Preliminary Human Factors Guidelines for Automated Highway System Designers (Second Edition) Volume II: User-System Transactions

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FOREWORD

This is the second volume of a two-volume report. The report presents the results of a comprehensive examination of human factors considerations related to the human-centered design of Automated Highway Systems (AHS). The results are shown as preliminary guidelines that AHS designers may utilize to maximize the effectiveness and efficiency of system performance, ensure a high level of system safety, and to improve user acceptance. These guidelines were compiled from material pertinent to AHS in existing handbooks, guidelines, human factors engineering texts and articles, as well as analyses in the current research projects in this effort. This report will be of interest to all AHS designers involved in such activities as specification of functional requirements, determination of interface philosophy, selection of controls and displays, design of controls and displays, design of driver-system dialogues, and design of driver workspace.

Sufficient copies of the report are being distributed to provide a minimum of two copies to each FHWA regional and division office, and five copies to each State highway agency. Direct distribution is being made to division offices.

A. George Ostensen, Director
Office of Safety and Traffic Operations
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NOTICE

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16. Abstract

Human factors can be defined as "designing to match the capabilities and limitations of the human user." The objectives of this human-centered design process are to maximize the effectiveness and efficiency of system performance, ensure a high level of safety, and maximize user acceptance. These objectives are achieved by systematically applying relevant information and principles about human abilities, characteristics, behavior, and limitations to specific design problems. This handbook provides a source document for automated highway system (AHS) designers that will facilitate a human-centered design process for the AHS. It is the second edition of these guidelines (first edition is report RD-94-116) and includes the addition of key AHS attributes proposed by the National Automated Highway System Consortium, updates to the chapter on general guidelines for electronic visual displays, and the addition of several operational guidelines (chapter 10).

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
	AREA			
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
	VOLUME			
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
	ILLUMINATION			
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
	FORCE and PRESSURE or STRESS			
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
	AREA			
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
	VOLUME			
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
	ILLUMINATION			
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
	FORCE and PRESSURE or STRESS			
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)

TABLE OF CONTENTS

Section Page

VOLUME I: GUIDELINES FOR AHS DESIGNERS

TABLE OF CONTENTS (CONTINUED)

Section Page

VOLUME I: GUIDELINES FOR AHS DESIGNERS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

Section Page

VOLUME I: GUIDELINES FOR AHS DESIGNERS (CONTINUED)

VOLUME II: USER-SYSTEM TRANSACTIONS

LIST OF FIGURES

Figure Page

VOLUME I: GUIDELINES FOR AHS DESIGNERS

LIST OF FIGURES (CONTINUED)

Figure — Page

VOLUME I: GUIDELINES FOR AHS DESIGNERS (CONTINUED)

VOLUME II: USER-SYSTEM TRANSACTIONS

LIST OF TABLES

Table Page

VOLUME I: GUIDELINES FOR AHS DESIGNERS

Table Page

VOLUME I: GUIDELINES FOR AHS DESIGNERS (CONTINUED)

VOLUME II: USER-SYSTEM TRANSACTIONS

Table Page

VOLUME II: USER-SYSTEM TRANSACTIONS (CONTINUED)

In this volume of the handbook are high level transactions between the user and the system for various phases of automated highway system (AHS) driving for each of three scenarios.[1] These transactions show the input to a driver action, how the driver processes the input, and the driver's response to the input (i.e., the output of the transaction). This volume is organized as follows:

- Distinguishing features of the three scenarios. These indicate what vision of the AHS is implied by each scenario.
- Notes on the user-system transactions.
- The transactions.

Distinguishing Features of the Scenarios

Transactions were done for the following three scenarios:

- Free Agency/Self-Contained. All instrumentation necessary for automated vehicle control is contained on the vehicle. The driver must enter the lane of choice manually and then switch on the vehicle automation systems. These include an automated gap- and speed-keeping system, an automated lane-keeping system, and a collision warning/avoidance system. As long as the driver stays within a given lane, driving is automatic. Lane changing, however, requires the resumption of manual steering control. Free mixing of manual and instrumented vehicles is allowed in all lanes.
- Barriers on the Highway with Grouped Vehicles. Automated and manual traffic share the same highway structure in this scenario. There are three types of lanes: manual, transition, and automated. The transition lane lies between the manual lanes and the automated lane(s). Only vehicles under automated control can use the automated lane(s). Access to an automated lane is via normal freeway entrance and exit ramps and the transition lane. For safety purposes, barriers with gaps between them for entry and exit are placed between the automated and transition lanes. All maneuvers, including lane changes, are automated and conducted by close-following groups of vehicles.
- Segregated Highway with Individual Vehicles. In this scenario, the automated lanes are completely isolated from the manual lanes of traffic, and access is directly from an automated ramp. Once in an automated lane, all driving is controlled by the system. All automated travel, including maneuvers, is performed by individual vehicles.

Table 1 summarizes the distinguishing features of the scenarios.

Table 1. Distinguishing features of the three scenarios.

	Roadside Sets Maximum Headway	Roadside Sets Maximum Speed	Lane Selection by Roadside or Driver	Lane Changing Automated or Manual	Automated Entrances and Exits	Metered Entry	Maneuvers by Individual Vehicles or Groups	Lane Types	Vehicles Enter/Exit Automated Lane As Individuals or by Groups	Lane Changes by Individual Vehicles or Groups	Other Features
Free Agency/ Self-Contained	No	No	Driver	Manual	No	No	Individuals	All lanes mixed: automated and manual	No strictly automated lanes	Individuals	• All lanes can support automated driving. • Mixed traffic in all lanes.
Barriers on the Highway with Grouped Vehicles	Yes	Yes	Roadside	Automated	Yes	Yes	Groups	Automated, transition, and manual	Groups	Groups	
Segregated Highway with Individual Vehicles	Yes	Yes	Roadside	Automated	Yes	Yes	Individuals	Automated	Individuals	Individuals	

Notes on the User-System Transactions

The notes in this section apply across the transactions for all three scenarios.

- Time limits that might be imposed by the system on user actions (e.g., the system may allow only a limited amount of time for the user to respond to an interrogation about readiness to resume control of the vehicle) are not indicated in the transactions. Where there are such time limits, information displayed at the time the action is requested will clearly indicate the time limit, and a running display of the amount of time remaining in which to make the required action will be presented until the action is made or the time has expired. Action taken by the system subsequent to expiration of a time limit will be clearly explained to the driver.
- Information will be presented to a driver far enough in advance to allow a reasonable response, but not so far as to lose its utility. The required time intervals will differ based on the responses required, and are to be determined (TBD).
- At some point after a driver has initiated contact with the AHS, probably at check-in, there will be a continuous display in the vehicle indicating whether the system is in control or the driver is in control. This display will continue until the driver has exited the system.
- A driver will be able to adjust such things as visual display contrast and brightness and auditory display volume, over limited ranges. The exact ranges are TBD, but at least for auditory displays used to draw a driver's attention to warnings and other emergency information, a driver will not be able to reduce the volume to zero intensity.
- Error messages presented to a driver will, to the extent possible, describe the specific error and provide explicit instructions about corrective action.

The Transactions

In this section are the user-system transactions. These transactions are intended to be representative of the types of transactions that will occur on the AHS. As indicated earlier in the handbook, system design is an iterative process, and the transactions shown here are subject to change as the design of the automated highway system proceeds.

Free Agency/Self-Contained Scenario

In this section are the transactions for the Free Agency/Self-Contained scenario.

Assumptions

Several operating assumptions were made for this scenario, and they are given here so the reader will understand the basis for the decisions made.

- The automated lateral control system will not provide steering for collision avoidance. The scenario requires manual lane changes, and the reasoning was that if the envisioned system could not accomplish an automated lane change, then it could not do the more complicated steering involved in avoiding a possibly moving object. The automated collision warning/avoidance system will do braking to avoid obstacles ahead.
- The automated longitudinal control system and the forward-looking component of the collision warning/avoidance system will share the same sensors. Consequently, if one of the two systems is inoperable, then the other is inoperable also.
- The driver can increase the physical gap between the driver's vehicle and the vehicle ahead, but cannot decrease the gap below some system-set minimum, which will be based (at least in part) on current vehicle speed: as speed increases, the minimum gap will increase.
- The automated lateral- and longitudinal-control systems will be bundled, so that either both are on or neither is on. Thus, the driver will be able to have on either the collision warning/avoidance system alone (in which case it will not provide collision avoidance) or the collision warning/avoidance system + automated lateral control system + automated longitudinal control system. This was done to reduce the likelihood that the driver will become confused about which system is on. (Note that this presents the logical problem that a driver will not be able to use cruise control if the AHS infrastructure to do lane-keeping is not in place. There are possible solutions to this dilemma, but they are not the subject of this report.) This bundling also means that when the driver makes a manual steering input to, for example, change lanes, both automated steering and automated speed control will disengage. The collision warning/avoidance system, however, will remain on. The driver will have to re-engage both control systems after the steering maneuver, which the driver will be able to do with a single control action.
- As appropriate (e.g., on curves), the roadway will be fitted with some type of device(s) that will allow the vehicle onboard system to determine a maximum safe speed, and the vehicle's speed will be decreased if necessary to comply with that maximum.

Transactions

Following system check-in, there are several events that can occur in this scenario that have an effect on the automation. Since the driver is free to actuate either the collision avoidance/warning system alone or in combination with the automated lateral- plus longitudinal-control systems, the events that are relevant for a particular driver depend upon the state of the automated systems aboard the driver's vehicle. Table 2 shows the transactions for system check-in, and ends with the driver having selected some unspecified combination of automated systems. Table 3 shows how the various events that can occur are affected by the various combinations of systems the driver could have actuated. This table should be used to guide the reader to tables 4 through 8, which show transactions for the various events noted in table 3.

