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Heavy Vehicle Driver Workload Assessment

Task 2: Standard Vehicle Configuration/Specifications

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16. Abstract

This report presents the identification of a standard heavy vehicle configuration and driver tasks that would serve as baseline conditions for measuring workload. A subject matter expert and review of Department of Transportation manuals determined that a standard configuration would have the following functional characteristics: combination tractor and single trailer vehicle; conventional cab configuration with sleeper box optional; flat panel dashboard; diesel power with air brakes; and an absence of high-technology devices. Standard driving tasks reviewed in Task 1 and those results were categorized, rewritten for application, and screened by a subject matter expert, thus identifying key driving tasks. A list of basic driver behaviors (sub-tasks) is presented to complement the key driving tasks.

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TO

NATIONAL HIGHWAY TRANSPORTATION SAFETY ADMINISTRATION

1.0 BACKGROUND

Introduction

A variety of high technology in-cab devices have been proposed for use in heavy trucks. Many of these devices introduce subsidiary tasks which may compete with the driver's primary task of safely controlling the vehicle at all times. The challenge of design, evaluation, and implementation of high technology from a driver-centered perspective is to determine the efficiency, effectiveness, and safety of such devices.

In this program of research, the Battelle team will develop a workload assessment protocol suitable to assess the safety implications of high technology systems that might be introduced into heavy trucks. This effort includes task **analysis,** literature review, definition of a baseline heavy vehicle configuration, workload assessment protocol development, data collection, and evaluation of two devices with the developed workload assessment protocol. This work will contribute to identification of biomechanical, perceptual, cognitive, and response demands imposed by high technology devices such as Advanced Driver Information Systems with a high degree of relevance to Intelligent Vehicle/Highway Systems (IVHS) as well. The goal is to contribute significantly toward enhancing roadway safety and promoting a driver-centered approach to the design, development, and implementation of high technology in-cab devices into the 21st century.

Task 1 of this project involved review of existing task analysis data and protocols (Tijerina, et al., 1991). Task 2 involved the definition of a "standard" heavy vehicle configuration and a set of "standard" driving tasks which will serve as a baseline condition for measuring workload in future phases of the project. The intent is to determine a common tractor-trailer combination which may be used for data collection and a set of driving tasks which may be used for selection of workload measures, for pilot testing, and for workload assessment scenarios.

Objectives and Scope

The objectives of Task 2 are as follows:

- identify a standard heavy vehicle configuration which will serve as a baseline condition for measuring workload. This standard configuration is defined as any typical truck tractor that does not incorporate advanced electronic controls (e.g., touch screen), head-up displays, navigation, route guidance, logging or advanced communication systems;

- identify a set of standard driving tasks which will serve as a baseline condition for measuring workload. This set will include those tasks typically associated with operating the "standard" heavy vehicle as defined above. Battelle has assumed that the intent of this project requires consideration of only those tasks in which the vehicle is in motion.

General Approach

Identification of a standard configuration was accomplished by the Battelle heavy vehicle operator consultant, based on his extensive experience and familiarity with United States trucking operations and trends. In addition, a sample of the Department of Commerce (1990) Truck Inventory and Survey data from several key states were reviewed for verification. Section 2.0 provides details of this work and discusses issues associated with the definition of a standard configuration for this project.

Identification of a set of standard driving tasks was accomplished by use of the task analysis data contained in the Task 1 Interim Report. Review of this data indicated the following:

- some tasks identified in the reviewed literature were either too global or addressed driving conditions rather than tasks per se (e.g., "drive at night"). This reflects the different uses to which the earlier task analyses were directed, e.g., training;

- other tasks were highly detailed and were prescriptive in nature. That is, they describe the sequence of driver behaviors which should be executed, not necessarily behaviors which are executed.

At this stage in the research program, it is important to identify intermediate level driving tasks. These are tasks which are of a higher level than individual driving behaviors and yet avoid being vague or directed at driving conditions within which a variety of tasks may be completed. They are essentially defined at the level of driving events or maneuvers which could be used in workload assessment protocol scenario or test conditions. The approach to identification of standard driving tasks and results of that work are provided in Section 3.0.

