided an opportunity for the research team to interact with state agencies and personnel for coordinating when and where research surveillance teams could be positioned improve their efficiency in gathering field data.

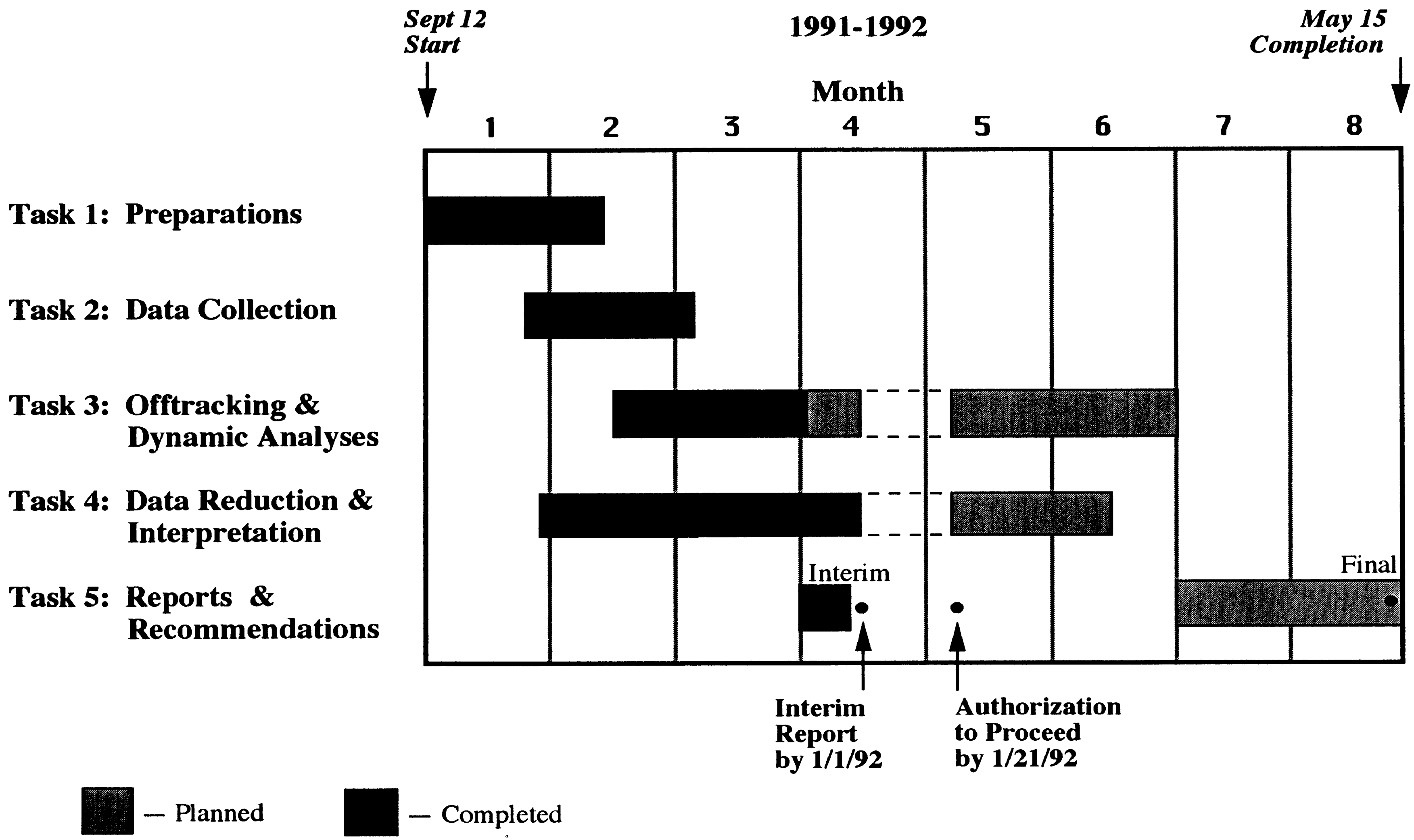
This task is now complete.

### *Task 2: Observations and Data Collection of Mobile Home - Traffic Interactions*

The goal of this task was to collect in-field data on actual 14-ft wide and 16-ft wide mobile home shipments on Michigan state highways. Two surveillance teams, equipment, and vehicles were organized and deployed along routes feeding into Michigan from northern Indiana where a large portion of such homes are manufactured. Homes of 70-80 feet in length and 14 or 16 feet wide were first identified and then followed from the pick-

# Figure 2-6. Task Schedule Chart

*16-ft-Wide Mobile Home Study*



up point (normally along I-69 just north of the Indiana-Michigan state line) to its destination for that day. This normally ranged in time from about 3 to 4 hours depending upon where the home was being shipped. Examples of daily destinations were such locations as Grayling, the Saginaw/Thumb area, Port Huron, Warren, and Canton. Various highways were followed depending upon the permit restrictions and designated routing. Common multi-lane divided highways were I-69 N, I-96, I-75 N, I-94 E, and portions of US-27 N. Two-lane undivided highways included M-13 N, M-57 E, and areas of M-59 E.

Videotapes and in-field timing measurements of vehicle encroachment and traffic behavior were recorded for each shipment. Analysis and observations from these measurements are being conducted in Task 4.

This task is now complete.

### *Task 3: Offtracking Analyses (Low-Speed Maneuvering and Highway-Speed Disturbances)*

Task 3 is utilizing computer analysis and simulation to calculate the offtracking behavior of mobile home / tractor combinations under low-speed turning conditions such as at intersections and exit ramp areas. Additional calculations and analyses will also be performed later in this task to evaluate lateral wandering behavior of such vehicles at highway speeds due to normal driver steering patterns, crosswind disturbances, and possibly road surface irregularities. Simplified computer animations will be prepared to help communicate basic findings from this task. Section 4.0 of this report presents those findings to date on low-speed turning abilities at intersections.

This task is approximately 30% completed.

### *Task 4: Data Reduction and Interpretation of Video Recordings*

This task is to review and analyze the measurements collected during the field activities of Task 2. Much of these data have been processed and findings from this work to date are presented in Section 3.0 of this report. Data processing and analysis activities are continuing, primarily from review of videotape footage collected during the field surveillance work.

This task is approximately 65% completed.

***Task 5: Reports and Recommendations***

This task will document and report findings from the study in a final project report at the conclusion of the project. Recommendations will also be made regarding the advisability of permitting 16-ft wide mobile homes on Michigan highways. Recommendations pertaining to hauling practices for transporting 16-ft wide homes will also be offered, irrespective of the permit recommendations from this study. Where applicable, recommendations and observations regarding 18-ft wide homes will also be included in the final report but will rely only upon the computer-based findings from Task 3 since field data were collected only for 14-ft wide and 16-ft wide homes.

This task is approximately 30% completed (as represented principally by this Interim Report).

The remaining portions of this report present findings to date on Task 1, 2, and 4 activities in Section 3.0. Findings relevant to low-speed turning abilities of tractor/home combinations at intersections from Task 3 activities appear in Section 4.0. A short summary of all findings to date appears in Section 5.0.

# 3.0 Interim Report on Field Study Observations

The field study was designed to gather data on the behavior of both the tractor/home unit and the behavior of vehicles as they pass the tractor/home unit. The focus of the field study was to determine if the behavior of tractor/home units and vehicles passing tractor/home units differed between 14-foot wide and 16-foot wide home units. As will be described in greater detail later, a vehicle equipped with a videotape unit followed behind the escort vehicle that followed behind the tractor/home unit. The videotape equipment in the observation vehicle generated a complete video record of each home delivery observed. In addition to the videotape record, observers in the observation vehicle recorded behaviors of the tractor/home unit (i.e., lane encroachment) and vehicles passing the tractor/home unit (i.e., shoulder encroachment of passing vehicles) during the trip on multi-lane divided highways. Videotape and observation data were collected for a total of six (6) deliveries of 14-foot wide home units and seven (7) 16-foot wide home units.

## General Data Collection Protocol

Two identically configured vehicles were used for the observations (Figure 3-1). Each data collection trip began with the observation vehicle traveling to the rest area on northbound I-69 located north of the Michigan-Indiana border, immediately south of I-94. Observers waited at this rest area until a tractor/home unit of appropriate size (i.e., 14-foot or 16-foot wide) was seen approaching from the south. Once the tractor/home unit was observed approaching, the observation vehicle positioned itself behind the escort vehicle that followed behind the tractor/home unit. At this time the observers started the video camera recording unit and completed the background data collection sections of the Route Log Sheet (see Appendix 1) and the Log Sheet for Vehicle Passing (see Appendix 2).

The video camera was positioned in the camera mount (Figure 3-2) so the view in the video monitor (Figure 3-3) was filled by the roadway and rear of the tractor/home unit. The field of view extended from the outside of the left shoulder to the outside of the right shoulder, the camera lens focused at infinity. In addition to the view of the roadway and tractor/home unit, the videotape was coded with the time the observation was made (hour, minute, second of real time). This time stamp allowed linkages between the data recorded on the observation data sheets and the videotape record of the trip. For example, as the tractor/home unit changed road segments (e.g., turned off of N.B. I-69 onto E.B. I-94) this change was recorded on the Route Log Sheet. The observer recorded not only the new

Figure 3-1. Observation Vehicle.

Figure 3-2. Video Camera and Vehicle Mount.

