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A REFERENCE ARCHITECTURE FOR AUTOMATED HIGHWAY SYSTEMS (AHS)*

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Abstract

This report provides a reference architecture for Automated Highway Systems (AHS). This is a diverse and dynamic research area, and this reference architecture provides a structured means of specifying an AHS. It is a multipurpose tool that can be expanded by adding additional information fields based on a given application. The architecture is based on a hierarchical coding of the major AHS areas into function, form, physical components, and carrier. An overview of the architecture and the coding scheme is presented, followed by detailed schematics within the AHS functional areas of Driving, Structural Support, and Traffic Regulation.

Table of Contents

List of Figures

List of Tables

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1. Introduction

The field of Automated Highway Systems (AHS) is a diverse area of research. In the past, many system configurations and approaches have been proposed for an AHS. This diversity has increased due to the variety of studies currently being performed for the Federal Highway Administration (FHWA) Precursor Systems Analyses (PSA) of AHS. At this time, the current authors have not seen a unifying approach to the representation of an AHS that encompasses the currently proposed systems as well as foreseeable systems in an organized manner. The architecture presented here is an attempt to provide such a unified and organized reference architecture for AHS.

This architecture can be used in a variety of ways. It can be used to specify an AHS at the functional level, in terms of the general systems and approaches to be included, or it can be used to provide detail down to the specific physical components to be used. The nature of the architecture allows different users to focus on different aspects of the AHS. For example, a system designer with a DOT perspective could choose to focus specifically on areas that relate to the infrastructure, while a vehicle manufacturer could focus specifically on vehicle-related areas. In addition, the architecture, in its fullest sense, can be used as a detailed design specification for an AHS. The architecture is expandable so that it can be customized to carry information required for a specific task. Here, we present a general overview of the reference architecture, followed by a detailed schematic diagram of the architecture, which at this time includes the functions of Driving, Structural Support, and Traffic Regulation. This architecture could form the basis for an expert system for AHS design and specification, providing a knowledge-based facility to aid in AHS research and analysis.

The information in this document is based on a broad search of the existing AHS literature. Detailed reference information is not provided here; however, much of the information included here can be cross-referenced using (Lasky and Ravani, 1993). Information regarding structural support and traffic regulation can be found in (Caltrans, 1992) and (Homburger and Kell, 1988). Additional information on structures has been obtained from (FHWA, 1994). Some of the details for various AHS sensors was found in (Martin Marietta, 1994). Additional component information and cross-references into the literature and product information can be found in (Lasky and Ravani, 1994). Finally, an overview of Group Technology Classification and Coding can be found in (Bedworth, Henderson, and Wolfe, 1991)

2. Overview of the Reference Architecture

The AHS Reference Architecture is designed around a classification coding system developed specifically for this purpose. The details of this classification are presented in schematic form in the appendices. A general overview of the architecture is shown in Figure 1. The architecture is divided into blocks based on function. At this time, the functional areas that have been classified in detail include Driving, Structural Support, and Traffic Regulation. Other functional areas can be added as needed, as the architecture is modular. Within the Functional Level, there are sub-function layers as required. The next level down in the architecture is the Form Level, which indicates the general form of the technology that will provide the specified function. The Form Level can also have multiple internal layers. Below this is the Physical Level, which indicates the specific technology and equipment to be included in the system. The bottom level of the architecture is the Carrier Level, which indicates the location of the particular technology. For each of the physical components indicated in the schematic, it may be possible for the given technology to reside in different parts of the AHS, e.g. the roadway or the vehicle. This choice will be coded in the Carrier Level. Currently identified carriers include the roadway, the roadside, the median, the vehicle, and satellites. In the interest of conserving space, the Carrier Level is not show on the schematic , and has not been included in the coding at this time. When

the Carrier level is added, it is anticipated that the size of the code strings will approximately double.

With the above approach, the AHS Reference Architecture allows a broad range of detail in specifying an AHS. A researcher could designate a general functional level specification of an AHS, simply indicating the overall form that each of the technologies, while leaving the details of the physical implementation for later study. On the other hand, an AHS designer could use the same architecture to completely specify a system down to the level of the specific type of sensor to be used for headway sensing, for example. The architecture has been designed to be flexible, so that future technological and conceptual innovations in the area of AHS can be incorporated with minimal impact on the overall structure.