2.0 STANDARD HEAVY VEHICLE CONFIGURATION

Introduction

Rather than approach this task with the goal of identifying the single most common vehicle make, model, and year, Battelle has attempted to define a standard configuration in functional terms. For completeness, this functional definition should address the following elements:

- Cab style (conventional vs. cabover; with sleeper, without sleeper)
- Trailer number and length
- Dashboard instrument and control package
- Dashboard style (flat vs. wrap-around)
- Transmission type (number of gears; manual vs. automatic)
- Absence of any high-technology in-cab devices (including cruise control)
- Number of axles
- Engine type
- Brake type
- Suspension system
- Overall length
- Overall wheelbase
- Tires used
- Load type (liquid, dry/refrigerated freight, timber, etc.)
- Mirrors

From this list, it appears at present that cab style, dashboard style, absence of high technology devices, and number of trailers would have the greatest effect on driver workload (but see also Table 2.2).

Approach

The following approach was used for this task. Battelle's trucking consultant tentatively defined a standard configuration based on his years of experience and current awareness of trends in the trucking industry. He contacted the American Trucking Association (ATA) to solicit statistics with which to evaluate the "straw man" configuration and was directed to the Department of Commerce (1990) Truck Inventory and Use Survey reports which contain information as of 1987 (the most recently tabulated data). A sample of these reports was collected from the State Library of Ohio for the states of California, Illinois, Indiana, Ohio, Texas, New York, New Jersey, and Georgia. These states span both coasts, the midwest, the south, and the southwest and are thought to be representative of trucking in the United States. From these reports, key characteristics were reviewed and the "straw man" standard configuration was verified and changed as needed. Note that since the standard configuration was not to include high-technology, in-cab devices, no survey was attempted to determine the incidence of such device use in the United States. Note also that straight trucks were not considered for this project, though results obtained will likely apply to a variety of truck configurations.

Results

The review of the Department of Commerce reports is summarized in Table 2.1. This table includes key tractor-trailer configuration attributes and, by state, the number of trucks which possess those attributes. From a review of the data in this table, it is evident that many types of data pertinent to driver comfort and safety found in an increasing number of the heavy truck population are not collected by the Department of Commerce. Data such as presence or absence of a sleeper box, type of transmission, type of suspension (air ride or spring), presence of power steering and air conditioning, use of aerodynamic fairings, and length of wheelbase of the tractor are not available. As it stands, a picture can be developed based on the few data points available in Table 2.1 and supplemented by knowledge of current industry equipment trends.

Table 2.1 shows the propensity of conventional cab tractors over cabovers, tractor-single trailer combinations over "doubles" or '"triples", and the use of air brakes as the most common type of brake for a **heavy truck.** Since medium duty truck data is, unfortunately, combined with the truck data categories of the Department of Commerce data, gasoline engines appear to be the most common type of engine used. This is not the case for heavy duty trucks in the U.S.

Based in part on these data (for data available in the Department of Commerce reports) and in part on the expertise of the trucking consultant (for data unavailable in those reports), Table 2.2 contains the proposed definition of the standard heavy vehicle configuration to be used in this project. Battelle believes that this configuration, functionally defined, captures the typical tractor-trailer configuration in the United States, both presently and in the near future. It is intentionally broad and omits details which might unduly constrain truck configurations selected for study in this project.

Discussion

From an ergonomic standpoint, the interior of the cab offers some key factors which might significantly alter driver workload in one or more ways. For example, the cab style (conventional vs. cabover) is thought to be important for at least three reasons. First, cabover tractors typically have a semi-wrap-around dashboard and a 'dog-house' or engine cowling which constrains movement and reach to the right side of the cab and mounting of in-cab devices. Conventional tractors, on the other hand, usually have flat dashboards. In addition, cabover tractors also have a broader field-of-view through the windshield than conventional tractors. Thirdly, cabovers usually possess a shorter wheelbase to allow for shorter turning radii to ease maneuvering, backing, and sharp turns. These factors could lead to significant differences in driver workload. For example, a wrap-around instrument panel and dog-house may prevent certain kinds of biomechanical interference by constraining the distances to which a driver must reach to manipulate an in-cab device. It will also probably limit the degree to which the driver may bend to pick something up on the right-hand side or lean over to allow for shorter turning radii to ease maneuvering, backing, and making sharp turns. These factors could lead to significant differences in driver workload. For example, a wrap-around instrument reach the right-hand seat, passenger door, etc. The broader field of view through the windshield may affect visual sampling behavior (as may the angle and vertical positioning of the dashboard). It was pointed out in the Results section that cabover tractors are in the minority in American trucking today. However, cabovers are a significant portion nonetheless and are the tractor-of-choice for some very prominent carriers (e.g., J. B. Hunt, Schneider National, and United Parcel Service). Therefore, it appears that an alternative "standard" tractor-trailer configuration might