Table 2. System check-in for the Free Agency/Self-Contained Scenario.

Input	Processing	Output
[1] The driver turns on the in-vehicle AHS system. The system displays vehicle inspection results —fluid levels, battery charge status, and information about AHS-specific hardware (sensors, processors, and actuators). Note: This assumes that when the vehicle is started, it performs a check on its systems. The results of this initial check are displayed to the driver. Included is information about which system is functional and therefore available for actuation: • Collision warning/avoidance. • Collision warning/avoidance + lateral control + longitudinal control. (Note: If the vehicle is not on an AHS roadway, use of the lateral control + longitudinal control systems will be denied. Also, if only the collision warning/avoidance system is turned on, it cannot provide avoidance maneuvers.)	[1] The driver receives the inspection information and decides which of the available systems to actuate.	[1] The driver actuates none of the AHS-related systems and continues manual driving. *(END)* [2] The driver engages one or more of the AHS-related systems.
[2] The system annunciates which system is on.	[2] The driver receives the annunciations.	[2] *(See table 3 to determine which events are relevant based on the driver's choice of systems.)*

Table 3. Events affecting automation.

Status of Automated Systems		Events That Can Occur That Have an Effect on the Automation				
Collision Warning/ Avoidance System	Lateral and Longitudinal Control Systems	Get Collision Warning	Set Speed and Gap	Change Lanes	Automated Highway Ends	Discontinue Use of Automation
On	On	3	3	3	3	3
On	Off	3				3
Off	Off					

Table 4. Collision warning/avoidance for the Free Agency/Self-Contained Scenario.

If only the collision warning/avoidance system is active, start at [1].
If the collision warning/avoidance + lateral control + longitudinal control systems are active, start at [3].

Input	Processing	Output
[1] The system displays a collision warning. Only the collision warning/avoidance system is active, and: • The threat is to the front. • The threat is to the side.	[1] The driver receives the warning and may observe the threat. The driver determines an appropriate response.	[1] The driver manually brakes to avoid the threat. *CONTINUE with 1a in the next row.* [2] The driver manually steers to avoid the threat. *CONTINUE with 1a in the next row.*
[1a] The system extinguishes the collision warning.	[1a] The driver perceives the warning extinguish.	[1a] The driver continues to manually control speed and steering. *(END)*
[3] The system displays a collision warning. The collision warning/avoidance system and the automated lateral and longitudinal control systems are active, and the threat is to the front. [4] The system displays a collision warning. The collision warning/avoidance system and the automated lateral and longitudinal control systems are active, and the threat is to the side. *CONTINUED four rows below.*	[3] The driver receives the warning and may observe the threat. The driver determines an appropriate response.	[3] The system automatically brakes to avoid the threat. [5] The driver manually steers to avoid the threat. This disengages the lateral and longitudinal control systems. *CONTINUED two rows below.*
[3] The system extinguishes the collision warning.	[3] The driver perceives the warning extinguish.	[3] The driver continues under automated lateral and longitudinal control. *(END)* [6] The driver does not re-engage the lateral and longitudinal control systems, and continues to control steering and speed manually. *(END)*
[5] The system extinguishes the collision warning and indicates that the lateral and longitudinal control systems are off and that the driver must steer and control speed manually.	[5] The driver perceives the warning extinguish and perceives the indication that lateral and longitudinal control are off. The driver decides whether to re-engage the lateral and longitudinal control systems.	[5] The driver re-engages the lateral and longitudinal control systems. [7] The driver does not re-engage the lateral and longitudinal control systems, and continues to control steering and speed manually. *(END)*
[5] The system indicates that the lateral and longitudinal control systems are on.	[5] The driver receives the indication that lateral and longitudinal control are on.	[5] The driver continues under automated lateral and longitudinal control. *(END)*
	[4] The driver receives the warning and may observe the threat. The driver determines an appropriate response.	[4] The system automatically brakes to avoid the threat, and the driver (unnecessarily) brakes also. This disengages the lateral and longitudinal control systems. *(Table continued on next page.)*

Table 4. Collision warning/avoidance for the Free Agency/Self-Contained Scenario (continued).

Input	Processing	Output
[4] The system extinguishes the collision warning and indicates that the lateral and longitudinal control systems are off and that the driver must steer and control speed manually.	[4] The driver perceives the warning extinguish and perceives the indication that lateral and longitudinal control are off. The driver decides whether to re-engage the lateral and longitudinal control systems.	[4] The driver re-engages the lateral and longitudinal control systems.
[4] The system indicates that the lateral and longitudinal control systems are on.	[4] The driver receives the indication that lateral and longitudinal control are on.	[4] The driver continues under automated lateral and longitudinal control. *(END)*

Table 5. Setting speed and setting gap for the Free Agency/Self-Contained Scenario.

Input	Processing	Output
[1] The driver observes current speed, traffic conditions, and anything else that might affect a decision to change speed.	[1] The driver decides to change speed.	[1] The driver brakes or accelerates to the new desired speed. This disengages the longitudinal and lateral control systems.
[1] The system displays the new speed and a message that the longitudinal and lateral control systems are off and that the driver must steer and control speed manually.	[1] The driver receives the new speed indication and the message.	[1] The driver re-engages the longitudinal and lateral control systems. [2] The driver does not re-engage the longitudinal and lateral control systems and continues to control speed and steering manually. *(END)*
[1] The system indicates that automated lateral and longitudinal control are on and that the system is in control of steering and speed.	[1] The driver receives the indication that lateral and longitudinal control are on.	[1] The driver continues under automated lateral and longitudinal control. *(END) GO TO 3 in the next row.*
[3] The system displays the current gap; the driver observes the current gap, road conditions, weather conditions, and anything else that might affect a decision to increase gap.	[3] The driver sees the information and decides to increase the gap.	[3] The driver initiates the gap setting.
[3] The system displays the new gap setting and executes the gap change.	[3] The driver sees the new gap setting and perceives the gap change. *(END)*	

Table 6. Changing lanes for the Free Agency/Self-Contained Scenario.

Input	Processing	Output
[1] The driver observes traffic conditions and anything else that might affect a decision to change lanes.	[1] The driver decides to change lanes and decides into which lane to change.	[1] The driver takes hold of the steering wheel and changes lanes. This disengages the lateral and longitudinal control systems.
[1] The system indicates that automated lateral and longitudinal control are off and that the driver must control steering and speed manually.	[1] The driver receives the indication that lateral and longitudinal control are off and observes that the vehicle is in the desired lane.	[1] The driver re-engages the lateral and longitudinal control systems. [2] The driver does not re-engage the lateral and longitudinal control systems and continues to control steering and speed manually. *(END)*
[1] The system indicates that automated lateral and longitudinal control are on and that the system is in control of steering and speed.	[1] The driver receives the indication that lateral and longitudinal control are on .	[1] The driver continues under automated lateral and longitudinal control. *(END)*

Table 7. When the automated highway ends for the Free Agency/Self-Contained Scenario.

Input	Processing	Output
[1] The infrastructure supporting automated lateral control is not part of the roadway ahead. The system displays a message indicating that lateral and longitudinal control will end in *x* miles (or feet) and that the driver must be prepared to assume manual control of speed and steering. The display changes at prespecified points (e.g., 1.6 km, .8 km, 457.2 m [1 mi, .5 mi, 1,500 ft]) until some critical system decision point before the infrastructure ends. (Note: Since the lateral and longitudinal control systems must be actuated together, they will also be deactuated together.)	[1] The driver receives the message.	[1] The driver prepares to resume manual control. [2] The driver does not prepare to resume manual control. *(Table continued on next page.)*

Table 7. When the automated highway ends for the Free Agency/Self-Contained Scenario (continued).

Input	Processing	Output
[1, 2] The critical decision point is reached. The system displays a message that the driver must control speed and steering manually.	[1, 2] The driver receives the message.	[1] The driver assumes manual control of speed and steering. *(END)* [2] The driver fails to assume manual control of speed and/or steering.
[2] The system displays a message that the vehicle is being stopped because the roadway will not support automated lateral control.	[2] (Unclear.)	[2] The vehicle's four-way emergency flashers are actuated and the vehicle is brought to a stop in its lane. The engine is shut down. *(END)*

Table 8. Discontinuing the use of automation for the Free Agency/Self-Contained Scenario.

Input	Processing	Output
[1] The driver observes his/her current location, traffic, weather conditions, and anything else that might affect a decision to discontinue automated operations.	[1] The driver decides to discontinue some or all automated operations.	[1] As appropriate, the driver does one or more of the following: • Takes hold of the steering wheel or actuates a STEERING OFF control and begins to steer manually. This disengages the lateral and longitudinal control systems. • Brakes slightly or actuates a SPEED OFF control. This disengages the lateral and longitudinal control systems. • Disengages the collision warning/ avoidance system. This disengages the collision warning/avoidance system and the lateral and longitudinal control systems.
[1] The system provides the appropriate indication in response to the driver's actions, indicating which systems are currently on and which are off.	[1] The driver receives the messages. *(END)*	

Barriers on the Highway with Grouped Vehicles Scenario

In this section are the transactions for the Barriers on the Highway with Grouped Vehicles Scenario.

Assumptions

Several operating assumptions were made for this scenario, and they are given here so the reader will understand the basis for the decisions made.