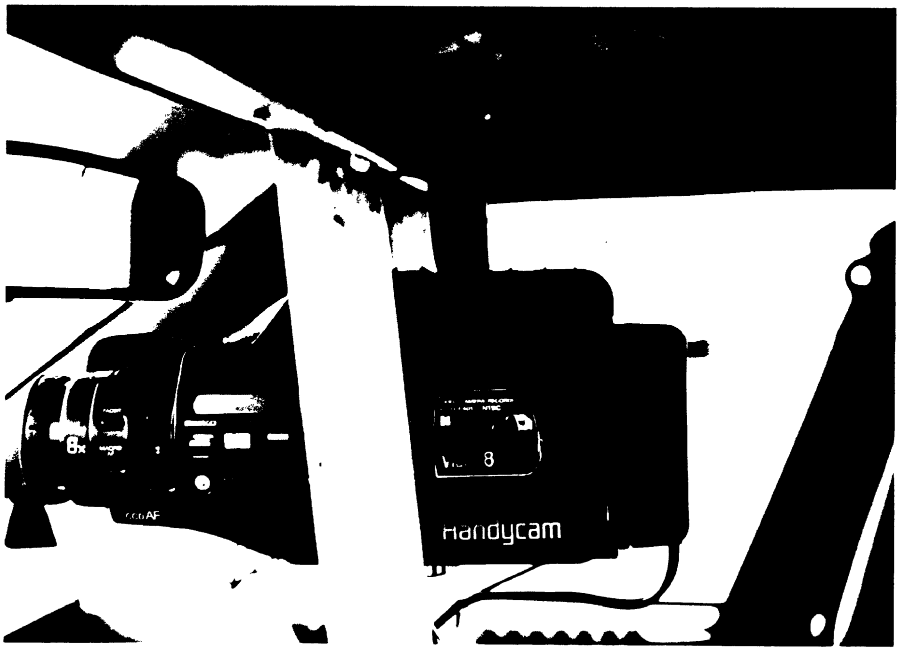


Figure 3-3. Video Monitor and Timer Display (foreground).

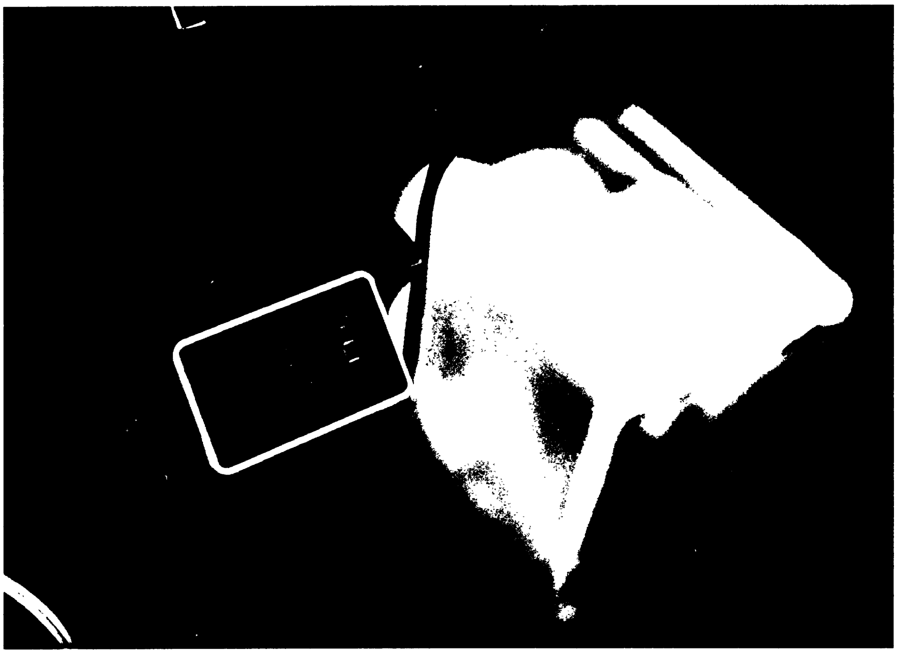
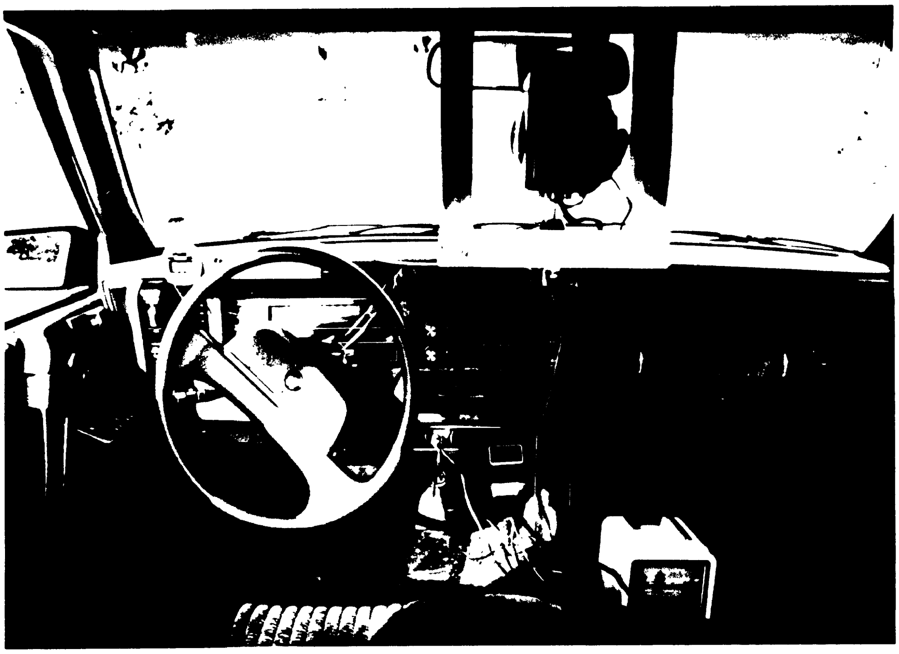


Figure 3-4. Total Data Collection Apparatus in Vehicle.



route segment (in this case E.B. I-94), but also the time the route change took place. By comparing the Route Log Sheet time with the time stamped on the videotape, observers are able to identify the specific road segment the tractor/home unit is travelling on in the videotape. Figure 3-4 shows the entire data collection apparatus in the observation vehicle. Specific data collection protocols for each behavior observed in the project are described with study results and a discussion of the findings in the following sections.

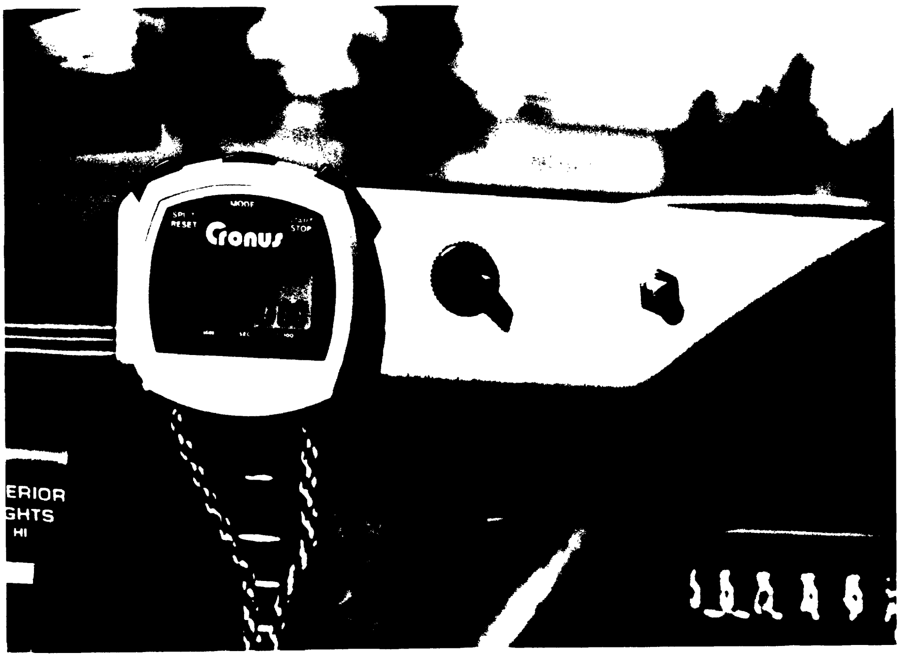
## Tractor/Home Unit Positioning

The goal of this portion of the study was to examine if 16-foot wide tractor/home units encroach into the adjoining lane of roadways more than 14-foot wide units. The results described in this preliminary analysis describe behavior on freeways and multi-lane divided highways (12-ft lanes) having wide and well maintained shoulder characteristics in general. Data have not yet been fully gathered from the videotape record and analyzed for encroachment behavior of the tractor/home units on 2-lane undivided roadways (these data will be available in the final report).

### *Data Collection Methods*

Encroachment time of the tractor/home unit was measured by the driver of the observation vehicle using the timing apparatus shown in Figure 3-5. Encroachment of the tractor/home unit was recorded only when a vehicle or platoon of vehicles began to attempt to pass the tractor/home unit. This procedure was used because tractor/home encroachment is of little safety consequence unless vehicles are attempting to pass. Encroachment was measured in discrete "events." An event was considered to be the period of time a vehicle or platoon of vehicles traveled from the front of the observation vehicle (passing maneuver initiation) to the front of the towing tractor (passing maneuver end, see Figure 3-6). Tractor/home unit encroachment was defined as the period of time any portion of the left edge of the tractor/home unit was observed to be over the center (dashed) line. As a vehicle approached the tractor/home unit in the passing lane, the stopwatch (used to record total event time) was started. Encroachment time was measured using a timer engaged by the switch on the timing apparatus panel (Figure 3-5). When the tractor/home unit was over the center line the switch was engaged in the left position (mimicking the movement of the tractor/home unit), starting the timer. When the tractor/home unit returned to the proper lane, the switch was returned to the right position, stopping the timer. This procedure was repeated as many times as the tractor/home unit swayed over and back across the center