TABLE 2.1 SELECTED TRUCK INVENTORY AND USE SURVEY STATISTICS [IN THOUSAND OF TRUCKS BY SELECTED STATES]

Configuration Feature	OH	CA	IL	TX	GA	IN	NJ	NY
Cab Type								
Cabover	40.5	106.8	62.6	44.6	25.0	29.9	21.0	30.7
Conventional	150.8	247.7	201.6	238.0	101.3	105.8	96.7	145.4
Combination Vehicle Type								
Tractor/Single Trailer	55.1	78.8	103.0	79.3	33.8	38.8	29.8	26.0
Tractor/Double Trailer	.9	14.4	8.6	0.8	.	0.1	.	0.3
Tractor/Triples	.	.	.	.	.	.	.	.
Transmission (No Longer Reported) →								
Engine Type[(a)]								
Gasoline	123.5	234.6	152.0	190.3	84.0	92.1	78.9	123.0
Diesel	89.0	164.8	142.1	131.6	58.6	55.4	59.9	80.8
Brake Type								
Hydraulic	54.0	95.3	68.5	90.9	34.4	44.8	36.1	51.2
Hydraulic (Power)	58.3	124.0	71.5	92.5	38.5	41.9	34.9	68.6
Air	85.7	144.8	126.5	114.4	52.1	52.7	53.2	67.1
Sleeper Equipped (Not Reported) →								

(a)NOTE: Survey includes medium duty straight trucks as well as combination tractor-trailer units.

TABLE 2.2 DEFINITION OF THE STANDARD HEAVY VEHICLE CONFIGURATION

- Combination tractor and single trailer vehicle
- Conventional cab configuration with sleeper box optional
- Flat panel dashboard (rather than wrap-around dash)
- Diesel powered with air brakes
- Absence of high technology in-cab devices

be a cabover. At this point in the research project, it is unclear how such variables will factor into later phases of the research, but the ergonomic differences and non-negligible proportion of cabover rigs on the road suggest it would be prudent to consider cabovers further.

Ultimately, the truck configuration may play a relatively minor role in driver workload compared to the demands of the driving conditions outside the cab and devices inside the cab.

TABLE 2.3 FUNCTIONAL ATTRIBUTES OF A STANDARD HEAVY VEHICLE CONFIGURATION AND THEIR POSSIBLE DRIVER WORKLOAD IMPLICATIONS

Functional Attributes	Range	Possible Workload Implications
Cab style	conventional vs. cabover	Conventionals have primarily flat dashboards, small field of view out of windshield, no 'dog house' engine cowling, and a longer wheelbase. May affect driver biomechanical interference by affecting reach requirements and limits, by changing visual sampling behavior, and increasing workload during turns.
Sleeper unit	with sleeper vs. without sleeper	Unknown. Also has practical implications for on-the-road data collection (e.g., extra storage space helpful).
Dashboard style	flat vs. wrap-around	May affect driver reach to in-cab device controls and displays, visual angles to monitor or read from displays.
Dashboard instrument and control package	Various	Different displays invite different kinds and frequency of visual sampling (e.g., status lights vs. gauges). Different controls and equipment invite different driver manipulations (e.g., toggle switches vs. 'seek' button for radio vs. rotary knob for channel selection).
Transmission type	number of gears; presence or absence of "splitter" button to present a "hi" or "lo" ratio choice in each gear selected, thereby effectively increasing the number of gear choices	Affects manual and clutch pedal loading.
High-technology in-cab devices	Various. Standard configuration should not be equipped with these.	May affect baseline significantly. For example, cruise control would presumably ease driver workload and visual sampling to the speedometer. An issue, however, is that over time what is "standard" in tractors changes. Cruise control and other in-cab devices may redefine the baseline in the future.