- If a vehicle fails the check-in inspection, the system will display a message stating that it has failed but not, in most cases, specifying the cause(s). (Where insufficient fuel is the problem, the system will include that information in its message.) It is assumed that the cause(s) of the failure will be determined during an electronic interrogation of the vehicle's computer system by a mechanic (which is what happens on most modern vehicles when, for example, the CHECK ENGINE light comes on).
- Sensors aboard the vehicle will keep a continuously updated record of the vehicle's fuel efficiency. This information will be used by the AHS, along with other variables, to determine how far a particular vehicle can travel toward the driver's selected destination. It is also assumed that the system will add a safety margin to the calculation [e.g., if the system determines that a vehicle can travel 450 km (280 mi), it will actually allow for a destination that is (say) only 400 km (249 mi) away].
- Unless a vehicle has some criterion minimum amount of fuel when the transition lane inspection is done, it will not be allowed to participate on the AHS. This amount will be based in part on how far it is from the current location of the vehicle to the nearest exit and in part on the fact that if the driver fails the test for driver readiness to resume manual control of the vehicle, the vehicle will have to be driven by the system to a safe depository.
- If the driver's exit becomes closed for some reason (e.g., an accident) after the driver's destination has been accepted, the AHS will use the nearest available exit after the original one selected. (Given sufficient advance notification by the system, the driver will, of course, be free to set a new destination.)
- It is assumed that the roadside system "knows" the location of every vehicle that is on an AHS roadway (in any lane) with the in-vehicle system turned on. This will allow the system to schedule safe times/places to change lanes. It will also allow the system to deny entry to the transition lane if a vehicle is not in the lane adjacent to it when the request is made: If the vehicle is in a nonadjacent lane, metering instructions for getting into the transition lane will be meaningless.

Transactions

The transactions are shown for the various major events in tables 9 through 12. Given the relative complexity of the enter-into-system transactions, which include destination

selection, it was thought that a flow-chart representation might prove helpful for some readers. The flow chart is shown in figure 1.

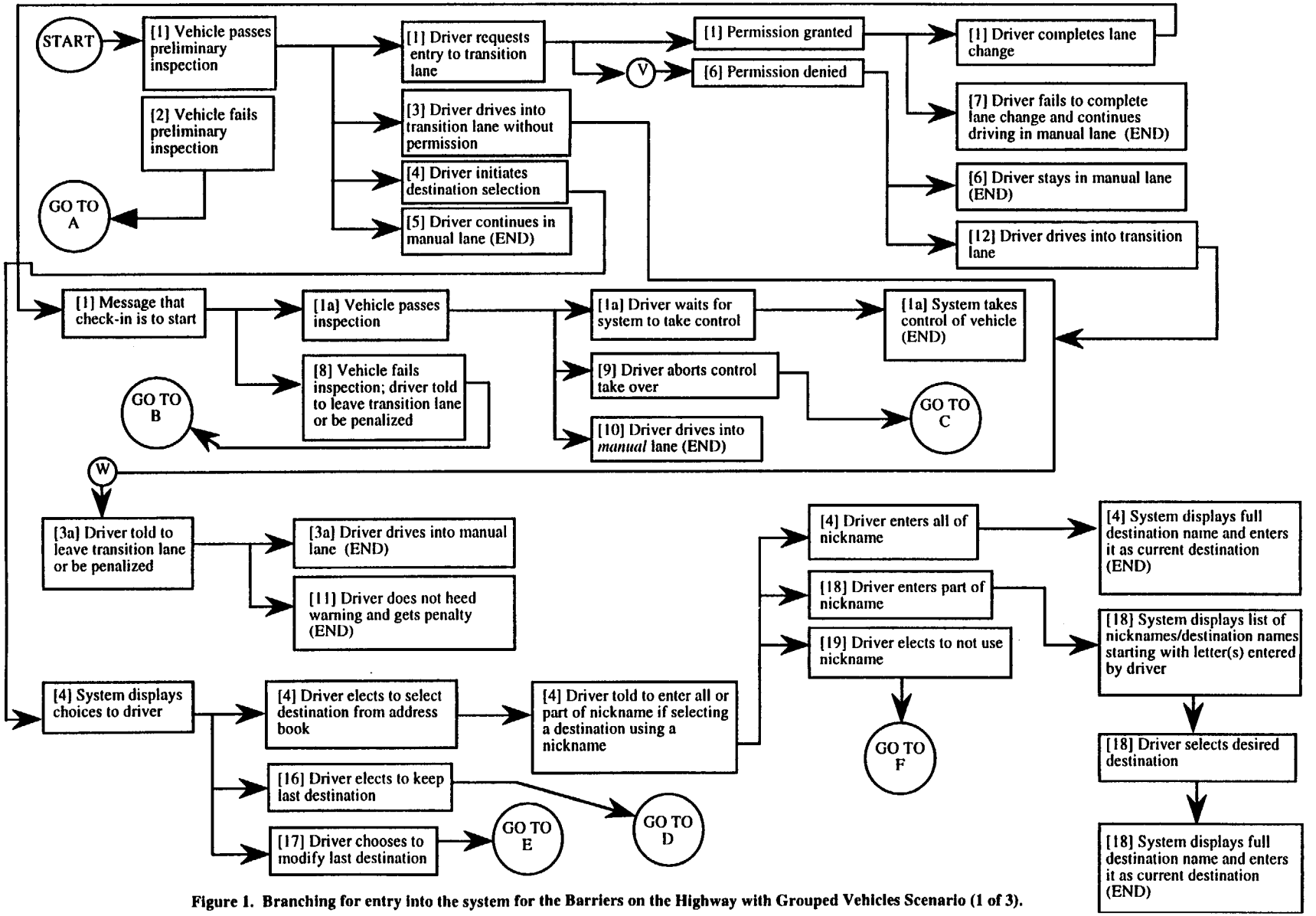

Figure 1. Branching for entry into the system for the Barriers on the Highway with Grouped Vehicles Scenario (1 of 3).

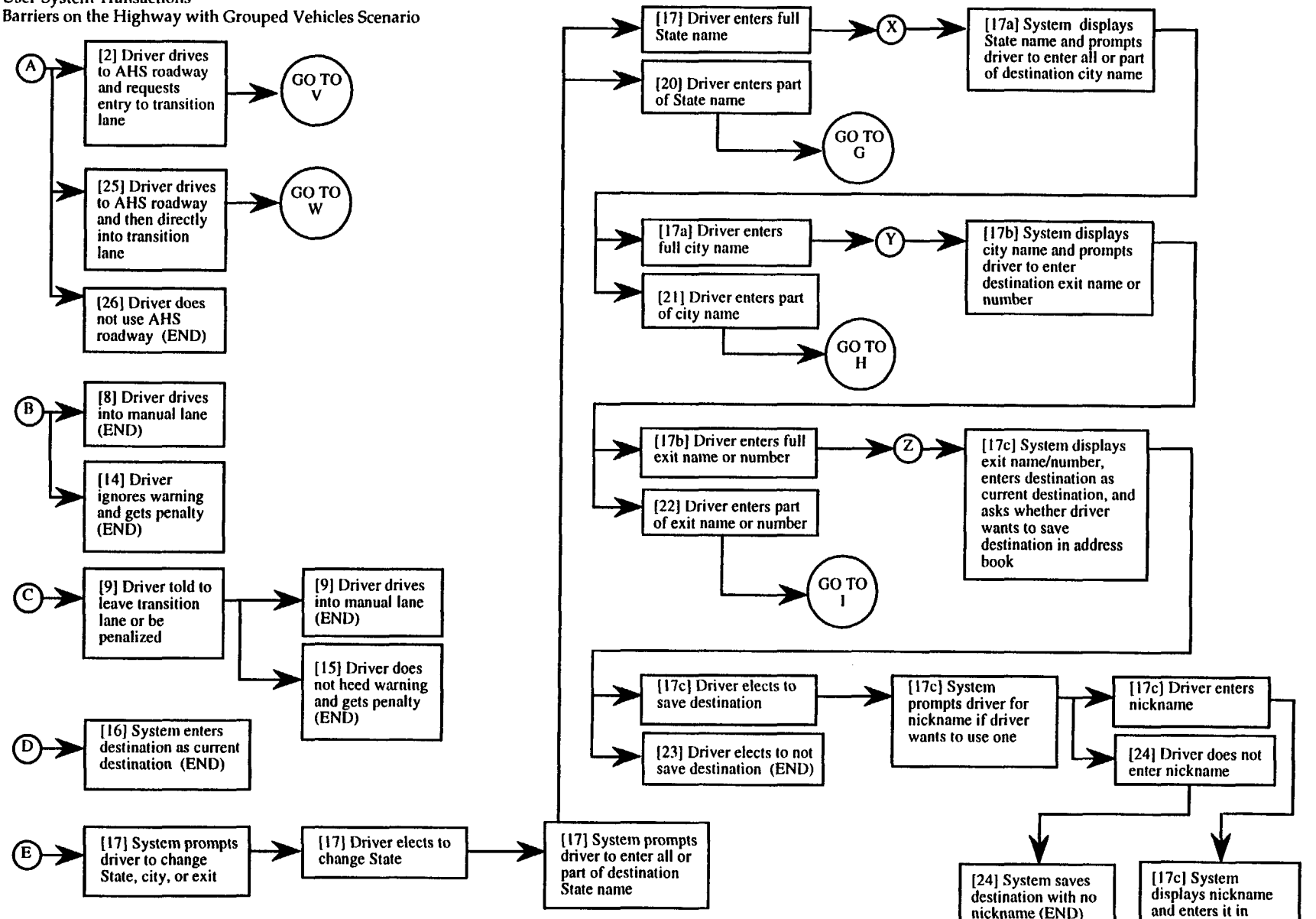

Figure 1. Branching for entry into the system for the Barriers on the Highway with Grouped Vehicles Scenario (2 of 3).