The architecture is hierarchical. Choices made at the higher levels of the architecture will constrain selections at the lower levels. However, every attempt has been made to minimize, and ideally eliminate, any dependencies across individual layers of the architecture. This will allow easier enumeration of possible AHS configurations. With this feature, once codes are assigned at all layers of the architecture, it is possible to enumerate all possible AHS Representative System Configurations (RSC's) to the required level of detail by simply cycling through all possible combinations of the codes. Note that this will yield an overwhelming number of RSC's if it is done for the entire architecture. However, this feature can also be utilized at any level of the architecture. For example, in a system that includes point-follower control for longitudinal control, it would be possible to enumerate all available position sensing approaches. The hierarchical nature of the architecture will be represented using a group technology hierarchical classification and coding scheme.

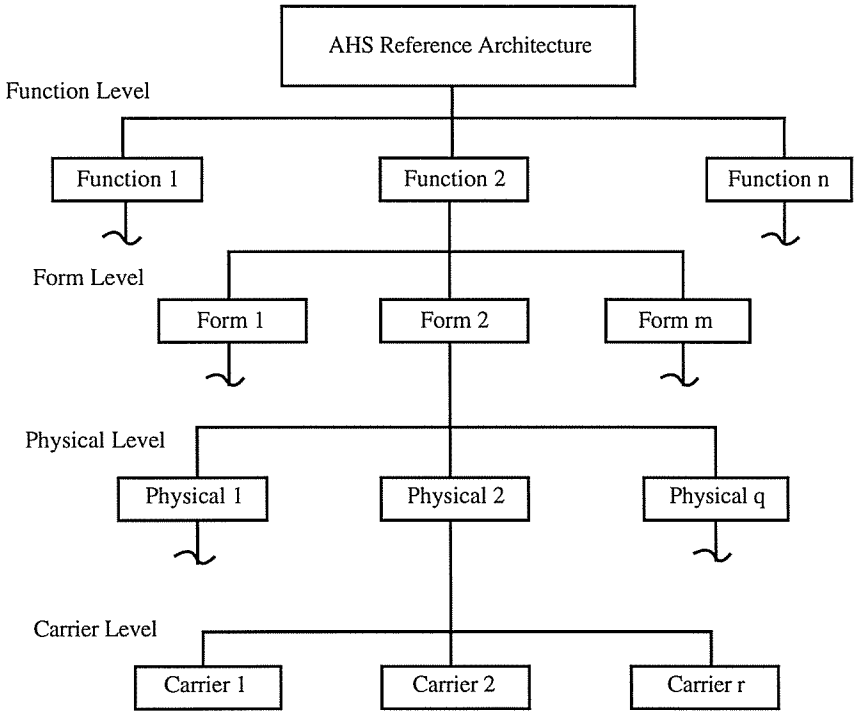

Figure 1: AHS Reference Architecture Format.

To provide a better feel for how the AHS Reference Architecture works, Figure 2 shows a more detailed overview of the architecture. In this figure, the actual functional areas are presented, along with some level of detail within each functional area. The amount of detail varies within each area based on two factors: the amount of information that

appears needed at this time to specify an AHS, and the information that can be found in the relevant literature. For example, the function of Traffic Regulation, here meaning