**Figure 3-5. Timing Apparatus.**



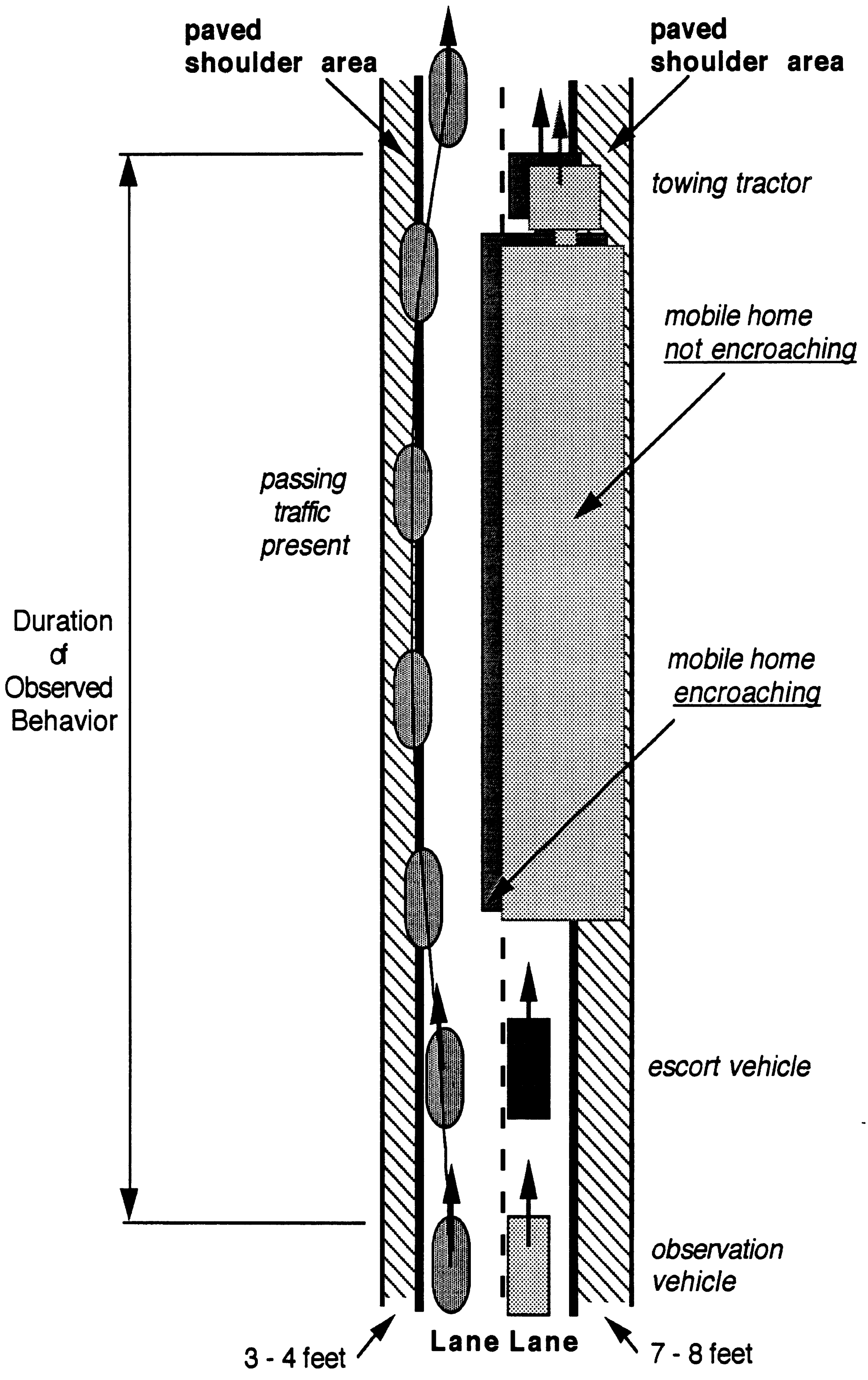
line. The switch timer recorded the total time the tractor/home unit was over the center line during the passing "event." When the last vehicle in the passing platoon completed the pass (i.e., passed beyond the front of the towing tractor), the total stopwatch time and time out of lane was recorded on the Log Sheet for Vehicle Passing. Once the data was recorded on the data sheet, the stopwatch was zeroed out using the timer-clear button on the stopwatch and the time on the encroachment timer was cleared using the button on the timing apparatus panel.

*Results*

Data recorded in the field were converted into the proportion of time the tractor/home unit was encroaching during each event by dividing the total event time (from the stopwatch) by the encroachment time from the timer. Each of the encroachment time analyses described in the following section uses this proportion as the dependent variable.

The data show that during passing events 16-foot tractor/home units encroached into the passing lane more than 14-foot units on average ($t(276)=6.15$, $p<.001$). Specifically, 16-foot units were observed encroaching an average of 40.3% of the time for

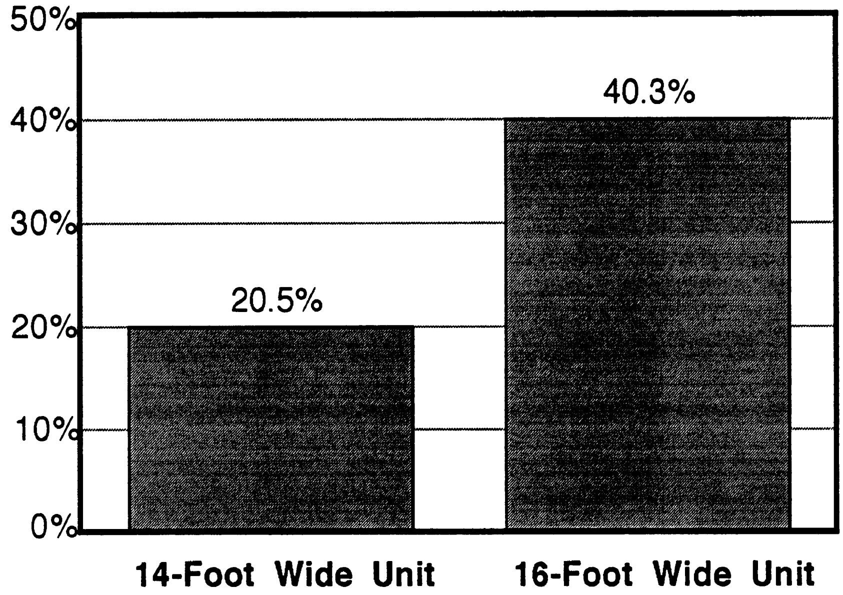
**Figure 3-6. Encroachment Behavior by Mobile Home When Passing Traffic is Present – Multi-Lane Highways.**



each passing event, while 14-foot units were observed encroaching an average of only 20.5% of the time for each passing event (see Figure 3-7). In other words, 16-foot wide units encroached into the passing lane during passing events twice as much as did 14-foot units.

**Figure 3-7. Tractor-Home Encroachment Proportion of Time Encroaching in Passing Lane (Multi-Lane Divided Highways)**

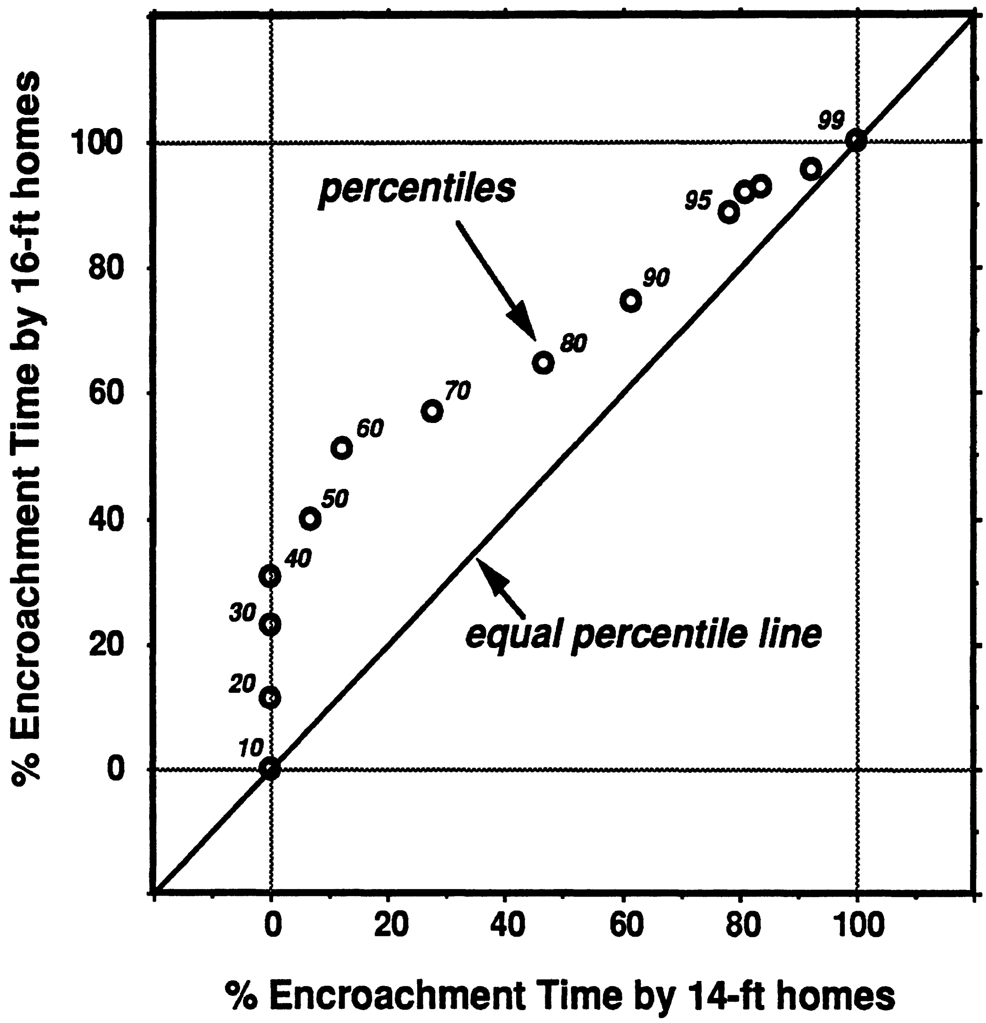
*(12-ft Lanes and Wide Shoulders - typical for both widths)*




There was a good deal of variation, however, between the encroachment behavior of individual tractor/home units. That is, some tractor/home drivers encroached into the passing lane significantly less than other drivers. The range of average encroachment (over an entire delivery trip when adjoining traffic was present) for 16-foot units was from a low of 3.4% to a high of 60.9%. The range of average encroachment (over an entire delivery trip) for 14-foot units was from a low of 2.3% to a high of 54.3%.

Another way to examine the encroachment data is to examine the entire range of encroachment time proportions. Figure 3-8 shows the relative percentiles of encroachment proportions for both 14-foot and 16-foot units plotted. Figure 3-8 shows that 14-foot units did not encroach into the passing lane in 40% of all passing events, but 16-foot units did not encroach into the passing lane in only 10% of all passing events. Taken as a whole, this figure emphasizes the finding that 16-foot wide units encroach into the passing lane more than do 14-foot units.