User-System Transactions
Barriers on the Highway with Grouped Vehicles Scenario

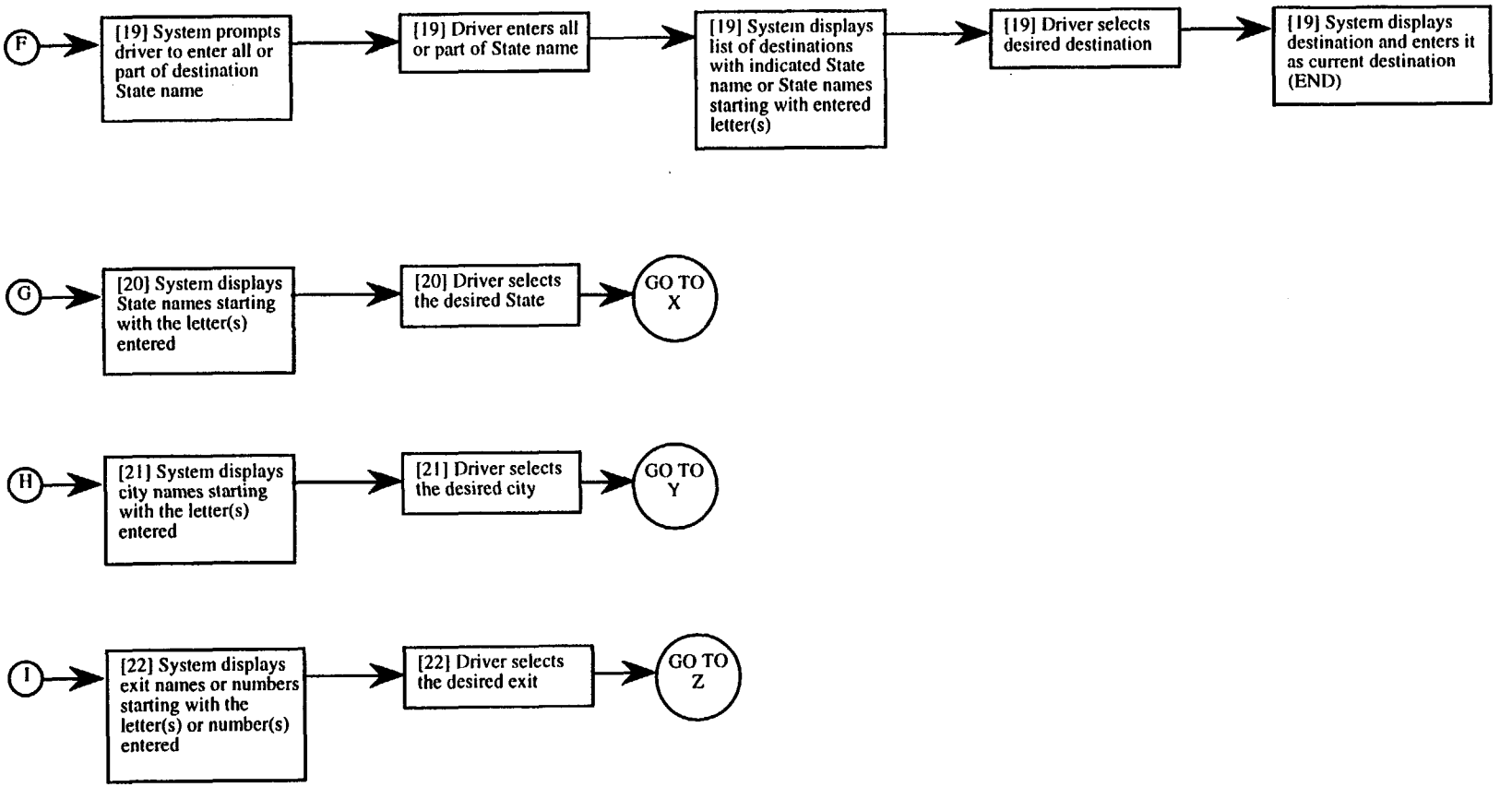

Figure 1. Branching for entry into the system for the Barriers on the Highway with Grouped Vehicles Scenario (3 of 3).

Table 9. Entry into tbe system for the Barriers on the Highway with Grouped Vehicles Scenario.

Input	Processing	Output
The driver is parked and turns on the in-vehicle AHS system. The system displays vehicle status information—fluid levels, battery charge status, and information about AHS-specific hardware (sensors, processors, and actuators). Note: This assumes that, when the vehicle is started, it performs a check on its systems. The results of this initial check are immediately displayed to the driver: [1] The vehicle passes the preliminary inspection. [2] The vehicle fails the preliminary inspection. *CONTINUED on page 20.*	[1] The driver receives the information and decides whether to use the AHS. The driver also decides whether to set destination at that time.	[1] The driver does not set the destination. The driver drives to an AHS roadway, gets into the manual lane, and requests entry to the transition lane. [3] The driver does not set the destination. The driver drives to an AHS roadway and, without requesting permission, drives directly into the transition lane. *CONTINUE with 3a, page 17.* [4] The driver initiates destination selection. *CONTINUED on page 18.* [5] The driver does not set the destination and does not use the AHS roadway. *(END)*
[1] The system displays a message granting permission to enter the transition lane. The message includes metering instructions, i.e., assistance as to when the lane change should be made. [6] The system displays a message denying entry into the transition lane and why entry has been denied. *CONTINUED on page 17.*	[1] The driver receives the message and decides when to begin the change into the transition lane.	[1] The driver successfully completes the lane change. *CONTINUE with 1a in the next row.* [7] The driver fails to complete the lane change and continues to drive in the manual lane. *(END) (Table continued on next page.)*

Table 9. Entry into the system for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
[1a] The system displays a message that the vehicle has passed the inspection and that it will take control of the vehicle in *x* minutes. The message also includes a reminder that if the driver wishes to abort entry into the AHS, the driver should either: (a) steer back into the adjacent manual lane within *x* minutes, or (b) enter an abort command and then steer into the manual lane. The abort command immediately cancels system plans for automatic takeover of the vehicle. If the driver aborts the entry, the system displays a message that the driver must maneuver back into the manual lane within *y* minutes or a penalty will be assessed. The nature of the penalty is specified. Following the initial message that the system will take control in *x* minutes, the system starts a clock and displays the time remaining until it assumes control of the vehicle. [8] The system displays a message that the vehicle has failed the inspection and must maneuver back into the manual lane within *y* minutes or a penalty will be assessed. The nature of the penalty is specified. The system displays the time remaining until the penalty is assessed. *CONTINUED on page 18.*	[1a] The driver receives the message, observes the clock counting down, and decides whether to have the system take control.	[1a] The driver takes no additional action, thereby approving assumption of control by the system. [9] The driver enters an abort command, canceling permission for transfer of control to the AHS. *CONTINUED on page 18.* [10] The driver maneuvers into the adjacent manual lane before the clock expires. *(END)*
[1a] As the AHS assumes control of the vehicle, it displays a message confirming the successful control transfer. It also displays information concerning waiting time to enter an automated lane, etc.	[1a] The driver receives the message. *(END)*	*(Table continued on next page.)*

Table 9. Entry into the system for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
[3a] The driver is informed that the driver has entered the transition lane illegally and that the driver must leave the transition lane within *y* minutes or be penalized. The nature of the penalty is specified. The system displays the time remaining until the penalty is assessed.	[3a] The driver receives the warning.	[3a] The driver heeds the warning and, within the time allotted, maneuvers back into the manual lane. *(END)* [11] The driver ignores the warning and continues driving in the transition lane. The system assesses the penalty.
[11] The system displays a message that it has assessed a penalty for violating the law concerning use of the transition lane.	[11] The driver receives the message. *(END)*	
	[6] The driver receives the message.	[6] The driver follows instructions and does not attempt to enter the transition lane. *(END)* [12] The driver ignores the entry denial and maneuvers into the transition lane anyway.
[12] The system displays a message that the driver has entered the transition lane illegally and that he/she must leave the transition lane within *y* minutes or be penalized. The nature of the penalty is specified. The system displays the time remaining until the penalty is assessed.	[12] The driver receives the message.	[12] The driver heeds the warning and, within the time allotted, maneuvers back into the manual lane. *(END)* [13] The driver ignores the warning and continues driving in the transition lane. The system assesses the penalty.
[13] The system displays a message that it has assessed a penalty for violating the law concerning use of the transition lane.	[13] The driver receives the message. *(END)*	
	[8] The driver receives the message.	[8] The driver maneuvers out of the transition lane as directed, within the required time, and continues manual driving. *(END)* [14] The driver fails to maneuver out of the transition lane, as directed, within the required time. The system assesses a penalty.
[14] The system displays a message that it has assessed a penalty for violating the law concerning use of the transition lane.	[14] The driver receives the message. *(END)*	*(Table continued on next page.)*