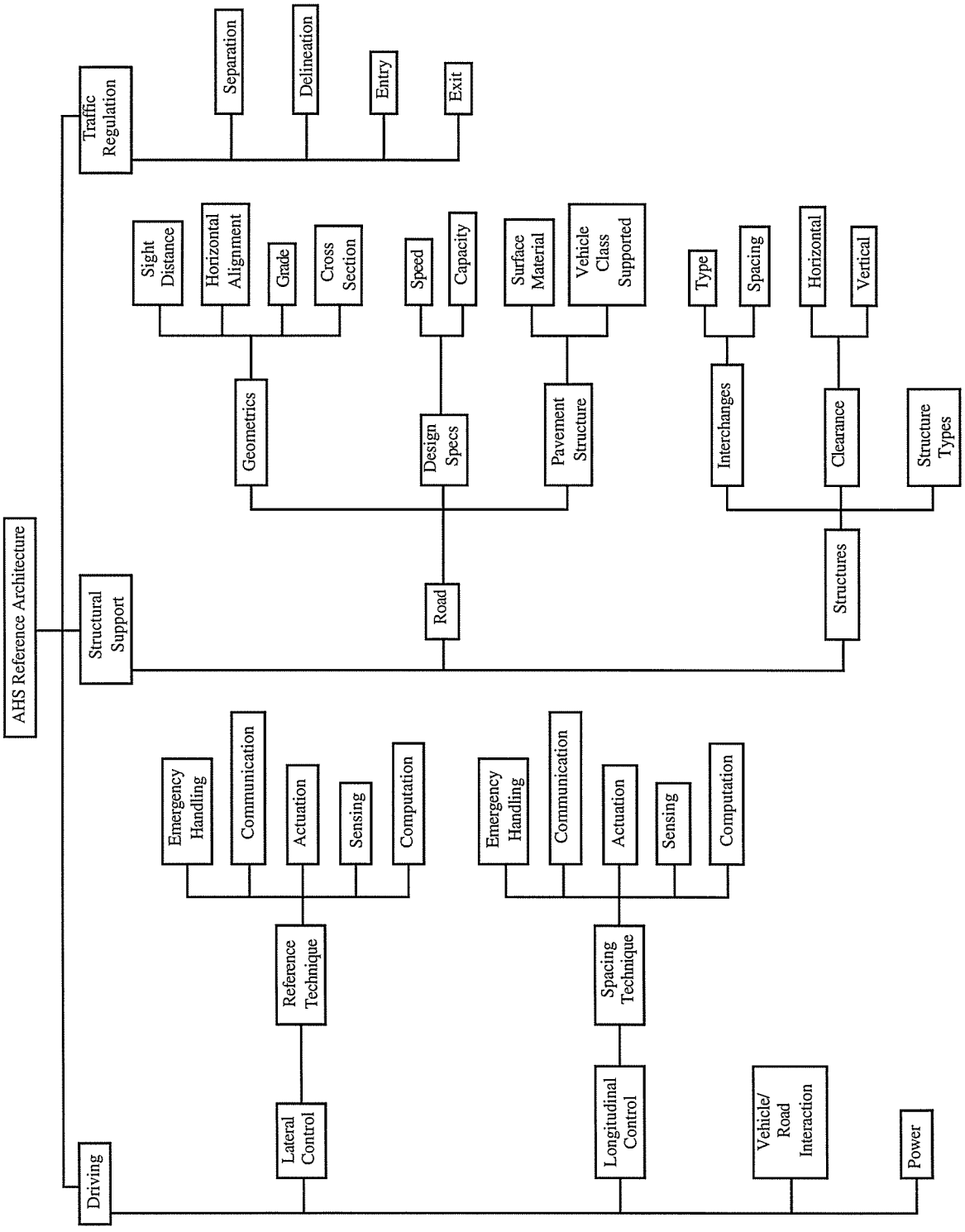

Figure 2: Detailed Overview of the AHS Reference Architecture.

separation of AHS and non-AHS traffic, lane delineation, and system entry and exit, requires significantly less detail than the area of automated driving. At the same time, there is far less discussion of this function in the literature when compared to the Driving function. Based on this, we have provided significantly more detail on the Driving function, and relatively less detail on the Traffic Regulation function. As noted earlier, the detailed schematic diagrams for the AHS Reference Architecture are presented in the appendices.

3. Code Details

The complete code for the AHS Reference Architecture consists of a string of digits, providing a convenient and compact representation of the Automated Highway System and its components. The digits are grouped according to the hierarchy of Figure 2, with the details of the hierarchy given in the appendices. The main groupings are by function, so that the code can be broken down into groups of digits for the Driving function, the Structural Support function, and the Traffic Regulation function. Each of these groups can be subdivided based on the information in the schematics. The top-level breakdown of the code is shown in Figure 3. Each of the sub-groups in Figure 3, e.g. Longitudinal Control, will consist of a set of digits describing that sub-function.