**Figure 3-8. Percentile Comparison of Encroachment Times for 16-ft versus 14-ft Wide Mobile Homes [On-Highway Measurements]**




*Summary*

The preceding analyses show that 16-foot wide tractor/home units are more likely to encroach into the passing lane while they are being passed by other vehicles on multi-lane divided highways than are 14-foot units. While these encroachments degrade the level of safety on these roadways, the level and effect of this degradation is unclear. One way to examine the significance of the effect of these encroachments on safety is to examine the behavior of the drivers attempting to pass the tractor/home units. One would expect that passing vehicles would be forced onto the shoulder of the roadway more often by the 16-foot units because these units are encroaching into the passing lane more. However, this is an empirical question that can be answered by data described in the following section.

Note that these preceding analyses describe encroachment behavior of tractor/home units on multi-lane divided highways only. Data on encroachment behavior on 2-lane undivided roadways is being collected and will be available in the final report.

### Shoulder Use of Vehicles Passing Tractor/Home Units

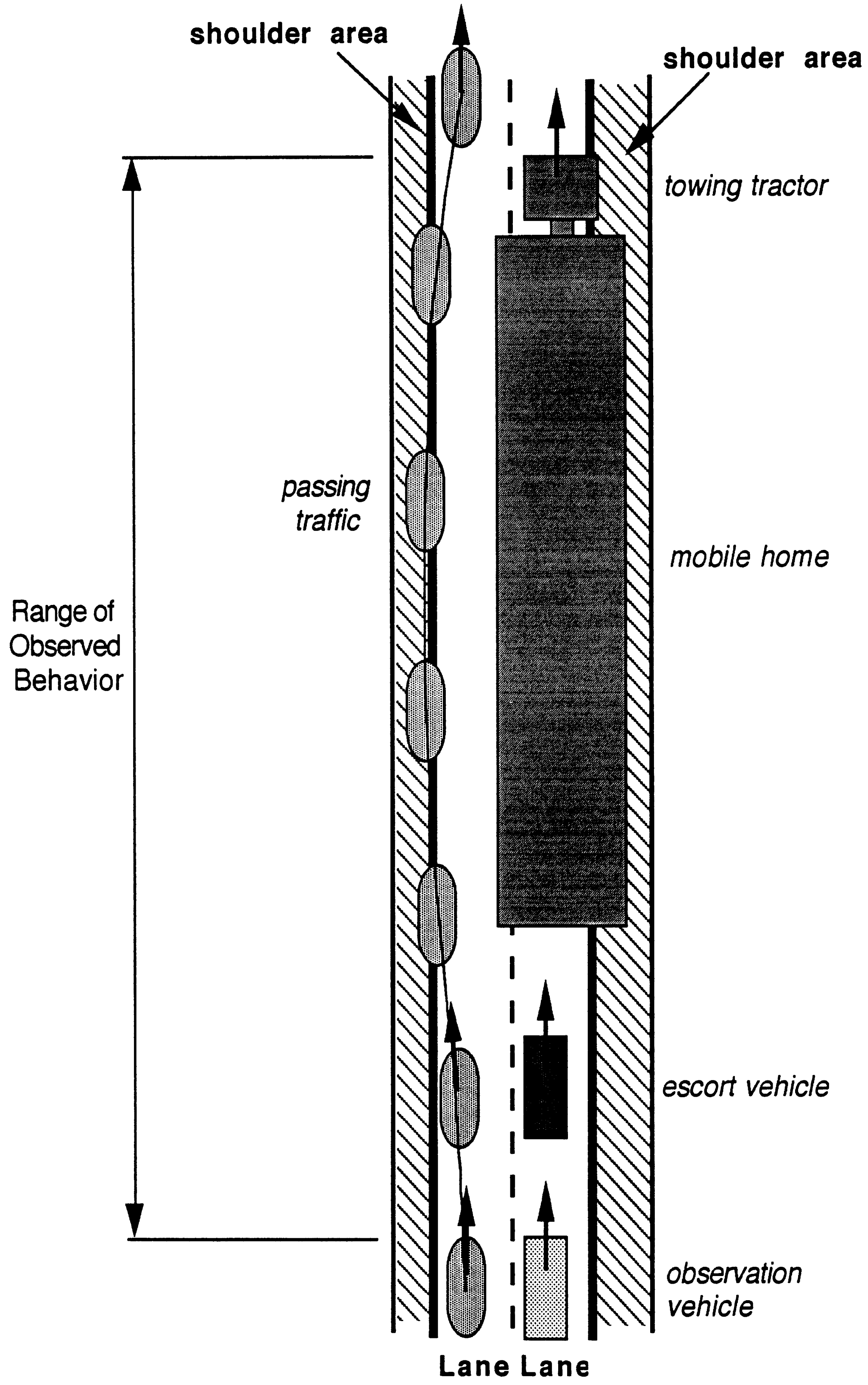
The goal of this portion of the study was to examine if vehicles passing 16-foot wide tractor/home units use the shoulder of the roadway during the passing maneuver more often than vehicles passing 14-foot wide units. Data were collected for passing behaviors on both multi-lane divided highways and 2-lane undivided roadways.

## *Passing Behavior on Multi-lane Divided Highways*

*Data Collection Methods*

Shoulder use of passing vehicles was measured by the driver or observer seated in the front passenger seat of the observation vehicle. Data were recorded on the Log Sheet for Vehicle Passing (Appendix 2). A vehicle was targeted for observation when it pulled even (in the passing lane) with the front of the observation vehicle. For each vehicle (or the first vehicle in a platoon of passing vehicles), the observer recorded the time from the video camera monitor on the Log Sheet (for data linkage purposes). The general scheme for shoulder encroachment observations is shown in Figure 3-9. A vehicle was considered to have encroached into the shoulder when one of that vehicle's left (driver) side tires crossed completely over the edge line marking the shoulder. A tire was considered to be completely over the edge line if the observer could see unmarked pavement between the inside of the left side tire and the left edge of the edge line. If the left side tires remained on the edge line, but did not cross completely over, the vehicle was considered to have not encroached onto the shoulder. A vehicle was considered to have encroached onto the shoulder if the left side tires passed across the edge line at any point in the range of observed behavior (Figure 3-9). In order for a vehicle to have been considered not to have encroached onto the shoulder, that vehicle had to remain on or to the right of the shoulder edge line while within the range of observed behavior described in Figure 3-9.

## Figure 3-9. Shoulder Usage by Passing Traffic on Multi-Lane Divided Highways.



*Results*

Shoulder encroachment data were analyzed using chi-square analysis. Chi-square analysis determines if there is a relationship (association) between frequencies of occurrence of events described by two variables (in this case whether a vehicle encroached onto the shoulder or not, and whether the vehicle being passed was a 16-foot or 14-foot wide tractor/home unit). As shown in Table 3.1, passing vehicles were more likely to encroach onto the shoulder than not encroach when passing either 14-foot and 16-foot wide units. However, the chi-square analysis showed that encroachment behavior of passing vehicles did not differ between 14-foot and 16-foot wide units ($X^2(1)=.291$, $p>.58$).

**Table 3.1**

Number of Passing Vehicles Encroaching
on to the Shoulder — by Tractor/Home Unit Width
(on Multi-lane Divided Highways)

| Frequency<br>Column Percent | 14-Foot<br>Wide | 16-Foot<br>Wide |
|---|---|---|
| Did Not<br>Encroach | 103<br>40.6% | 186<br>38.5% |
| Did<br>Encroach | 151<br>59.4% | 297<br>61.5% |

*Summary*

Despite the earlier finding that 16-foot wide tractor/home units encroached into the passing lane more than 14-foot wide units (when vehicles were passing), no relationship was found between the shoulder encroachment behavior of passing vehicles and the width of the tractor/home unit being passed. This finding further muddles the question of the safety impact of permitting the 16-foot units on the road. That is, while intuitively it would seem that if tractor/home units encroached more into other lanes and that these encroachments would have a detrimental effect on the ability (or desire) of passing vehicles to remain in their lane, this was not found to be the case. In fact, passing vehicles (on multi-lane 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. This finding does not support the contention that 16-foot wide tractor/home units degrade the safety of drivers traveling around those units more than do 14-foot wide units. However, these findings do suggest that both 14-foot and 16-foot units degrade the safety of vehicles trying to pass those units.