Functional Attributes	Range	Possible Workload Implications
Number of axles	single vs. tandem	Longer wheelbase increasing workload during turns.
Engine type	late model diesel vs. gasoline	High torque rise diesel engines have more power for greater sustained road speeds and less shifting.
Brake type	air brakes vs. other systems	May influence braking distances and times which are reflected in driver visual sampling strategies, amount of manual (steering wheel) loading involved in quick stops (e.g., ABS brake system vs. conventional braking systems), etc.
Suspension system	air-ride suspension vs. spring suspension	Better suspension will reduce visual jitter in displays, make reading easier. From a practical standpoint air-ride suspension is needed for video data collection anticipated in later phases of this program.
Overall length		The longer the combination vehicle length, the greater the demand for situation awareness on the driver's part.
Overall wheelbase		Wider configurations or loads increase the tolerances for lane keeping, making turns, and backing up.
Tires used	radial vs. fabric	Radial tires experience less flats and blowouts than older fabric ply tires, posing less problems for drivers in this regard.
Trailer number and length	single vs. dual vs. triple; lengths may vary from 28 feet for each trailer of a double or triple trailer combination to single trailers of 48 to 53 feet in length	Presumably, multiple trailers or longer trailers increase the demand for situation awareness because of the longer lags in completing maneuvers and greater 'area of responsibility' drivers have.
Load type	liquid, dry/refrigerated freight, timber, etc.	Liquid bulk tank trailers without baffling present a sloshing effect which must be compensated for by the driver during deceleration, turns, and acceleration.

3.0 STANDARD DRIVING TASKS

Introduction

As was mentioned in Section 1.0, identification of a set of standard driving tasks was accomplished by reviewing the task analysis data contained in the Task 1 Interim Report. Review of this data indicated the following:

- some tasks identified in the reviewed literature were either too global (e.g., "maneuver a vehicle combination in built-up area") or addressed driving conditions rather than tasks per se (e.g., "drive at night"). This reflects the different uses to which the earlier task analyses were directed, e.g., training;

- some descriptions were highly detailed (i.e., subtasks) and were prescriptive in nature. That is, they describe the set of driver behaviors which should be executed, not necessarily behaviors which are executed.

At this stage in the research program, it is important to identify driving tasks at the level of maneuvers. Such tasks can then be used as the building blocks for scenarios or test conditions which are needed for the workload assessment protocols. Occurring within various driving conditions (see below), these tasks form the situations within which driver workload is exhibited. It is within these tasks that visual, manual, pedal, cognitive, and auditory loads will be exhibited. So defined, driving subtasks can be observed during the execution of the task and compared to those given in the Task 1 interim report and the original sources.

Approach

The task listings and descriptions given in the Task 1 interim report were reviewed to identify tasks in which the vehicle is in motion. This first pass was aimed at identifying those tasks thought to be of most interest to the current project and excluded pre-trip and post-trip activities. Next, the various task listings were reviewed to provide a comprehensive set of such tasks. It was noted that many different sources identified the same tasks but there were also differences among lists from which the broadest set of relevant tasks was derived. This set of tasks was collated and organized into conceptual categories for convenience. The set was then reviewed by Battelle's driver consultant for completeness and correctness. The task phrases were rewritten to capture language with which a professional truck driver would be familiar and comfortable; they may be subject to further modification of wording as the need arises. No data are provided with regard to safety criticality, frequency, or difficulty at this point because such data will be collected as part of the Task 3 data collection effort. The results are provided below.

Results

The listing of standard driving tasks proposed for consideration in this project is given in Table 3.1. It is organized in terms of basic driving tasks, parking and related activities, lane changes and passing/overtaking, turns and curves, intersections and crossings, and nonstandard (emergency)

TABLE 3.1 PROPOSED STANDARD DRIVING TASKS

Conceptual Categories	Associated Driving Tasks
Basic Driving Tasks	Start vehicle in motion Shift gears Reach desired speed in each gear Reach desired cruise speed * Control truck speed to allow for safe stopping distance * Brake under normal circumstances * Maintain safe following distance * Control direction via the steering wheel * Maintain lane position and spacing, straight road * Be aware of changes in the road scene [the primary visual task] Glance at gauges * Glance at mirrors Drive on a downgrade (steep gradient) Drive on an upgrade
Parking and Related Activities	Park tractor-trailer Back-up
Lane Changes and Passing/Overtaking	* Change lanes Pass on the left, cars (multi-lane, divided road) Pass on the left, other trucks (multi-lane, divided road) Pass on the left, cars (two-lane, undivided road) Pass on the left, other trucks (two-lane, undivided road) Pass construction zones * Merge Exit using an exit ramp
Turns and Curves	Make a left turn Make a right turn * Negotiate a curve and remain in your lane * Negotiate a curve and change lane in a multi-lane divided highway Turn your tractor-trailer around
Intersections and Crossings	Travel through intersections (You have right-of-way) Stop at intersections (They have right-of-way) Start truck in motion from a stop at an intersection Cross railway grade crossings * Negotiate l-lane and narrow 2-lane bridges * Negotiate narrow lane tunnels Stop at and start from narrow-lane toll plaza