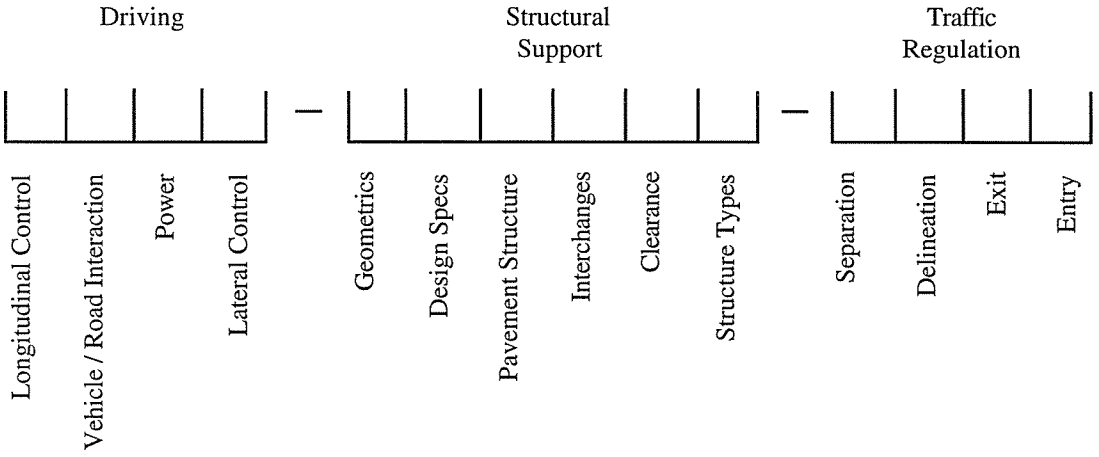

Figure 3: Top-Level AHS Reference Architecture Code Grouping.

The details of various code groups are given in the subsequent figures. Within the Driving function, the Power and Vehicle / Road Interaction sub-groups do not require further breakdown, as the level of detail here is minimal. On the other hand, the Lateral and Longitudinal Control sub-functions contain significant detail, and are well-suited to further breakdown. The details of the Longitudinal Control code sub-string are shown in Figure 4. The Lateral Control code sub-string details are given in Figure 5. The Structural Support function code segment also bears further breakdown; details are shown in Figure 6. Finally, the Traffic Regulation code breakdown is shown in Figure 7. These figures present the breakdown of the code strings into sub-strings, but do not actually show the codes themselves, or the options within each of the areas. Each of the groups of digits within the sub-strings will consist of one or more digits. For the details of the classification and coding, see the appendices.