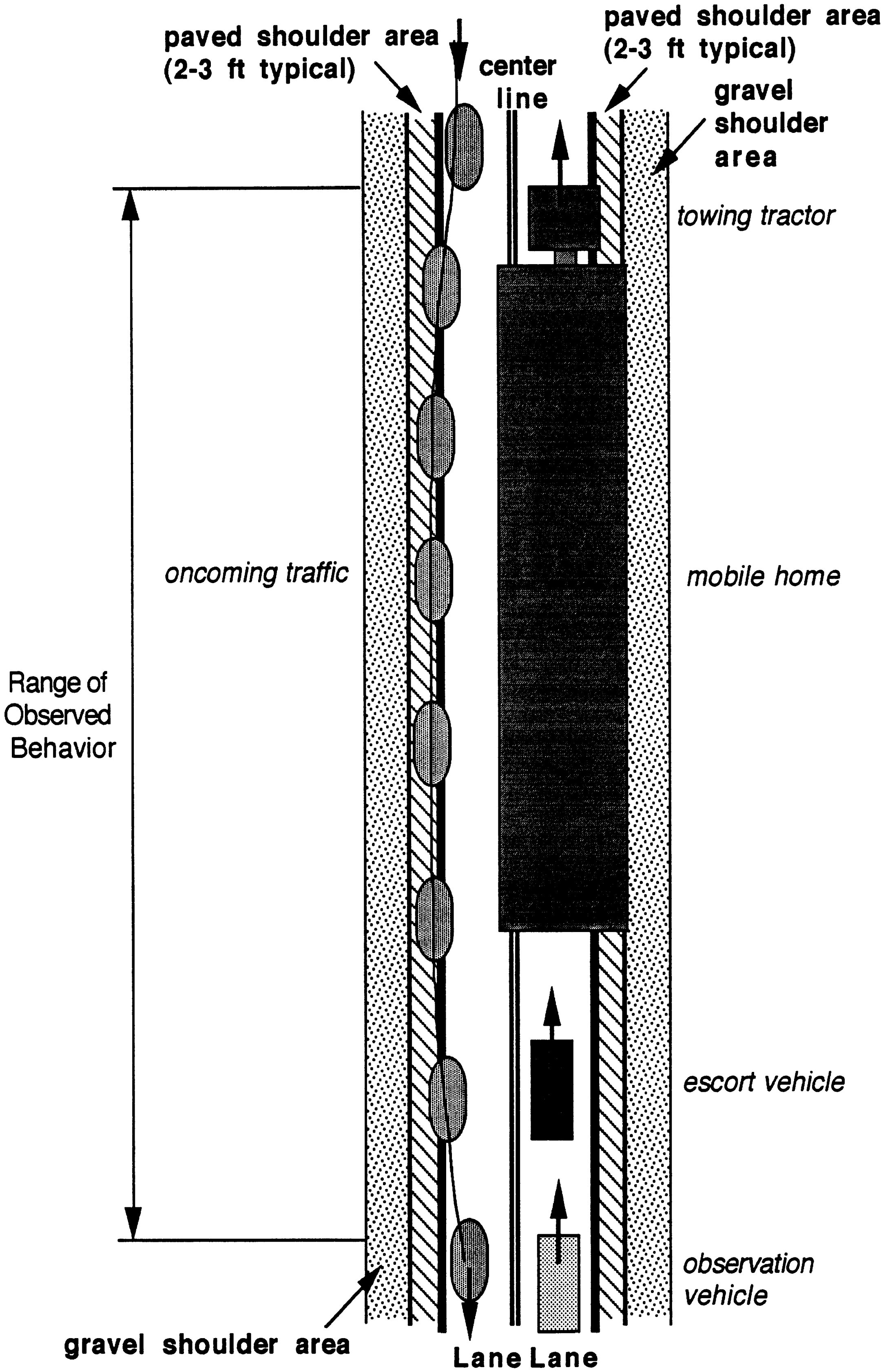
*Additional Observations to be Documented in the Final Report.* In several instances, particularly when the passing vehicle was a large truck, the passing vehicle encroached beyond the paved shoulder and onto the grass or dirt areas adjoining the left shoulder. No unusual queuing or reluctance to pass was normally observed by passing vehicles, except when tractor/home units were temporarily encroaching more than a foot or two into the passing lane. Large trucks were more likely to utilize the shoulder area than passenger cars when passing.

## *Passing Behavior on 2-lane Undivided Roadways*

### *Data Collection Methods*

Shoulder use of vehicles passing the tractor/home unit in the oncoming lane on 2-lane undivided roadways was measured by observers viewing the videotape log of the trips. Data were recorded for each passing vehicle independently by two observers for about half the vehicles to attain a measure of inter-observer reliability. A vehicle was targeted for observation when it pulled even (in the oncoming lane) with the front of the tractor/home unit. The general scheme for shoulder encroachment observations is shown in Figure 3-10. A vehicle was considered to have encroached into the shoulder when one of that vehicle's right (passenger) side tires crossed completely over the edge line marking the shoulder. A tire was considered to be completely over the edge line if the observer could see unmarked pavement between the inside of the right side tire and the right edge of the edge line. If the right side tires remained on the edge line, but did not cross completely over, the vehicle was considered to have not encroached onto the shoulder. A vehicle was considered to have encroached onto the shoulder if the right side tires passed across the

**Figure 3-10. Shoulder Usage by On-Coming Traffic on Two-Lane Highways.**



edge line at any point in the range of observed behavior (Figure 3-10). In order for a vehicle to have been considered not to have encroached onto the shoulder that vehicle had to remain on or to the left of the shoulder edge line while within the range of observed behavior described in Figure 3-10.

*Results*

Inter-observer reliability was found to be quite high (over 90% agreement overall) indicating that observers were able to reliably observe and record shoulder encroachment data. Shoulder encroachment data from a single observer were analyzed using chi-square analysis. Chi-square analysis determines if there is a relationship (association) between frequencies of occurrence of events described by two variables (in this case whether a vehicle encroached onto the shoulder or not, and whether the vehicle being passed was a 16-foot or 14-foot wide tractor/home unit). As shown in Table 3.2, passing vehicles were more likely to encroach onto the shoulder than not encroach when passing 16-foot wide units ($X^2(1)=23.06$, $p<.001$).

**Table 3.2**

Number of Oncoming Vehicles Encroaching on to the Shoulder — by Tractor/Home Unit Width (on 2-lane Undivided Roadways)

| Frequency<br>Column Percent | 14-Foot<br>Wide | 16-Foot<br>Wide |
|---|---|---|
| Did Not<br>Encroach | 79<br>67.5% | 219<br>42.9% |
| Did<br>Encroach | 38<br>32.5% | 291<br>57.1% |

*Summary*

The findings of shoulder encroachment behavior on 2-lane undivided roadways differ somewhat from those from multi-lane divided highways. That is, no difference in shoulder encroachment was found for vehicles passing 14-foot versus 16-foot wide tractor/home units on multi-lane divided highways (although a majority of drivers passing 14-foot or 16-foot wide units encroached onto the shoulder), but a statistically significant difference in shoulder encroachment was found between vehicles passing 14-foot versus 16-foot wide units on 2-lane undivided roadways. Drivers passing an oncoming 16-foot wide tractor/home unit were more likely to encroach onto the shoulder than were drivers passing oncoming 14-foot wide units. In fact, while 57% of drivers encroached onto the shoulder when passing an oncoming 16-foot wide unit, only 32% of drivers encroached onto the shoulder when passing an oncoming 14-foot wide unit.

The rationale for these differences is unclear at this time. It would be instructive to know if the lane encroachment behavior of 16-foot versus 14-foot wide units differs on 2-lane undivided roadways. Further data collection from the videotape record is currently planned to explore this possibility. What is clear is that the encroachment of vehicles onto the shoulders of 2-lane undivided roadways represents an unsafe condition. In many of the shoulder encroachments on <u>2-lane undivided roadways</u>, observed drivers chose to move off of the paved road surface onto an unpaved shoulder area. The drop-off from and return to a paved road surface is a potentially hazardous vehicle maneuver that should generally be avoided because it can lead to loss of control. In addition, driving on an unpaved surface is generally more hazardous than driving on a paved surface because of reduced tire friction and the uneven surface. This type of behavior by passing drivers — to utilize unpaved shoulder areas — was far less frequent on freeways.

## Speed of Tractor/Home Units

The goal of this portion of the study was to examine the speeds that each of the tractor/home units traveled at during their trip.

*Data Collection Methods*

Once the observation vehicle caught up with the tractor/home unit and achieved a steady speed, the passenger seat observer queried the observation vehicle driver to determine the speed at which the vehicle was traveling. The driver reported the speed from the observation vehicle speedometer to the nearest five mile per hour level. The passenger seat observer then held a prepared flash card up in front of the video camera to record the speed. This query and record system was repeated every five (5) minutes throughout the trip. The speed data were transcribed from the videotape later by another observer who recorded not only the speed of travel (from the flash card) but also the road type (i.e., multi-lane divided highway, multi-lane undivided roadway, two-lane undivided roadway).

*Results*

Results from the speed observations are summarized in Table 3.3. The speed limit for such vehicles is **45 mph** on highways with 4 or more lanes and **35 mph** on highways with less than 4 lanes. As shown in the table, vehicles of both widths consistently drove in excess of the speed limit prescribed on their travel permits. There was no difference between the average speeds of 14-foot versus 16-foot units.

**Table 3.3**

Speed of Tractor/Home Units
by Tractor/Home Unit Width and Roadway

| Number of Observations<br>Average Speed | 14-Foot<br>Wide | 16-Foot<br>Wide |
|---|---|---|
| Multi-lane<br>Divided | 109<br>54.9 mph | 127<br>54.1 mph |
| Multi-lane<br>Undivided | None | 1<br>45.0 mph |
| Two-lane<br>Undivided | 5<br>51.0 mph | 30<br>51.2 mph |

*Summary*

These data show that tractor/home units of both widths regularly travel in excess of the maximum speed specified on their travel permits. 16-foot wide units were found to be traveling at almost exactly the same average speeds as the 14-foot wide units, however, the effects of this speeding behavior on safety may differ between the units. The specific effects of this speeding behavior on the safety of the tractor/home units and on the traffic that must interact with the units is unclear. Some may argue that the higher tractor/home unit speeds simply act to reduce the speed variance on the roadway and thus actually improve safety. On the other hand, these units are in clear violation of their lawful permit. In addition, the dynamics of the tractor/home units' stability can be affected negatively by the higher travel speeds observed.