Table 9. Entry into the system for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
[9] The system displays a message to leave the transition lane within *y* minutes and that continued use of the transition lane, beyond that point, will result in a penalty. The nature of the penalty is specified. The system displays the time remaining until the penalty is assessed.	[9] The driver receives the message.	[9] The driver heeds the warning and leaves the transition lane within the required time. *(END)* [15] The driver continues in the transition lane beyond the time permitted. The system assesses the penalty.
[15] The system displays a message that it has assessed a penalty for violating the law concerning use of the transition lane.	[15] The driver receives the message. *(END)*	
[4] The system displays the driver's choices.	[4] The driver receives the message and decides what option to choose.	[4] The driver chooses to select a destination from the address book. [16] The driver chooses to keep the last destination. *CONTINUED on page 20.* [17] The driver chooses to modify the last destination. *(Note: The driver may choose to change the State [and city and exit], the city [and exit], or just the exit. All three transactions are contained within the transaction for changing the State, and it is therefore the only transaction shown here.) CONTINUED on page 19.*
[4] The system prompts the driver to enter all or part of a nickname if the driver will be selecting a destination using its nickname.	[4] The driver receives the message and decides whether to select a destination using a nickname.	[4] The driver enters all of the nickname. [18] The driver enters part of the nickname. *CONTINUED on page 19.* [19] The driver elects to not use a nickname. *CONTINUED two rows below.*
[4] The system displays the destination corresponding to the nickname and enters it as the current destination.	[4] The driver receives the message. *(END)*	
[19] The driver is prompted to enter all or part of the destination's State name.	[19] The driver receives the message.	[19] The driver enters all or part of the State name.
[19] The system displays the destinations starting with the letter(s) entered by the driver.	[19] The driver receives the message.	[19] The driver selects the destination desired. *(Table continued on next page.)*

Table 9. Entry into the system for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
[19] The system displays the destination and enters it as the current destination.	[19] The driver receives the message. *(END)*	
[18] The system displays the nicknames (and their corresponding destinations) starting with the letter(s) entered by the driver.	[18] The driver receives the choices.	[18] The driver selects the destination desired.
[18] The system displays the destination and enters it as the current destination.	[18] The driver receives the message. *(END)*	
[17] The system prompts the driver to enter the destination State name or part thereof.	[17] The driver receives the message.	[17] The driver enters the full State name. *CONTINUE with 17a in the next row.* [20] The driver enters part of the State name. *CONTINUED on page 20.*
[17a] The system displays the State name and prompts the driver to enter the destination city name or part thereof.	[17a] The driver receives the message.	[17a] The driver enters the full city name. *CONTINUE with 17b in the next row.* [21] The driver enters part of the city name. *CONTINUED on page 20.*
[17b] The system displays the city name and prompts the driver to enter the destination exit name or number.	[17b] The driver receives the message.	[17b] The driver enters the full exit name or number. *CONTINUE with 17c in the next row.* [22] The driver enters part of the exit name or number. *CONTINUED five rows below.*
[17c] The system displays the exit name and number, enters the destination as the current destination, and asks the driver whether the driver wants to save it in the address book.	[17c] The driver receives the message and decides whether to save the destination.	[17c] The driver elects to save the destination. [23] The driver elects to not save the destination. *(END)*
[17c] The system prompts the driver to enter a nickname if the driver wants to use one.	[17c] The driver receives the message and decides whether to use a nickname.	[17c] The driver enters a nickname. [24] The driver does not enter a nickname. *CONTINUED two rows below.*
[17c] The system displays the nickname and enters it in the address book.	[17c] The driver receives the message. *(END)*	
[24] The system saves the destination with no nickname.	[24] The driver receives the message. *(END)*	
[22] The system displays exit names or numbers starting with the letter(s) or number(s) entered by the driver.	[22] The driver receives the message.	[22] The driver selects the exit desired. *GO TO 17c, four rows above. (Table continued on next page.)*

Table 9. Entry into the system for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
[21] The system displays city names starting with the letter(s) entered by the driver.	[21] The driver receives the message.	[21] The driver selects the city desired. *GO TO 17b, page 19.*
[20] The system displays State names starting with the letter(s) entered by the driver.	[20] The driver receives the message.	[20] The driver selects the State desired. *GO TO 17a, page 19.*
[16] The system enters the destination.	[16] The driver receives the message. *(END)*	
	[2] The driver receives the information and decides whether to use the AHS.	[2] The driver drives to an AHS roadway, gets into the manual lane, and requests entry to the transition lane. *GO TO 6, page 15.* [25] The driver drives to an AHS roadway and, without requesting permission, drives directly into the transition lane. *GO TO 3a, page 17.* [26] The driver does not use the AHS roadway. *(END)*

Table 10. Entry into an automated lane for the Barriers on the Highway with Grouped Vehicles Scenario.

Input	Processing	Output
[1] If any of the following occur, the vehicle will make an automatic speed change: • To create a gap for a vehicle or group entering from an adjacent lane or to allow formation of a group. • To bring a vehicle or group up to automated-lane speed. • To have driver's vehicle close on other vehicles to form a group. Prior to the speed change, the system will display a message stating the direction of the change and why it is occurring.	[1] The driver receives the message and observes the speed change. *(END)*	
[2] When the vehicle is under full automated control, immediately before any change between adjacent lanes begins the system will display a message that the group is about to make a lane change.	[2] The driver receives the message and observes the lane change. *(END)*	

Table 11. Moving in an automated lane for the Barriers on the Highway with Grouped Vehicles Scenario.

Input	Processing	Output
	DESTINATION SELECTION	
[1] The vehicle enters an automated lane.	[1] The system checks to see whether a destination has already been entered. *If a destination has already been entered, CONTINUE with [1] in the next row.* *If a destination has not already been entered, see the destination selection sequence in table 9, starting with 4 on page 15.*	
	[1] The system compares the previously entered destination against the vehicle's fuel supply and against an internal map of the AHS network.	[1] The vehicle has sufficient fuel to reach the destination and the AHS network extends continuously from the current location to the destination. [2] The vehicle does not have sufficient fuel to reach the destination or the AHS network does not extend continuously from the current location to the destination. *CONTINUED two rows below.*
[1] The system displays a message that the destination has been accepted.	[1] The driver receives the message. *(END)*	
[2] The system displays a message indicating an intermediate destination to which the vehicle will be driven and explains why this is necessary (i.e., there is not sufficient fuel to reach the entered destination or the AHS network ends before the destination).	[2] The driver receives the message.	[2] The driver accepts the intermediate destination. *(END)* [3] The driver rejects the intermediate destination. *(END) (Note: To change the destination, the driver would go through the destination selection sequence, shown in table 9, starting with 4 on page 15.)* *(Table continued on next page.)*

Table 11. Moving in an automated lane for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
	ON-VEHICLE MONITORING	
[4] The system displays information about the status of AHS-specific vehicle systems (e.g., sensors, actuators). As necessary, cautionary and warning messages related to failures will also be displayed, and may include both AHS-specific systems (e.g., gap sensor malfunction) and general vehicle systems (e.g., low oil pressure). For cautions and warnings, the driver will be instructed as to what action has been taken by the system (if any) and/or what action the driver should take (if any).	[4] The driver receives the information and determines what action to take.	[4] The driver takes whatever action is appropriate (which will typically be to take no action at all). *(END)*
	OFF-VEHICLE MONITORING	
[5] The system displays information about the status of roadside systems (e.g., communications) and other off-vehicle information (e.g., traffic, accidents, weather). As necessary, cautionary and warning messages related to problems will be displayed, along with information about what action has been taken by the system (if any) and/or what action the driver should take (if any).	[5] The driver receives the information and determines what action to take.	[5] The driver takes whatever action is appropriate (which will typically be to take no action at all). *(END)*
	SPEED ANNUNCIATION	
[6] If any of the following occur, the vehicle will make an automatic speed change: • To create a gap for a vehicle or group entering from an adjacent lane or to allow formation of a group. • To bring a vehicle or group up to automated-lane speed. • To have driver's vehicle close on other vehicles to form a group. Prior to the speed change, the system will display a message stating the direction of the change and why it is occurring. There will also be a continuous display of current speed.	[6] The driver receives the message and observes the speed change. *(END)*	*(Table continued on next page.)*

Table 11. Moving in an automated lane for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
LANE CHANGE ANNUNCIATION		
[7] Prior to any lane change, the system will display a message indicating that a lane change is about to occur and the direction of the change (left or right).	[7] The driver receives the message and observes the lane change. *(END)*	
REQUEST IMMEDIATE EXIT		
[8] The system displays information about traffic, accidents, and weather; time passes, etc.	[8] The driver decides to request an immediate exit.	[8] The driver requests an immediate exit.
[8] The system displays the request for immediate exit and requests confirmation.	[8] The driver receives the message and decides whether to confirm the request.	[8] The driver confirms the request for immediate exit. [9] The driver denies the request for immediate exit. *(END)*
[8] The system displays the confirmation and begins the test for driver readiness to resume manual control of the vehicle. [Note: At any time after the test for readiness is started until (a) the driver has control of the vehicle (meaning the driver has passed the test and is now in the transition lane) or (b) the vehicle is on the exit ramp to a safe depository (meaning the driver has failed the test), the driver can initiate selection of a new destination, unless the vehicle does not have the criterion minimum amount of fuel. If the vehicle has sufficient fuel, whatever transaction is in progress will be aborted, and destination selection will begin (see table 9, starting with 4 on page 15). If the vehicle does not have sufficient fuel, the request to select a new destination is denied and the driver informed of the reason. If the driver passes the test for readiness, after the driver has control of the vehicle the driver can request entry to the transition lane and the vehicle inspection process, etc. will begin.]	[8] The driver receives the message.	[8] The driver passes the test for readiness. *CONTINUE with 8a in the next row.* [10] The driver fails the test for readiness. *CONTINUE with 10a on page 25. (Table continued on next page.)*