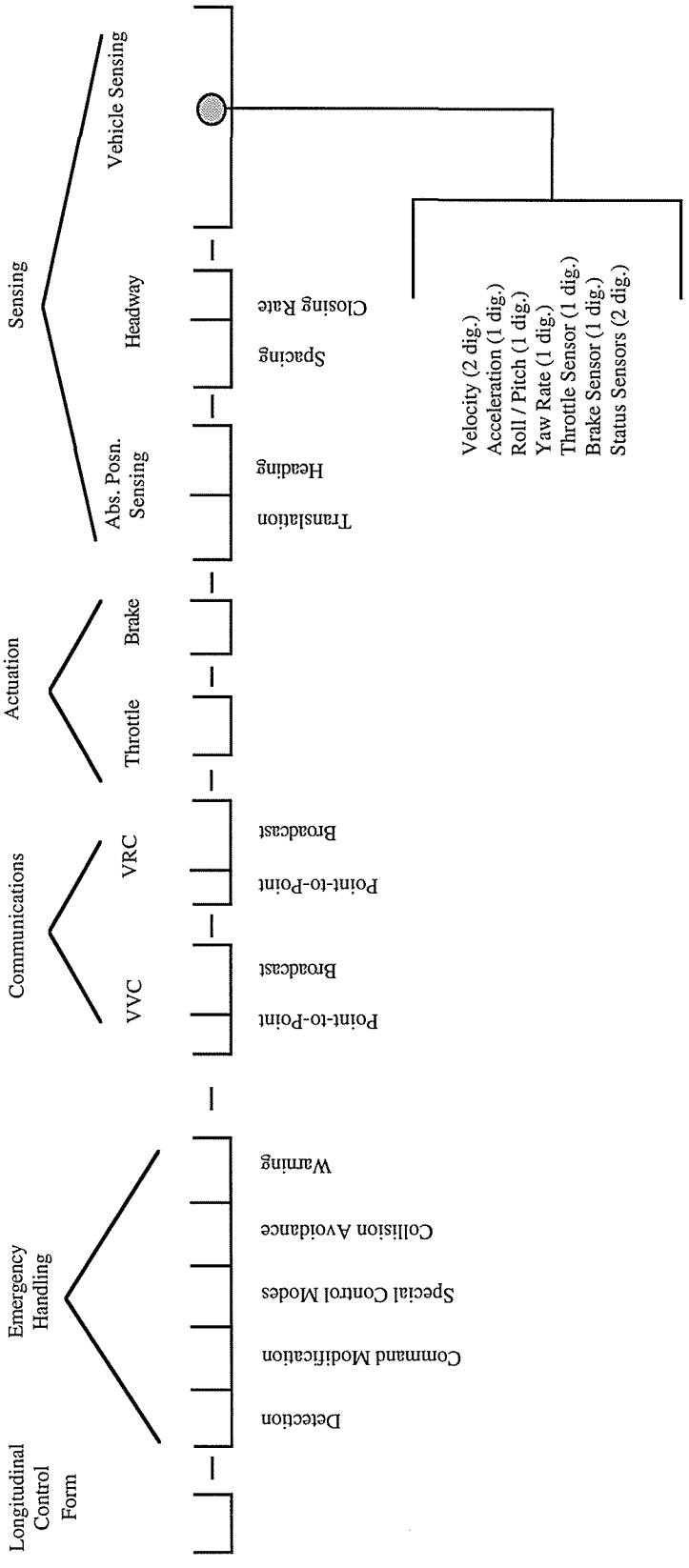

Figure 4: Longitudinal Control Code Sub-String.

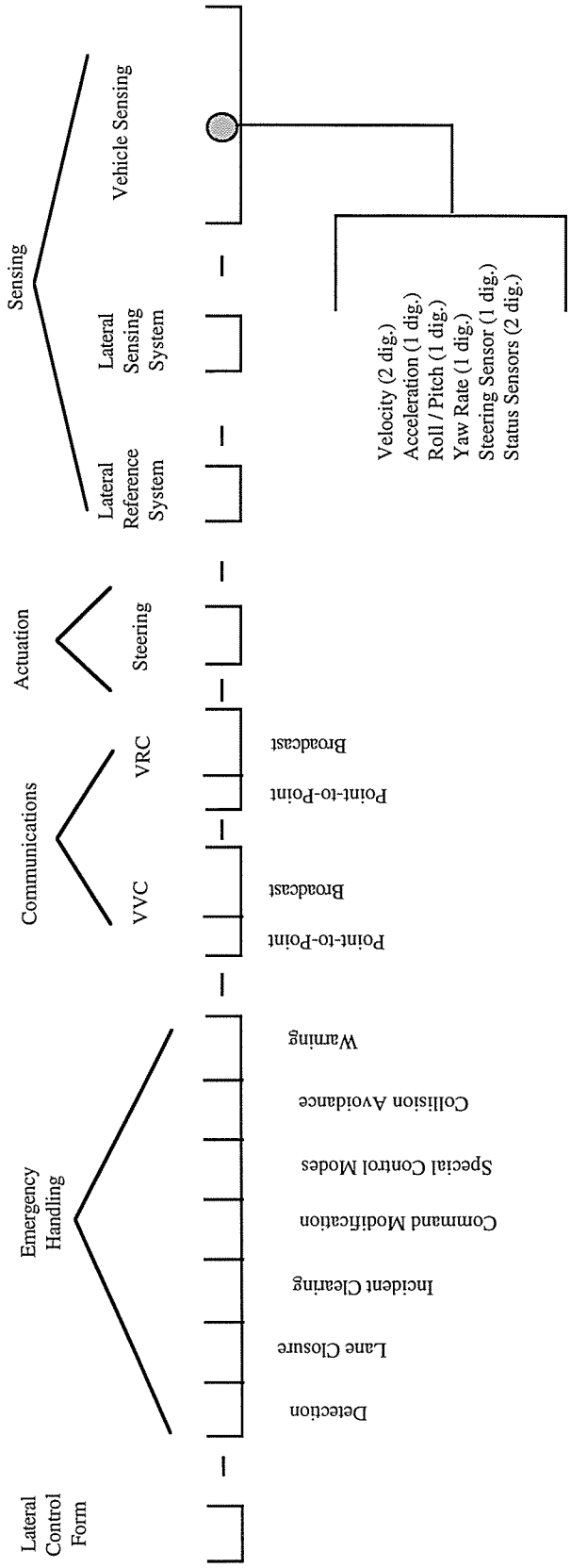

Figure 5: Lateral Control Code Sub-String.