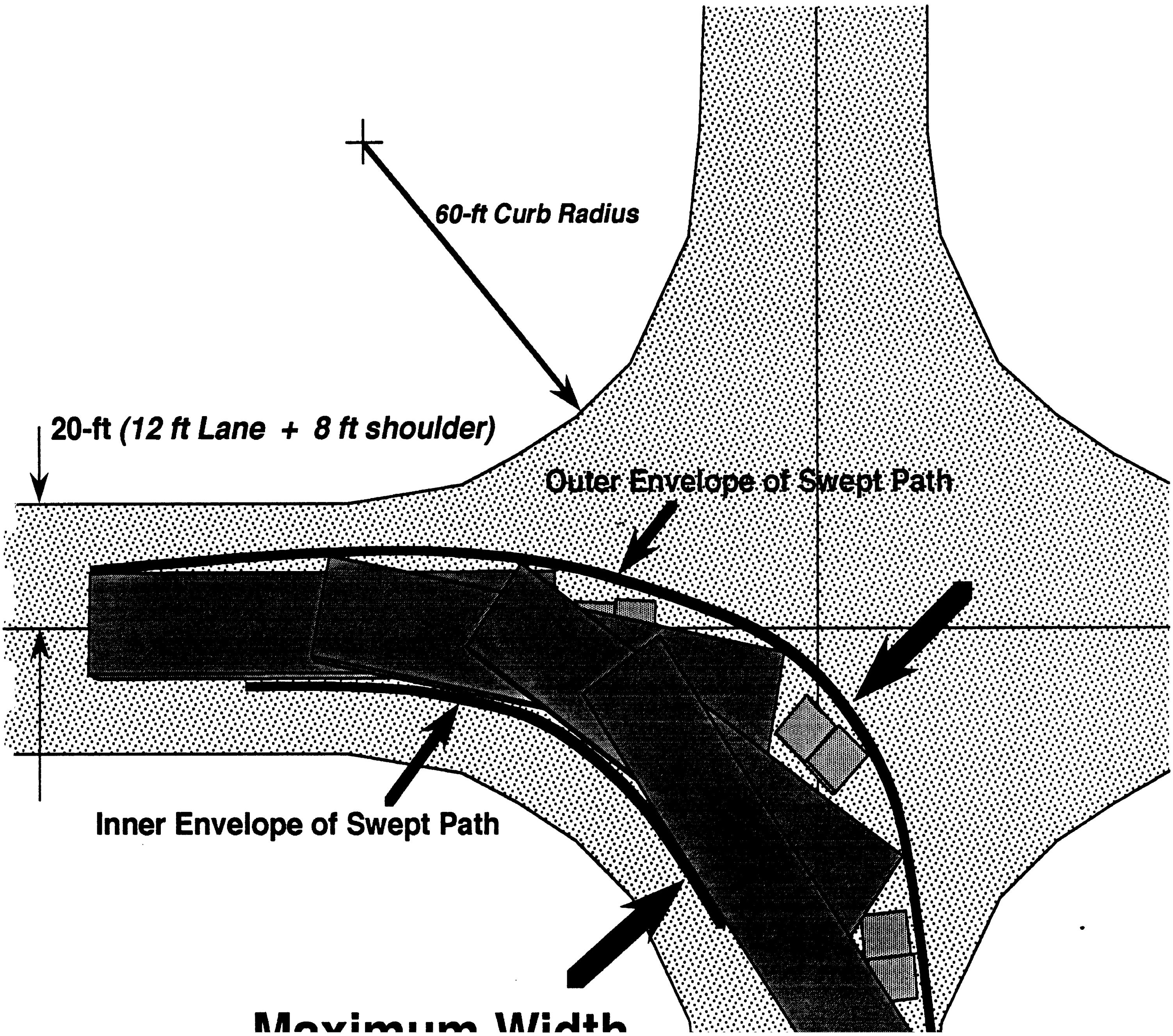
# 4.0 Interim Findings on Low-Speed Turning at Intersections

The issue of low speed turning ability, or maneuverability, of mobile homes and how such capabilities change when home width is increased is currently under study within Task 3 of the research project. This section of the interim report highlights certain findings pertaining to the low speed turning results obtained to date.

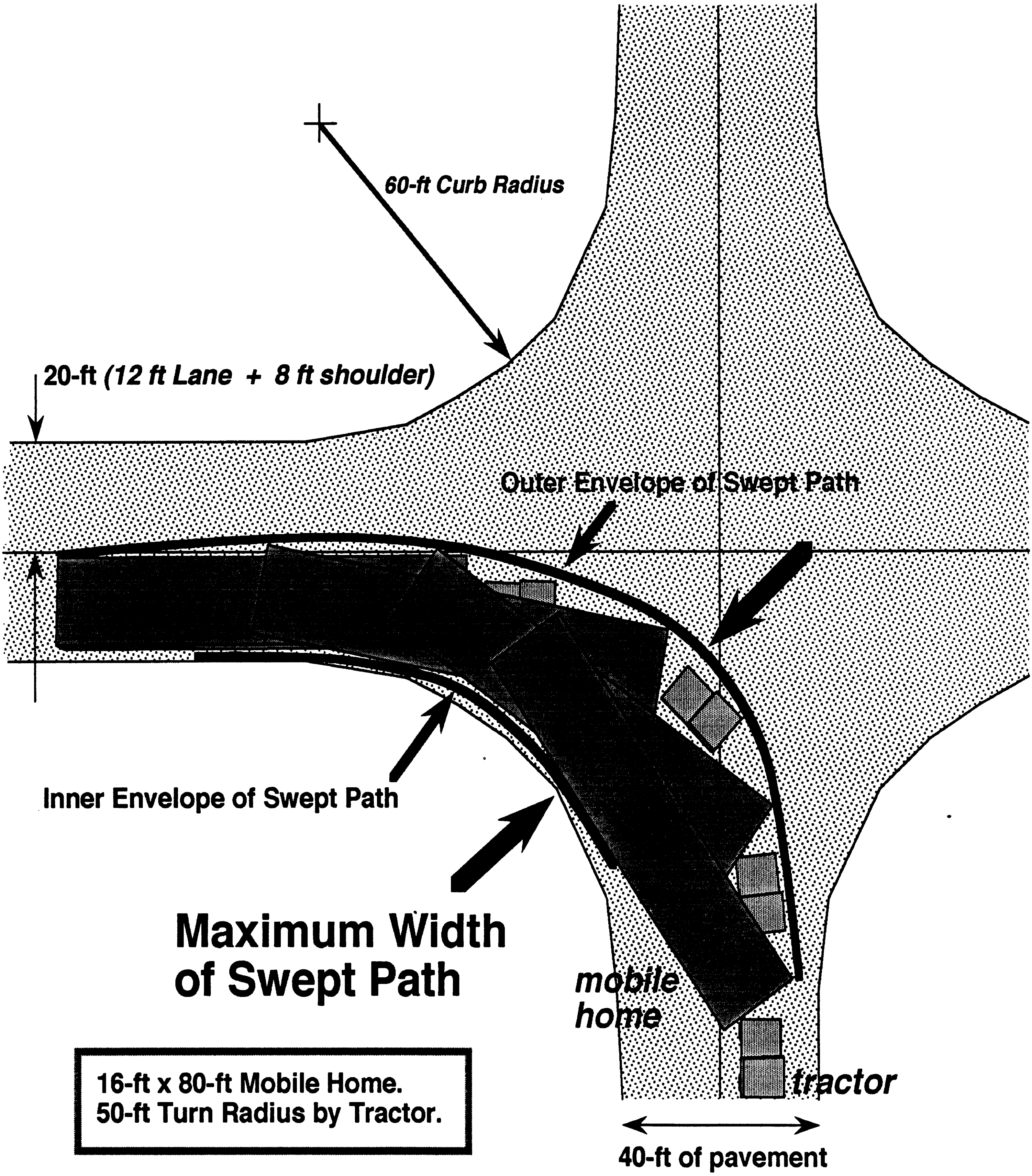
A conventional intersection geometry is used to help communicate the nature of the turning mechanics of mobile homes and the type of constraints imposed by normal highway design. To illustrate, Figure 4-1 shows an overhead view of a two-lane highway intersection. The paved road surface is assumed here to be 40 feet wide (two 12-ft lanes and two paved shoulders each 8-ft in width). The intersection of the two roads is joined by circular curbs having radii of 60 feet. A time-lapse sequence of four snapshots of a mobile home (16-ft wide by 80-ft long) being towed by a tractor through the intersection in a right-hand turn are overlaid in the figure. As the mobile home progresses through the intersection, an outer and inner envelope of points is swept out by the vehicle as it moves forward. The area enclosed by the outer and inner envelopes is referred to as a swept path and is shaped somewhat like a "banana." The swept path has a maximum width at some point in the middle of the "banana" and this maximum width is commonly used to characterize and define how well different types of vehicles are able to turn. Vehicles having larger maximum swept path widths take up more room when turning and consequently are deemed less maneuverable. (The term "offtracking" is also commonly used to describe the degree of lateral movement occurring in rearward portions of a vehicle as it turns.)

The turning maneuver seen in Figure 4-1 was selected to produce a large curb clearance (between the inner envelope and the curb) by utilizing a good portion of the entire intersection. If the vehicle was constrained (by traffic conflicts or other constraints) to utilize less of the intersection in the turning maneuver, a view like that seen in Figure 4-2 might occur instead. In Figure 4-2, the vehicle hugs the right-hand curve more closely and turns through the intersection with minimal clearance on the inside. The difference in clearances between that seen in Figure 4-1 and Figure 4-2 describes the amount of adjustment or free-play that a tractor driver has to work with when negotiating an intersection turn with a mobile home. The amount of clearance available to a driver depends primarily upon the *geometry of the intersection*, the *path curvature of the towing tractor* through the turn, and the *geometry of the vehicle.*