Table 11. Moving in an automated lane for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
REQUEST IMMEDIATE EXIT (CONTINUED)		
[8a] The system drives the vehicle into the transition lane and instructs the driver to grasp the steering wheel so steering control can be assumed by the driver. The system indicates this must be done within the allotted time, which is indicated, or the vehicle will be driven to a safe depository. The system displays the time remaining for the driver to comply. (Note: Either steering or speed control could be transferred first. The order shown here is arbitrary.) (Note: The lane change into the transition lane may not be possible because of the presence of unauthorized manually-driven vehicles. See table 12, numbers 8 and 9 on pages 28 and 29, respectively, for aborted lane change transactions.)	[8a] The driver receives the messages.	[8a] The driver grasps the steering wheel. *CONTINUE with 8b in the next row.* [11] The driver does not grasp the steering wheel within the allotted time minus *x* seconds. *CONTINUED on page 25.*
[8b] The system transfers steering control to the driver and displays a message that the driver is in control of steering. The system instructs the driver to tap the brake or accelerator so speed control can be assumed by the driver. The system indicates this must be done within the allotted time, which is indicated, or the vehicle will be driven to a safe depository. The system displays the time remaining for the driver to comply.	[8b] The driver receives the message.	[8b] The driver taps the brake or accelerator. *CONTINUE with 8c in the next row.* [12] The driver does not tap either the brake or accelerator within the allotted time minus *x* seconds. *CONTINUED on page 25.*
[8c] The system transfers speed control to the driver and displays a message that the driver is in control of speed. The system instructs the driver to leave the transition lane within *y* minutes or be penalized. The nature of the penalty is specified. The system displays the time remaining until the penalty is assessed.	[8c] The driver receives the message.	[8c] The driver leaves the transition lane within the allotted time. *(END)* [13] The driver does not leave the transition lane within the allotted time. *(Table continued on next page.)*

Table 11. Moving in an automated lane for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
REQUEST IMMEDIATE EXIT (CONTINUED)		
[13] The system displays a message that it has assessed a penalty for violating the law concerning use of the transition lane.	[13] The driver receives the message. *(END)*	
[12] The system presents an auditory alert (and perhaps a visual message) reminding the driver to tap either the brake or accelerator.	[12] The driver receives the alert (and perhaps the visual message).	[12] The driver taps the brake or accelerator within the allotted time. *GO TO 8c, page 24.* [14] The driver does not tap either the brake or accelerator within the allotted time. *CONTINUE with 14a in the next row.*
[14a] The system indicates that the driver has failed to take control within the allotted time and that the vehicle is being driven to a safe depository.	[14a] (Unclear.)	[14a] The system drives the vehicle to a safe depository, parks it, and shuts off its engine. *(END)*
[11] The system presents an auditory alert (and perhaps a visual message) reminding the driver to grasp the steering wheel.	[11] The driver receives the alert (and perhaps the visual messge).	[11] The driver grasps the steering wheel within the allotted time. *GO TO 8b, page 24.* [15] The driver does not grasp the steering wheel within the allotted time. *GO TO 14a, one row above.*
[10a] The system indicates that the driver has failed the test for readiness and that the vehicle is being driven to a safe depository.	[10a] (Unclear.)	[10a] The system drives the vehicle to a safe depository, parks it, and shuts off its engine. *(END)*
REQUEST EMERGENCY HELP		
[16] There is a medical emergency for one of the vehicle's occupants.	[16] A vehicle occupant decides to request emergency help.	[16] The vehicle occupant initiates a request for emergency help.
[16] The system acknowledges the request, drives the vehicle to a safe depository, and transmits a message to the emergency services dispatch center that there is a medical emergency, identifying the vehicle, the depository to which it is being driven, and the estimated time of arrival at the depository.	[16] Emergency services personnel receive the message.	[16] The vehicle is driven to a safe depository and emergency services personnel go to the depository to provide medical assistance. *(END)*

Table 12. Exiting the automated lane for the Barriers on the Highway with Grouped Vehicles Scenario.

Input	Processing	Output
[1] The system displays a message that the driver's exit is coming up and starts the test for driver readiness to resume manual control of the vehicle. If the driver's exit is closed or otherwise unavailable, the system will indicate the reason and state which exit will be used instead. [Note: At any time after the test for readiness is started until (a) the driver has control of the vehicle (meaning the driver has passed the test and is now in the transition lane) or (b) the vehicle is on the exit ramp to a safe depository (meaning the driver has failed the test), the driver can initiate selection of a new destination, unless the vehicle does not have the criterion minimum amount of fuel. If the vehicle has sufficient fuel, whatever transaction is in progress will be aborted, and destination selection will begin (see table 9, starting with number 4 on page 15). If the vehicle does not have sufficient fuel, the request to select a new destination will be denied and the driver will be informed of the reason. If the driver passes the test for readiness, after the driver has control of the vehicle the driver can request entry to the transition lane and the vehicle inspection process, etc. will begin.]	[1] (Unclear.)	[1] The driver passes the test for readiness. *CONTINUE with 1a in next row.* [2] The driver fails the test for readiness. *CONTINUED on page 28. (Table continued on next page.)*

Table 12. Exiting the automated lane for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
[1a] The system drives the vehicle into the transition lane and instructs the driver to grasp the steering wheel so steering control can be assumed by the driver. The system indicates this must be done within the allotted time, which is indicated, or the vehicle will be driven to a safe depository. The system displays the time remaining for the driver to comply. (Note: Either steering or speed control could be transferred first. The order shown here is arbitrary.) (Note: The lane change into the transition lane may not be possible because of the presence of unauthorized manually driven vehicles. See numbers 8 and 9 on pages 28 and 29, respectively, for aborted lane change transactions.)	[1a] The driver receives the messages.	[1a] The driver grasps the steering wheel. *CONTINUE with 1b in the next row.* [3] The driver does not grasp the steering wheel within the allotted time minus *x* seconds. *CONTINUED on page 28.*
[1b] The system transfers steering control to the driver and displays a message that the driver is in control of steering. The system instructs the driver to tap the brake or accelerator so speed control can be assumed by the driver. The system indicates this must be done within the allotted time, which is indicated, or the vehicle will be driven to a safe depository. The system displays the time remaining for the driver to comply.	[1b] The driver receives the message.	[1b] The driver taps the brake or accelerator. *CONTINUE with 1c in the next row.* [4] The driver does not tap either the brake or accelerator within the allotted time minus *x* seconds. *CONTINUED on page 28.*
[1c] The system transfers speed control to the driver and displays a message that the driver is in control of speed. The system instructs the driver to leave the transition lane within *y* minutes or be penalized. The nature of the penalty is specified. The system displays the time remaining until the penalty is assessed.	[1c] The driver receives the message.	[1c] The driver leaves the transition lane within the allotted time. *(END)* [5] The driver does not leave the transition lane within the allotted time. *(Table continued on next page.)*

Table 12. Exiting the automated lane for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
[5] The system displays a message that it has assessed a penalty to the driver for violating the law concerning use of the transition lane.	[5] The driver receives the message. *(END)*	
[4] The system presents an auditory alert (and perhaps a visual message) reminding the driver to tap either the brake or accelerator.	[4] The driver receives the alert (and perhaps the visual message).	[4] The driver taps the brake or accelerator within the allotted time. *GO TO 1c, page 27.* [6] The driver does not tap either the brake or accelerator within the allotted time. *CONTINUE with 6a in the next row.*
[6a] The system indicates that the driver has failed to take control within the allotted time and that the vehicle is being driven to a safe depository.	[6a] (Unclear.)	[6a] The system drives the vehicle to a safe depository, parks it, and shuts off its engine. *(END)*
[3] The system presents an auditory alert (and perhaps a visual message) reminding the driver to grasp the steering wheel.	[3] The driver receives the alert (and perhaps the visual message).	[3] The driver grasps the steering wheel within the allotted time. *GO TO 1b, page 27.* [7] The driver does not grasp the steering wheel within the allotted time. *GO TO 6a, one row above.*
[2] The system indicates that the driver has failed the test for readiness and that the vehicle is being driven to a safe depository.	[2] (Unclear.)	[2] The system drives the vehicle to a safe depository, parks it, and shuts off its engine. *(END)*
ABORTED LANE CHANGE		
[8] Prior to a lane change into the transition lane, a manual vehicle intrudes into the transition lane and prevents the automated lane change. The system aborts the lane change and displays a message indicating why the change was not made. The system may also display a message indicating that an exit other than the original destination must be used instead.	[8] The driver receives the messages. *(END)*	*(Table continued on next page.)*

Table 12. Exiting the automated lane for the Barriers on the Highway with Grouped Vehicles Scenario (continued).

Input	Processing	Output
	ABORTED LANE CHANGE (CONTINUED)	
[9] While a lane change into the transition lane is underway, a manual vehicle intrudes into the transition lane and prevents the entire group of exiting vehicles from completing the automated lane change. The system determines which vehicle(s) in the group must abort the lane change, aborts it for those vehicles, and displays a message to the appropriate vehicles indicating why the change was not made. The system may also display a message indicating that an exit other than the original destination must be used instead.	[9] The driver of the vehicle that was not able to complete the lane change receives the messages. *(END)*	

Segregated Highway with Individual Vehicles Scenario

In this section are the transactions for the Segregated Highway with Individual Vehicles Scenario.

Assumptions

Several operating assumptions were made for this scenario, and they are given here so the reader will understand the basis for the decisions made.