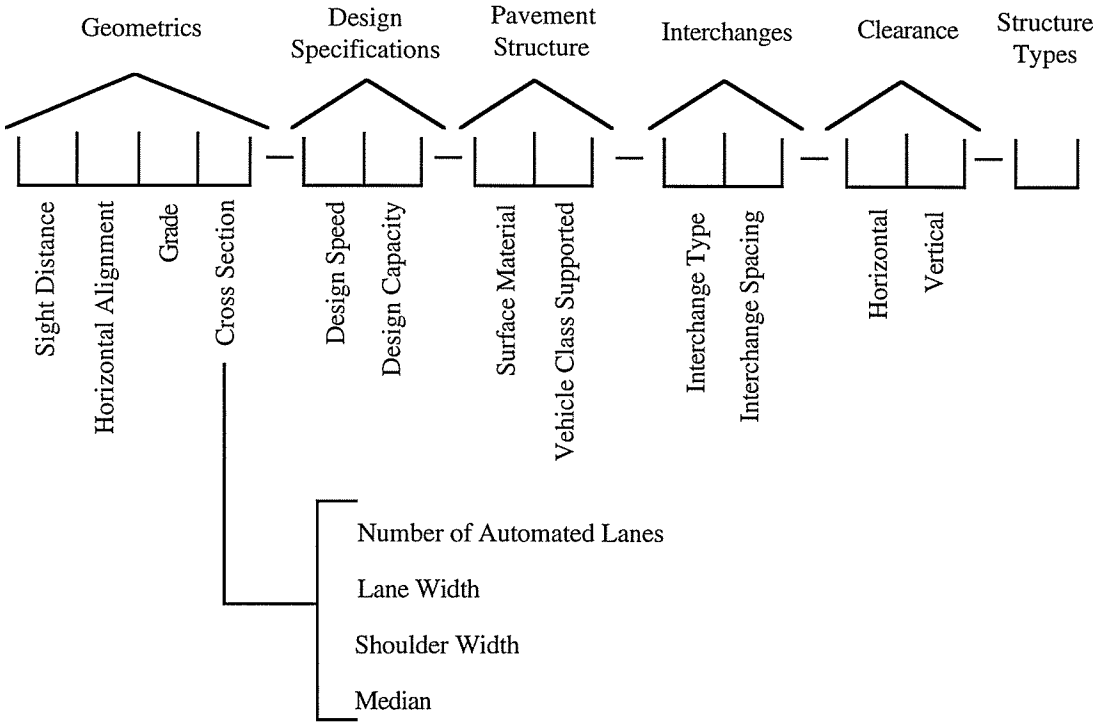

Figure 6: Structural Support Code Sub-String.

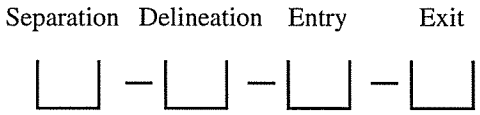

Figure 7: Traffic Regulation Code Sub-String.

4. Comments on the Reference Architecture Details

A number of areas in the detailed classification bear further discussion. Some areas have not been completely classified and coded; this may indicate topics that require further research before they are well-defined. Other areas require some clarification, as detailed commentary is not provided in the appendices. These issues will be discussed here.

Command modification for both lateral and longitudinal control bears further scrutiny and classification. The approaches identified here are not mutually exclusive, and do not provide the details of how the command modifications are to be made. For example, in platooning, the command modifications that have been identified are headway modification, speed modification, and platoon size adjustment. All of these will likely be used in an AHS which uses platooning for lateral control. The mechanics of how these decisions are made have not been addressed here, but may be available in literature by PATH or others.

Similar comments apply for special control modes for both lateral and longitudinal control. In longitudinal control, both emergency braking and emergency acceleration will be required, and some form of degraded control must be provided for fail-soft operation.

Thus, the options identified here are again not mutually exclusive. In addition, there is overlap between the area of special control modes and collision avoidance. The intent here is that collision avoidance, for longitudinal control, will require emergency braking and acceleration, but that special control laws may be required for these exceptional maneuvers. The control laws required for such maneuvers are beginning to be addressed in the literature. Special control modes and collision avoidance for lateral control share similar concerns.

In the specific area of sensing of absolute translation, a number of approaches have been listed. Most of these approaches can be classified as radio-navigation techniques. Within these, GPS is clearly the most likely candidate for application in an AHS. The other radio-navigation techniques, including Loran-C, Omega, TACAN, Transit, and TACTIC, are only included for completeness. On a related note, throughout this classification, GPS should always be considered Differential GPS, as differential operation will be required to achieve the desired accuracy.

The computational requirements for lateral and longitudinal control have only been roughly indicated. The needed areas include control law calculation, sensor data acquisition, and communication support. Once again, these areas will not be mutually exclusive. In addition, the detailed physical components in these areas have not been indicated, as they will vary considerably based on implementation, and may be significantly different in the future.