Conceptual Categories	Associated Driving Tasks
Nonstandard Driving	Recover from locked brakes due to extreme loss of air pressure Make a quick stop (Put a lot of pressure on brakes, but with no smoking tires, no danger of losing control) Make a hard braking stop (smoking tires, danger of losing control) Stop due to lighting problem (e.g., trailer lights go out) Stop due to engine problem (e.g., high engine coolant temperature, low oil pressure) Recover from tire failure, front tire(s) Recover from tire failure, other tire(s) Steer to avoid something on the road Recover from a tractor/trailer skid Respond to cargo or tire fire Execute off-road recovery (veer off the road to avoid collision, then immediately return to roadway)

driving. This is thought to be a relatively comprehensive set of driving tasks suitable for use in further phases of this project. At this stage in the project, the asterisked tasks appear to be those most relevant to in-cab device interaction.

It is evident that driving tasks can only be considered in the context of driving conditions and the driver. While we are not yet prepared to discussed driver characteristics, driving conditions are addressed here for completeness. Table 3.2 includes a listing of the critical driving conditions which might affect driver workload. It includes two levels each of the four basic factors identified by NHTSA in the Statement of Work: traffic density, roadway, lighting, and weather. Weather has been operationally defined in terms of visibility and traction. An additional driving factor of locale (urban streets vs. open highways) is included to capture speed effects. It should be noted, however, that at NHTSA direction emphasis will be placed on highway driving.

<u>Discussion</u>

In order to complete this listing of standard driving tasks, it is worthwhile to note the basic driver behaviors which lead to the completion of tasks given in Table 3.1. These include the following:

- Looking at the road scene through the windshield
- Turning the head to view either westcoast (side) mirror
- Glancing down at gauges or controls
- Turning the steering wheel
- Holding the steering wheel steady
- Moving the transmission gear selection lever
- Moving the accelerator pedal
- Moving the brake pedal
- Moving the clutch pedal
- Manipulating dashboard controls for fan motor, wipers, lights, etc.
- Adjusting the driver's seat for comfort
- Adjusting windows for proper ventilation
- Adjusting air conditioning vents for comfort.

It is important to note that these behaviors will be among those observed and in some way measured in the workload assessment of heavy vehicle drivers. Ultimately, which of these behaviors, in what sequence, and for how long is determined by the driving task to be accomplished which, in turn, is affected by the prevailing driving conditions.

It is also worth noting that there are a variety of non-driving behaviors which may affect driver workload nonetheless. These are discretionary tasks which presumably are engaged in when the driver feels he can safely do so. Examples of these kinds of in-cab discretionary behaviors include the following:

- Concentrating on CB activity
- Talking on the CB
- Pouring coffee or other beverages
- Drinking coffee or other beverages
- Fumbling with and eating snacks

- Manipulating the radio
- Manipulating smoking materials (e.g., cigarettes, lighter, snuff, etc.)

TABLE 3.2. CRITICAL DRIVING CONDITIONS

Driving Condition **Factor**	**Levels**
Lighting	Day (sunny) vs. night (moonless)
Traffic	Light vs. heavy
Roadway Division	Divided vs. undivided
Visibility	Good vs. poor (e.g., foggy with visibility of barely one truck length ahead)
Road Traction	Good traction vs. poor traction (slippery ice, heavy rain, mud, snow)
Locale	Open highways vs. urban streets

- Attempting to read a map, shipping papers, or written directions
- Writing in a log book while driving
- Dealing with an in-cab distraction (pet, insect, rider)
- Intense daydreaming
- Attending to irrelevant distractions on the roadway (e.g., billboard or hitchhiker).

The impact of these behaviors on driver workload and highway safety can be quite negative. It is not yet clear how or even if such contributions to driver workload can be factored into the workload assessment protocols. However, given that such behaviors are realistic and reflect additional concurrent "tasks", they merit mention at a minimum.

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