- If a vehicle fails the check-in inspection, the system will display a message stating that it has failed but not, in most cases, specifying the cause(s). (Where insufficient fuel is the problem, the system will include that information in its message.) It is assumed that the cause(s) of the failure will be determined during an electronic interrogation of the vehicle's computer system by a mechanic (which is what happens on most modern vehicles when, for example, the CHECK ENGINE light comes on).
- Sensors aboard the vehicle will keep a continuously updated record of the vehicle's fuel efficiency. This information will be used by the AHS, along with other variables, to determine how far a particular vehicle can travel toward the driver's selected destination. It is also assumed that the system will add a safety margin to the calculation [e.g., if the system determines that a vehicle can travel 450 km (280 mi), it will actually allow for a destination that is (say) only 400 km (249 mi) away].
- Unless a vehicle has some criterion minimum amount of fuel when the check-in-area inspection is done, it will not be allowed to participate on the AHS. This amount will be based in part on how far it is from the current location of the vehicle to the nearest exit and in part on the fact that if the driver fails the test for driver readiness to resume manual control of the vehicle, the vehicle will have to be driven by the system to a safe depository.
- If the driver's exit becomes closed for some reason (e.g., an accident) after the driver's destination has been accepted, the AHS will use the nearest available exit after the original one. (Given sufficient advance notification by the system, the driver will, of course, be free to set a new destination.)
- Check-in will consist of two stages:
  - With the vehicle under manual control, the system will interrogate the vehicle's on-board computer to determine the status of whatever systems can be checked on a continual basis while the vehicle is being driven normally.
  - If the first-stage inspection is passed, the system will assume control of the vehicle to perform whatever tests are necessary to ensure that communications with the actuators (e.g., for braking) and the actuators themselves are working properly, that the steering tracks properly, that the vehicle holds the commanded speed, and so on.

  If the vehicle fails the second-stage inspection, the vehicle will be stopped and control will be returned to the driver without a test for driver readiness to resume

manual control of the vehicle. It is believed that the conditions that might make the readiness test necessary after a period of automated driving will not exist, for the most part, in the check-in area. In addition, instruction will be given to the driver to help ensure that the driver remains alert during the inspection process.

Transactions

In terms of transactions, this scenario is identical in many respects to the Barriers on the Highway with Grouped Vehicles scenario. In fact, aside from the obvious differences in check-in procedures, other functional differences between the two scenarios may be transparent to the driver.

The transactions for the various major events are shown in tables 13 through 16.

Table 13. Entry into the system for the Segregated Highway with Individual Vehicles Scenario.

Input	Processing	Output
[1] The system displays vehicle status information—fluid levels, battery charge status, and information about AHS-specific hardware (sensors, processors, and actuators). [Note: This assumes that, when the vehicle is started, it performs a check on its systems. The results of this initial check are displayed to the driver.] [Note: The driver may also get AHS status information (e.g., entrance closings) from local radio or other sources.]	[1] The driver receives the information and decides whether to use the AHS.	[1] The driver continues on arterial roads. (*END*) [2] The driver maneuvers into the check-in area, indicating his/her intent to enter the AHS.
[2] The system displays a message to the driver indicating the maximum speed in the inspection area. The system also begins inspecting the vehicle as it moves.	[2] The driver receives the message.	[2] The driver adjusts speed to within limits indicated by the system. *CONTINUE with 2a in the next row.* [3] The driver exceeds the requested maximum speed. *CONTINUED on page 34.*
[2a] If the vehicle passes the first stage of inspection, the system displays a message that it will take control of the vehicle momentarily. The message also includes a reminder that if the driver wishes to abort entry into the AHS, the driver should enter an abort command immediately and then steer off into the rejected-vehicle lane. [4] If the vehicle fails the first stage of the inspection, the system displays a message that the vehicle has failed the inspection and that the driver must maneuver into the rejected-vehicle lane immediately or a penalty will be assessed. The nature of the penalty is specified. *CONTINUED on page 34.*	[2a] The driver receives the message, and decides whether to have the system take control.	[2a] The driver takes no additional action, thereby approving assumption of control by the system. [5] The driver enters an abort command within the time permitted, canceling permission for transfer of control to the AHS. *CONTINUED on page 33.*
[2a] As the AHS assumes control of the vehicle, it displays a message confirming the successful control transfer and reminding the driver that the driver must remain ready to resume manual control if the vehicle fails inspection.	[2a] The driver receives the message.	[2a] The vehicle moves under automatic control through the second stage testing. *(Table continued on next page.)*

Table 13. Entry into the system for the Segregated Highway with Individual Vehicles Scenario (continued).

Input	Processing	Output
[2a] If the vehicle passes the second stage of the inspection, the driver is notified, and the vehicle continues automatically down the entrance ramp to the automated lane. [6] If the vehicle fails the second stage of testing, the system drives the vehicle to the rejected-vehicle lane, stops it, and gives control back to the driver. The system also displays a message indicating that the vehicle has failed the inspection and that the driver has control. It will direct the driver to leave the inspection area or be penalized. The nature of the penalty will be specified. [Note: If the failure is such that the system cannot safely drive the vehicle, the vehicle will be stopped in place and control transferred back to the driver. The system will display a message indicating that the vehicle has failed the inspection and that the driver has control. It will direct the driver to leave the inspection area or be penalized. The nature of the penalty will be specified.] *CONTINUED in the next row.*	[2a] The driver observes the vehicle as it moves down the ramp under automatic control. *(END)*	
	[6] The driver observes the message.	[6] The driver leaves the inspection area. *(END)* [7] The driver does not leave the inspection area.
[7] The system displays a message that it has assessed a penalty for violating its instructions.	[7] The driver receives the message. *(END)*	
[5] The system displays a message that the driver must maneuver into the rejected vehicle lane immediately or a penalty will be assessed. The nature of the penalty is specified.	[5] The driver receives the message.	[5] The driver leaves the inspection area. *(END)* [8] The driver does not leave the inspection area. *CONTINUE with 8a in the next row.*
[8a] The system displays a message that it has assessed a penalty for violating its instructions.	[8a] The driver receives the message. *(END)*	*(Table continued on next page.)*

Table 13. Entry into the system for the Segregated Highway with Individual Vehicles Scenario (continued).

Input	Processing	Output
	[4] The driver receives the message.	[4] The driver leaves the inspection area. *(END)* [9] The driver does not leave the inspection area. *GO TO 8a in on page 33.*
[3] If the vehicle's speed has caused the inspection process to fail, the driver is informed that the vehicle's speed exceeded that allowed and prevented the inspection from being completed. The driver is instructed to leave the inspection area immediately at the first rejected-vehicle ramp, or a penalty will be assessed. The nature of the penalty is specified. [9] If the vehicle's speed has not impeded the inspection and the inspection is completed, the driver proceeds as any vehicle that has passed the first stage of inspection. *GO TO 2a, page 32.*	[3] The driver receives the message.	[3] The driver leaves the inspection area. *(END)* [10] The driver does not leave the inspection area.
[10] The system displays a message that it has assessed a penalty for violating its instructions.	[10] The driver receives the message. *(END)*	

Table 14. Entry into an automated lane for the Segregated Highway with Individual Vehicles Scenario.

Input	Processing	Output
[1] Prior to any speed change that must be made to get the vehicle up to automated lane speed, the system will display a message stating the direction of the change and why it is occurring. There will also be a continuous display of current speed.	[1] The driver receives the message and observes the speed change. *(END)*	

Table 15. Moving in an automated lane for the Segregated Highway with Individual Vehicles Scenario.

Input	Processing	Output
	DESTINATION SELECTION	
[1] The vehicle enters an automated lane.	[1] The system checks to see whether a destination has already been entered. *If a destination has already been entered, CONTINUE with [1].* *If a destination has not already been entered, see the destination selection sequence in table 9, starting with 4 on page 15.*	
	[1] The system compares the previously entered destination against the vehicle's fuel supply and against an internal map of the AHS network.	[1] The vehicle has sufficient fuel to reach the destination and the AHS network extends continuously from the current location to the destination. [2] The vehicle does not have sufficient fuel to reach the destination or the AHS network does not extend continuously from the current location to the destination. *CONTINUED two rows below.*
[1] The system displays a message that the destination has been accepted.	[1] The driver receives the message. *(END)*	
[2] The system displays a message indicating an intermediate destination to which the vehicle will be driven and explains why this is necessary (i.e., there is not sufficient fuel to reach the entered destination or the AHS network ends before the destination).	[2] The driver receives the message.	[2] The driver accepts the intermediate destination. *(END)* [3] The driver rejects the intermediate destination. *(END) (Note: To change the destination, the driver would go through the destination selection sequence in table 9, starting with 4 on page 15.)* *(Table continued on next page.)*

Table 15. Moving in an automated lane for the Segregated Highway with Individual Vehicles Scenario (continued).

Input	Processing	Output
	ON-VEHICLE MONITORING	
[4] The system displays information about the status of AHS-specific vehicle systems (e.g., sensors, actuators). As necessary, cautionary and warning messages related to failures will also be displayed, and may include both AHS-specific systems (e.g., gap sensor malfunction) and general vehicle systems (e.g., low oil pressure). For cautions and warnings, the driver will be instructed what action has been taken by the system (if any) and/or what action he/she should take (if any).	[4] The driver receives the information and determines what action to take.	[4] The driver takes whatever action is appropriate (which will typically be to take no action at all). *(END)*
	OFF-VEHICLE MONITORING	
[5] The system displays information about the status of roadside systems (e.g., communications) and other off-vehicle information (e.g., traffic, accidents, weather). As necessary, cautionary and warning messages related to problems will be displayed, along with information about what action has been taken by the system (if any) and/or what action the driver should take (if any).	[5] The driver receives the information and determines what action to take.	[5] The driver takes whatever action is appropriate (which will typically be to take no action at all). *(END)*
	SPEED ANNUNCIATION	
[6] If either of the following occur, the vehicle will make an automatic speed change: • To create a gap for a vehicle entering from an adjacent lane. • To bring a vehicle up to automated-lane speed. Prior to the speed change, the system will display a message stating the direction of the change and why it is occurring. There will also be a continuous display of current speed.	[6] The driver receives the message and observes the speed change. *(END)*	*(Table continued on next page.)*

Table 15. Moving in an automated lane for the Segregated Highway with Individual Vehicles Scenario (continued).