## Figure 4-1. Low-Speed Turning and Maneuverability at Intersections: Large Curb Clearance Turn.



## Figure 4-2. Low-Speed Turning and Maneuverability at Intersections: Minimal Curb Clearance Turn.



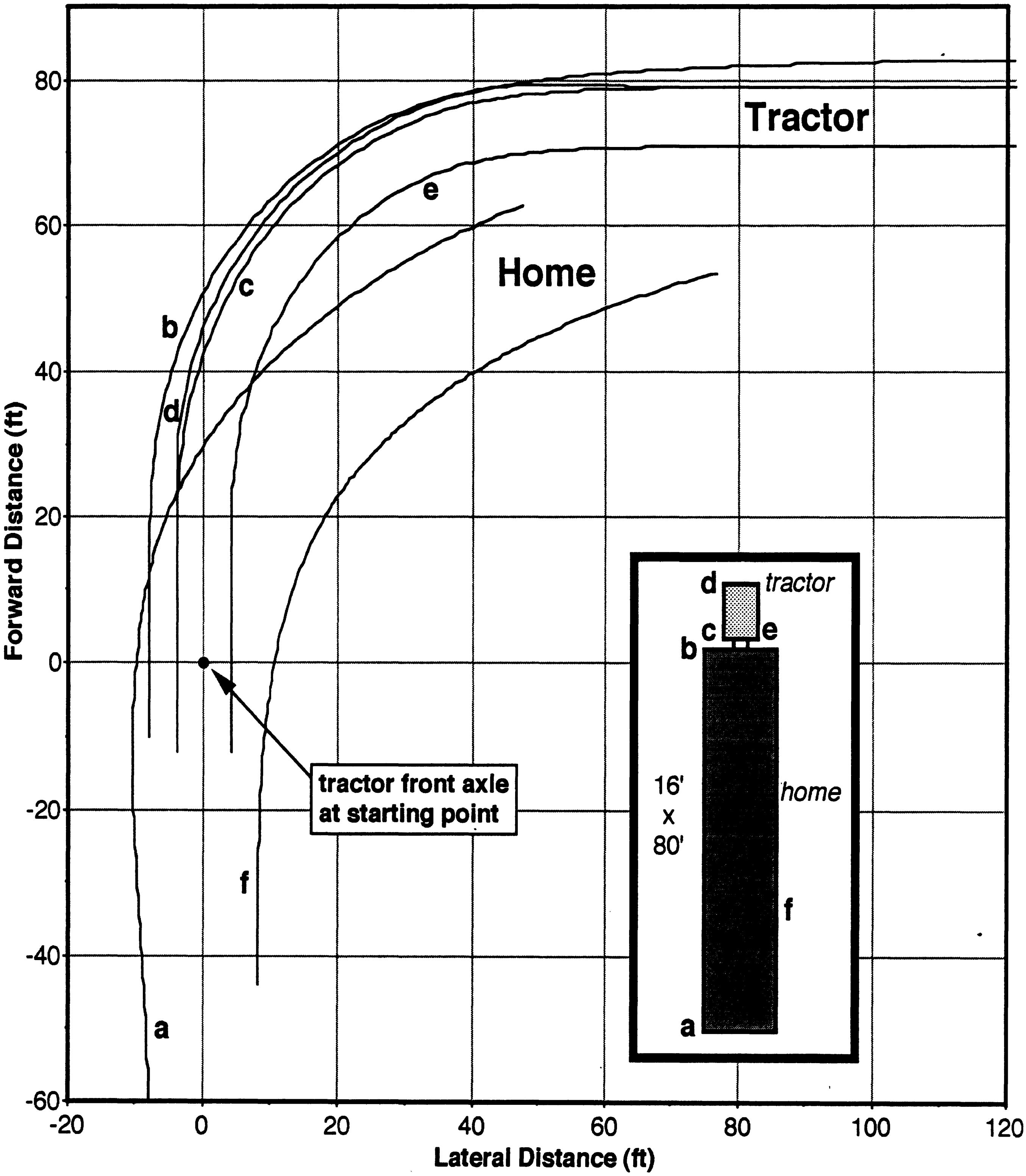
The *intersection geometry* selected in this example is based approximately upon MDOT design guides for certain 2-lane, two-way, intersecting highways. In practice, the shoulder width will be somewhat tapered and different curb radii may be employed based upon the expected usage and design. If, for example, the curb radii seen in Figures 4-1 and 4-2 are reduced from 60 feet to a value of 40 feet or less, the amount of clearance available to a tractor/home combination will be reduced accordingly. If the curb radius is less than a certain threshold value, the tractor/home combination will not be able to turn cleanly through the intersection without encroaching over the curb or into adjacent roadside structures. Likewise, if shoulder width (or highway lane width) is reduced, the amount of curb clearance available to the tractor/home combination will be diminished similarly.

The *turning radius* of the towing tractor is assumed to be 50-ft for most of the analyses performed to date. This is based upon a set of recent low-speed turning measurements conducted by MDOT on a similar 16-ft by 80-ft home and tractor combination. Those tests indicated a minimum turning radius by the towing tractor of approximately 50 to 55-ft and were largely dictated by the nature of the hitching mechanism commonly deployed for connecting the the mobile home to the tractor unit. (Tractors normally can turn much tighter when towing conventional semitrailers.)

The *vehicle geometry* in this particular study is largely fixed except for the *width* of the home unit (14-ft, 16-ft, and 18-ft widths being examined). The length of the home is approximately 80-ft and is being towed by a tractor with a 10-ft wheelbase. It is easy to see from the diagrams in Figures 4-1 and 4-2 that if the home width is allowed to increase, the thickness of the swept path ("banana") will increase more or less in direct proportion. For example, a 14-ft wide home that has a certain curb clearance available to it at a particular intersection, will have that clearance reduced by 2 feet if the home width is increased to 16 feet.

To better visualize and dissect how different parts of a mobile home and tractor combination move as they progress through a turn, a somewhat more detailed diagram of the turning process is seen in Figure 4-3. In this figure, the trajectories of six distinct points (a, b, c, d, e, and f) on the combination vehicle are traced out on a grid as the vehicle moves through a right-hand turn. The maneuver is precisely the same as that seen in Figures 4-1 and 4-2. However, Figure 4-3 is less descriptive and more quantitative. In fact, the outermost portions of curves a, b, and f actually define the banana-shaped swept path described in Figures 4-1 and 4-2. Diagrams like Figure 4-3 are being used in the

## Figure 4-3. Trajectories of Various Points on a Tractor & Mobile Home Combination Vehicle as it Moves Along a 50-ft Radius Right-Hand Turn.




a: Outside Rear Corner of Home
b: Outside Front Corner of Home
c: Outside Rear End of Tractor
d: Outside Front Corner of Tractor
e: Inside Rear End of Tractor
f: Inside Rear Tire(s) of Home

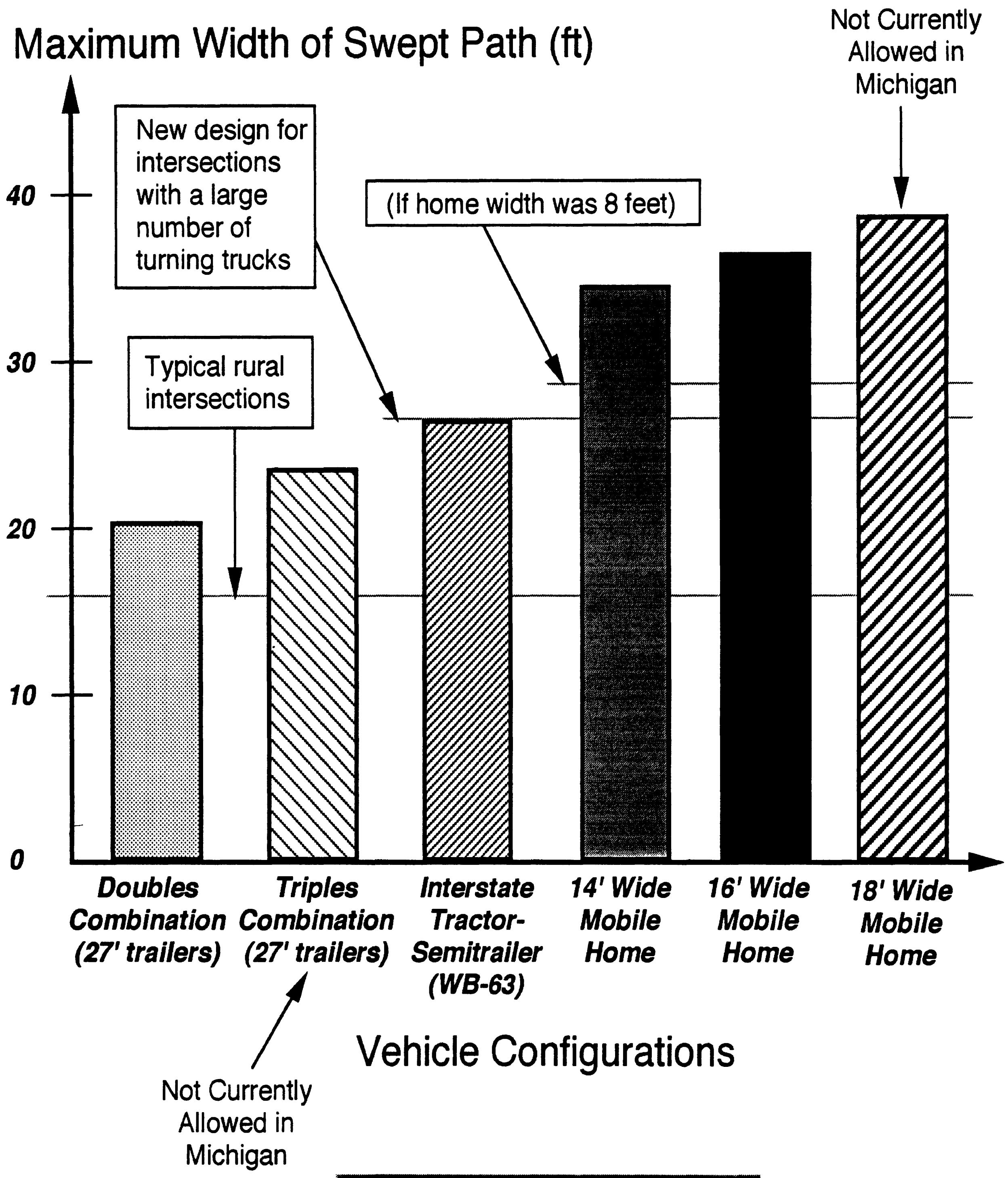
study to accurately calculate the amount of offtracking or maneuverability available to various tractor/home combinations.

In order to compare, in a side-by-side manner, how well other highway vehicles are able to turn and maneuver through an intersection relative to mobile homes, a sequence of calculations was conducted for three, large highway vehicles. These included a 70-ft long double combination vehicle, a 105-ft long triple combination vehicle, and a long interstate tractor-semitrailer with an overall length of 70 feet. Each of these vehicles was steered through the same turn (as seen in Figures 4-1 to 4-3) used for the mobile home. The maximum widths of the swept paths were then tabulated. The results are seen in Figure 4-4 where each of the large highway vehicles are compared with identical calculations for three mobile home / tractor combinations of various widths (14-ft, 16-ft, and 18-ft widths). Two of the vehicle combinations seen on this chart (the triple trailer combination and the 18-ft wide mobile home) are not currently permitted to operate in the state of Michigan but are included here for comparison. As seen, each of the mobile homes do exhibit considerably larger swept path widths when compared with the three highway vehicles — exceeding the largest of these (the long interstate tractor-semitrailer) by 9 feet or more.

One primary reason for the large swept path widths exhibited by the mobile home is its length — 80 feet. The other contributing factor seen here is width. If the width of the mobile homes was the same as most other large highway vehicles (8 feet), the maximum width values seen in Figure 4-4 would be reduced to values of about 28.5 feet on the maximum swept path width chart. If one were to assign a percentage contribution to length and width as factors associated with swept path width for the example intersection seen above, mobile home length would contribute about 56% and mobile home width about 44%. Consequently, width is an important ingredient in the overall picture of how well mobile homes (and other highway vehicles) are able to turn and maneuver through actual intersections encountered on the highway system.