Input	Processing	Output
	LANE CHANGE ANNUNCIATION	
[7] Prior to any lane change, the system will display a message indicating that a lane change is about to occur and the direction of the change (left or right).	[7] The driver receives the message and observes the lane change. *(END)*	
	REQUEST IMMEDIATE EXIT	
[8] The system displays information about traffic, accidents, and weather; time passes, etc.	[8] The driver decides to request an immediate exit.	[8] The driver requests an immediate exit.
[8] The system displays the request for immediate exit and requests confirmation.	[8] The driver receives the message and decides whether to confirm the request.	[8] The driver confirms the request for immediate exit. [9] The driver denies the request for immediate exit. *(END)*
[8] The system displays the confirmation and begins the test for driver readiness to resume manual control of the vehicle. [Note: At any time after the test for readiness is started until (a) the driver has control of the vehicle (meaning the driver has passed the test and is now in the transition lane) or (b) the vehicle is on the exit ramp to a safe depository (meaning the driver has failed the test), the driver can initiate selection of a new destination, unless the vehicle does not have the criterion minimum amount of fuel. If the vehicle has sufficient fuel, whatever transaction is in progress will be aborted, and destination selection will begin (see table 9, starting with number 4 on page 15). If the vehicle does not have sufficient fuel, the request to select a new destination is denied and the driver informed of the reason. If the driver passes the test for readiness, after the driver has control of the vehicle the driver can request entry to the transition lane and the vehicle inspection process, etc. will begin.]	[8] The driver receives the message.	[8] The driver passes the test for readiness. *CONTINUE with 8a on page 38.* [10] The driver fails the test for readiness. *CONTINUE with 10a on page 39. (Table continued on next page.)*

Table 15. Moving in an automated lane for the Segregated Highway with Individual Vehicles Scenario (continued).

Input	Processing	Output
REQUEST IMMEDIATE EXIT (CONTINUED)		
[8a] The system drives the vehicle onto the exit ramp and instructs the driver to grasp the steering wheel so steering control can be assumed by the driver. The system indicates this must be done within the allotted time, which is indicated, or the vehicle will be driven to a safe depository. The system displays the time remaining for the driver to comply. (Note: Either steering or speed control could be transferred first. The order shown here is arbitrary.)	[8a] The driver receives the messages.	[8a] The driver grasps the steering wheel. *CONTINUE with 8b in the next row.* [11] The driver does not grasp the steering wheel within the allotted time minus *x* seconds. *CONTINUED on page 39.*
[8b] The system transfers steering control to the driver and displays a message that the driver is in control of steering. The system instructs the driver to tap the brake or accelerator so speed control can be assumed by the driver. The system indicates this must be done within the allotted time, which is indicated, or the vehicle will be driven to a safe depository. The system displays the time remaining for the driver to comply.	[8b] The driver receives the message.	[8b] The driver taps the brake or accelerator. *CONTINUE with 8c in the next row.* [12] The driver does not tap either the brake or accelerator within the allotted time minus *x* seconds. *CONTINUED on page 39.*
[8c] The system transfers speed control to the driver and displays a message that the driver is in control of speed. The system instructs the driver to leave the exit ramp within *y* minutes or be penalized. The nature of the penalty is specified. The system displays the time remaining until the penalty is assessed.	[8c] The driver receives the message.	[8c] The driver leaves the exit ramp within the allotted time. *(END)* [13] The driver does not leave the exit ramp within the allotted time.
[13] The system displays a message that it has assessed a penalty for violating the law concerning use of the transition lane.	[13] The driver receives the message. *(END)*	*(Table continued on next page.)*

Table 15. Moving in an automated lane for the Segregated Highway with Individual Vehicles Scenario (continued).

Input	Processing	Output
REQUEST IMMEDIATE EXIT (CONTINUED)		
[12] The system presents an auditory alert (and perhaps a visual message) reminding the driver to tap either the brake or accelerator.	[12] The driver receives the alert (and perhaps the visual message).	[12] The driver taps the brake or accelerator within the allotted time. *GO TO 8c, page 38.* [14] The driver does not tap either the brake or accelerator within the allotted time. *CONTINUE with 14a in the next row.*
[14a] The system indicates that the driver has failed to take control within the allotted time and that the vehicle is being driven to a safe depository.	[14a] (Unclear.)	[14a] The system drives the vehicle to a safe depository, parks it, and shuts off its engine. *(END)*
[11] The system presents an auditory alert (and perhaps a visual message) reminding the driver to grasp the steering wheel.	[11] The driver receives the alert (and perhaps the visual message).	[11] The driver grasps the steering wheel within the allotted time. *GO TO 8b, page 38.* [15] The driver does not grasp the steering wheel within the allotted time. *GO TO 14a in the row above.*
[10a] The system indicates that the driver has failed the test for readiness and that the vehicle is being driven to a safe depository.	[10a] (Unclear.)	[10a] The system drives the vehicle to a safe depository, parks it, and shuts off its engine. *(END)*
REQUEST EMERGENCY HELP		
[16] There is a medical emergency for one of the vehicle's occupants.	[16] A vehicle occupant decides to request emergency help.	[16] The vehicle occupant initiates a request for emergency help.
[16] The system acknowledges the request, drives the vehicle to a safe depository, and transmits a message to the emergency services dispatch center that there is a medical emergency, identifying the vehicle, the depository to which it is being driven, and the estimated time of arrival at the depository.	[16] Emergency services personnel receive the message.	[16] The vehicle is driven to a safe depository and emergency services personnel go to the depository to provide medical assistance. *(END)*

Table 16. Exiting the automated lane for the Segregated Highway with Individual Vehicles Scenario.

Input	Processing	Output
[1] The system displays a message that the driver's exit is coming up, and starts the test for driver readiness to resume manual control of the vehicle. If the driver's exit is closed or otherwise unavailable, the system will indicate the reason and state which exit will be used instead. [Note: At any time after the test for readiness is started until the vehicle is on the exit ramp, the driver can initiate selection of a new destination, unless the vehicle does not have the criterion minimum amount of fuel. If the vehicle has sufficient fuel, whatever transaction is in progress will be aborted, and destination selection will begin (see table 9, starting with number 4 on page 15). If the vehicle does not have sufficient fuel, the request to select a new destination will be denied and the driver informed of the reason.]	[1] (Unclear.)	[1] The driver passes the test for readiness. *CONTINUE with 1a in the next row.* [2] The driver fails the test for readiness. *CONTINUED on page 41.*
[1a] The system drives the vehicle onto the exit ramp, slows down the vehicle, and instructs the driver to grasp the steering wheel so steering control can be assumed by the driver. The system indicates this must be done within the allotted time, which is indicated, or the vehicle will be driven to a safe depository. The system displays the time remaining for the driver to comply. (Note: Either steering or speed control could be transferred first. The order shown here is arbitrary.)		[1a] The driver grasps the steering wheel. *CONTINUE with 1b in the next row.* [3] The driver does not grasp the steering wheel within the allotted time minus *x* seconds. *CONTINUED on page 41. (Table continued on next page.)*

Table 16. Exiting the automated lane for the Segregated Highway with Individual Vehicles Scenario (continued).

Input	Processing	Output
[1b] The system transfers steering control to the driver and displays a message that the driver is in control of steering. The system instructs the driver to tap the brake or accelerator so speed control can be assumed by the driver. The system indicates this must be done within the allotted time, which is indicated, or the vehicle will be driven to a safe depository. The system displays the time remaining for the driver to comply.	[1b] The driver receives the message.	[1b] The driver taps the brake or accelerator. *CONTINUE with 1c in the next row.* [4] The driver does not tap either the brake or accelerator within the allotted time minus *x* seconds. *CONTINUED three rows below.*
[1c] The system transfers speed control to the driver and displays a message that the driver is in control of speed. The system instructs the driver to leave the exit ramp within *y* minutes or be penalized. The nature of the penalty is specified. The system displays the time remaining until the penalty is assessed.	[1c] The driver receives the message.	[1c] The driver leaves the exit ramp within the allotted time. *(END)* [5] The driver does not leave the exit ramp within the allotted time.
[5] The system displays a message that it has assessed a penalty for violating its instructions for use of the exit ramp.	[5] The driver receives the message. *(END)*	
[4] The system presents an auditory alert (and perhaps a visual message) reminding the driver to tap either the brake or accelerator.	[4] The driver receives the alert (and perhaps the visual message).	[4] The driver taps the brake or accelerator within the allotted time. *GO TO 1c, two rows above.* [6] The driver does not tap either the brake or accelerator within the allotted time. *GO TO 8, two rows below.*
[3] The system presents an auditory alert (and perhaps a visual message) reminding the driver to grasp the steering wheel.	[3] The driver receives the alert (and perhaps the visual message).	[3] The driver grasps the steering wheel within the allotted time. *GO TO 1b, four rows above.* [7] The driver does not grasp the steering wheel within the allotted time. *GO TO 8 in the next row.*
[8] The system indicates that the driver has failed to take control within the allotted time and that the vehicle is being driven to a safe depository.	[8] (Unclear.)	[8] The system drives the vehicle to a safe depository, parks it, and shuts off its engine. *(END)*
[2] The system indicates that the driver has failed the test for readiness and that the vehicle is being driven to a safe depository.	[2] (Unclear.)	[2] The system drives the vehicle to a safe depository, parks it, and shuts off its engine. *(END)*

Reference

1. Tsao, H.S.J., Hall, R.W., Shladover, S.E., Plocher, T.A., & Levitan, L. (1993). *Human factors design of automated highway systems: First generation scenarios*. Technical Report No. FHWA-RD-93-123. Washington, DC: Federal Highway Administration.