The issue of how much additional swept path width is required by mobile homes if permitted home widths increase from 14 feet to 16 feet (or possibly 18 feet) is illustrated in Figure 4-4 by the three mobile home bars. The additional width requirement in swept path (beyond that currently utilized by a 14-ft wide home) will be 2 feet for a 16-ft mobile home and 4 feet for an 18-ft wide mobile home.

## Figure 4-4. Comparison of Maximum Swept Path Widths for Various Types of Highway Vehicles




**Turning Maneuver:**

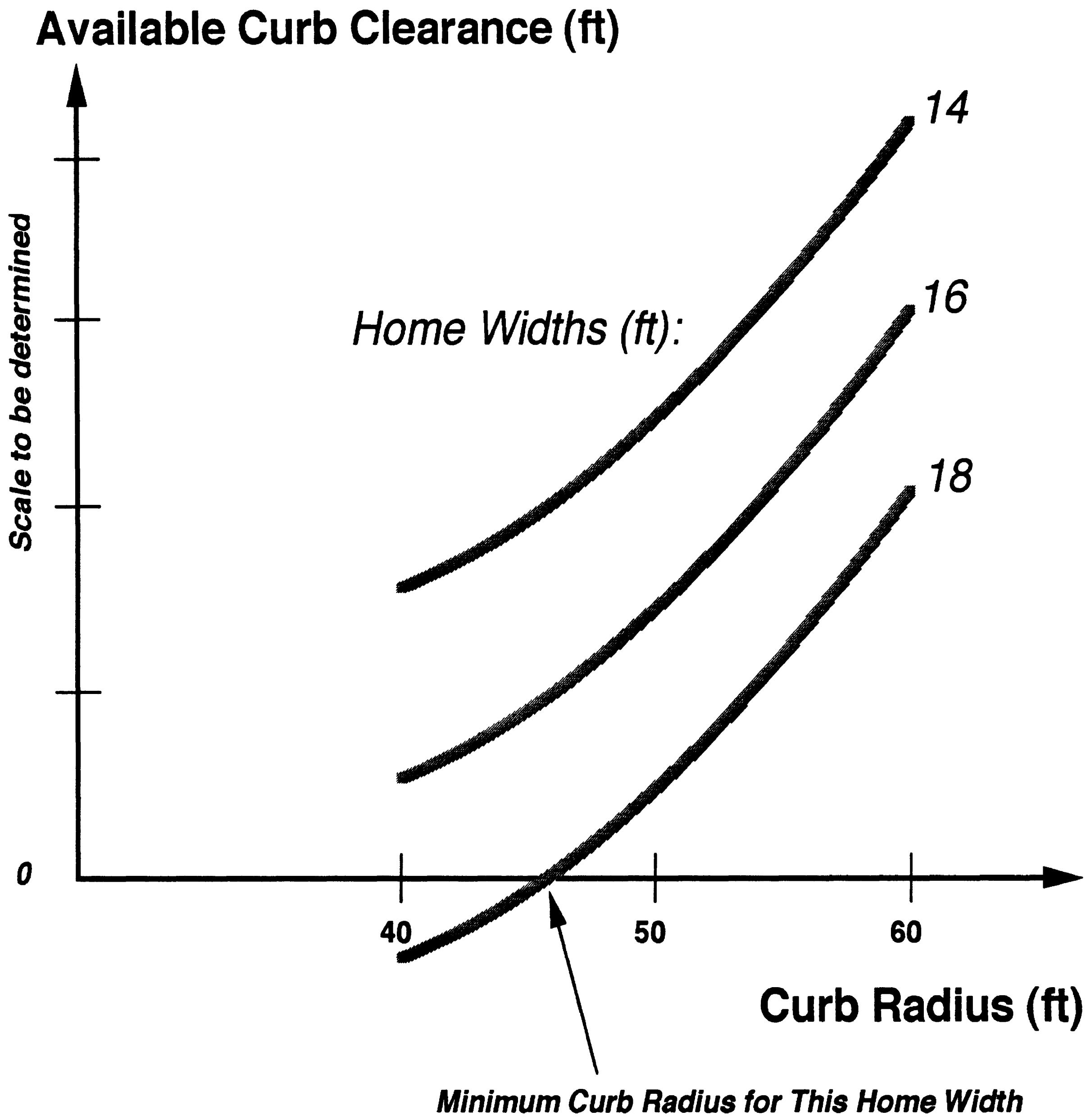
- **50-ft Tractor Turn Radius**
- **90-degree Turn**

Another factor which has not been discussed, but is particularly important for mobile homes, is the overhang or swing-out behavior exhibited by the outside rear-end of such vehicles during tight turning that occurs at intersections. This occurs primarily because the forward location of the axles on the mobile home is at a point slightly rearward of the mid-point of the home. It was noted above that the minimum turning radius of the towing tractor is observed to be about 50 feet based upon recent MDOT tests. For that degree of turning curvature, the outside rear end of an 80-ft long mobile home swings out about 2 feet towards the left-hand lane (from its initial straight-line direction at the beginning of the turn) See, for example, Figure 4-2 or 4-3. If however, the tractor was capable of turning on a tighter circular path, for example a 25-ft radius, the swing-out effect at the rear end of the mobile home would increase considerably to about 6 feet. Consequently, offtracking advantages accruing from being able to turn more sharply with the towing tractor are to some extent offset by the pronounced development of swing-out behavior of the outside rear end of the home unit. (For most highway vehicles this swing-out behavior is extremely small due to the more rearward position of the axles on such vehicles.)

For oncoming traffic on a two-lane highway that encounters a 16-ft wide home (instead of a 14-ft wide home) at an intersection, the amount of encroachment by the rear end of the home unit (towards the oncoming traffic) will be the amount of swing-out that occurs with a 14-ft wide home *plus* an additional 1 foot (half the difference in home widths). This of course assumes that the towing tractor follows the same turning path through the intersection for both homes. Consequently, the net effect for oncoming traffic is an additional encroachment amount that is equal to half the difference in home widths, beyond that already produced by the rear end swing-out behavior.

The above discussion and results have described findings to date related to low-speed turning at intersections. In the remaining months of the project, additional analyses will be conducted for low speed turning scenarios and potential impact of wider homes on highway and intersection geometry. For example, analyses of curb radii at intersections will be conducted to evaluate adequate curb clearances for mobile homes of various widths. In Figure 4-5, an example analysis is seen which outlines how increased home width will affect the amount of available curb clearance for intersections having different curb radii. Depending upon the intersection geometry, the turning radius of the towing tractor, and the size of the home unit, curb clearances will diminish for increased home width and for

## Figure 4-5. Type of Analysis Still to be Conducted in Remainder of Intersection Study




**Intersection Geometry:**

- 50-ft Tractor Turn Radius
- 12-ft Lanes
- 8-ft Shoulders

reduced curb radii. As curb radius is reduced, a minimum curb radius is reached for each mobile home such that it will not be able to turn cleanly through the intersection without curb encroachment or collision with roadside structures. Graphs like those seen in Figure 4-5 will help in evaluating the sensitivity of available curb clearance to home width for example intersection geometries. Similar analyses may be conducted for highway exit ramp geometries or other intersections, depending upon the priorities suggested subsequently by the steering committee.

# 5.0 Summary

*The interim results obtained to date from the field study observation data indicate that:*

- During passing events on multi-lane 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 multi-lane 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 multi-lane 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 passing an oncoming 16-foot wide tractor/home unit were more likely to encroach onto the shoulder than were drivers passing 14-foot wide units. Approximately 57% of passing drivers (oncoming) encroached onto the shoulder when passing a 16-foot wide unit; only 32% of drivers encroached onto the shoulder when passing 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 traveling at almost the same average speeds as the 14-foot wide units.

*The interim low-speed turning analyses indicate that:*

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

- 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.

- 16-ft wide mobile homes require an additional 2 feet of swept path width beyond that required of 14-ft wide homes when turning at intersections. 18-foot wide homes require 4-feet of additional swept path width.

- 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.

# Appendix 1

A copy of the "Route Log Sheet" used by the observation teams is attached in this appendix.

# 16'-Wide Observation -- Route Log Sheet

Date_______________ Time start_________________ Time end____________

Driver_________________________ Observer______________________

Manufactured
Home Size: Width_______________

Approx.
Length_______________

Tractor License #_______________

Tractor # Axles_____________

Trailer # Axels_____________

Road Segment 1:____________________ Monitor Start Time___________________

Road Segment 2:____________________ Monitor Start Time___________________

Road Segment 3:____________________ Monitor Start Time___________________

Road Segment 4:____________________ Monitor Start Time___________________

Road Segment 5:____________________ Monitor Start Time___________________

Road Segment 6:____________________ Monitor Start Time___________________

Videotape Data Code_____________________

Tape Coding Scheme:

| 16 or 14 | XX/XX | $$ | N |
|---|---|---|---|
| Home Size | Date of observ. | Observer Initials | Sequence Number of tape |

Example: Carl Christoff observing 16' home on October 14, second tape of 3 – videocassette should be coded: 1610/14CC2

Complete Videotape Data Code for Log Sheet would be:
1610/14CC1 - 1610/14CC2 - 1610/14CC3

# Appendix 2

A copy of the "Log Sheet for Vehicle Passing" used by the observation teams is attached in this appendix.

# Log Sheet for Vehicle Passing

Date______________________ Observer______________________________

Monitor Clock Time__________________________

**Vehicle Over Left Edgemarker** | **Vehicle NOT Over Left Edgemarker**

**Total Stopwatch Time**_____________ **Time out of lane**____________

Monitor Clock Time__________________________

**Vehicle Over Left Edgemarker** | **Vehicle NOT Over Left Edgemarker**

**Total Stopwatch Time**_____________ **Time out of lane**____________

Monitor Clock Time__________________________

**Vehicle Over Left Edgemarker** | **Vehicle NOT Over Left Edgemarker**

**Total Stopwatch Time**_____________ **Time out of lane**____________

Monitor Clock Time__________________________

**Vehicle Over Left Edgemarker** | **Vehicle NOT Over Left Edgemarker**

**Total Stopwatch Time**_____________ **Time out of lane**____________

Monitor Clock Time__________________________

**Vehicle Over Left Edgemarker** | **Vehicle NOT Over Left Edgemarker**

**Total Stopwatch Time**_____________ **Time out of lane**____________