The issue of lane closure has been included under the area of lateral control, as it appears to be most influenced by the form of the lateral reference that has been selected. In most of the areas, specific physical measures have been identified as possible ways of closing a lane for either routine maintenance or an incident. In all areas, the possibility of lane closure based on an external controller command appears reasonable. At this time, this is the only approach that seems reasonable for the dead reckoning and discrete radar lateral control approaches. However, more information in this area may be available from other Precursor System Analysis literature in the near future.

Incident clearing has also been included under the emergency handling sub-function of lateral control. The available lateral reference system will have significant impact on the possible approaches here. For most forms of lateral control, it appears feasible to use an automated or semi-automated tow vehicle. This option may be applicable for dead reckoning lateral control, but does not seem feasible at this time. The feasibility of the dead reckoning approach for lateral control is questionable in general, but this option has been included for completeness. More options have been identified for the guideway case, as incident clearing will be most critical for this form of lateral control. Some of the options listed here may be applicable to other lateral control forms, but may not be justifiable based on cost. In general, standard approaches for incident clearing may also be applicable for most of the lateral control forms.

The areas of vehicle / road interaction and vehicle power have not been developed in detail in the reference architecture. Most of the AHS literature has assumed that interaction will be through rubber tires on the road; as such, the concentration here is on this case, and the architecture is strongly biased in that direction. The possibility of a pallet system has been included here to avoid omission, and as a provision for future expansion in the architecture, if this approach appears more likely in the future. Vehicle power has been included here, but again only in a cursory fashion. Most of the architecture will be only minimally influenced by the choice of vehicle power technology, with the possible exception of roadway-provided electric power, which could have significant impact on other areas of the architecture. Further information may be provided from other Precursor System Analysis studies in the area of Alternative Propulsion Systems.

Within Structural Support, the area of sight distance may require further investigation. The figures given in the three areas are taken from (Caltrans, 1992), and are based on human driver responses. At the very least, these numbers may need to be modified for the case of automated longitudinal control. In addition, the concepts themselves may require

rethinking as they apply to an AHS. Passing distance will only be applicable in rural areas. The inclusion of "Unknown" as an option for these areas should alleviate any difficulties.

5. Conclusions

The AHS Reference Architecture presented here can be used in many ways. It can delineate possible AHS Representative System Configurations to the level of detail required. It can also be used to completely specify an AHS, down to the physical components to include in the roadway, the vehicle, and elsewhere. The architecture can also be used to develop a knowledge-based expert system to aid in AHS research and analysis. It represents a unified classification of the current and foreseeable possible AHS configurations. Finally, the architecture can be expanded to include additional functions as needed in the future. This is an important feature, as AHS research is still in its early stages, and many changes are likely over the coming years.

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Appendix A: Longitudinal Control

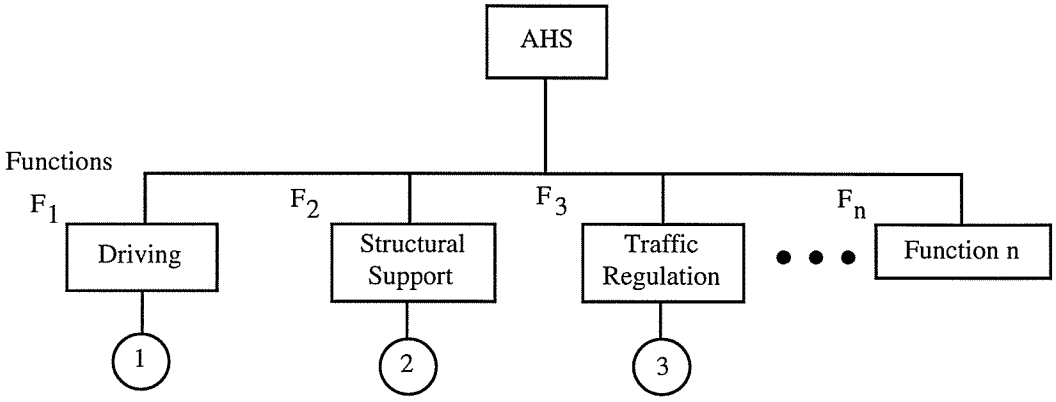

Figure A-1: AHS Reference Architecture Functional Overview.

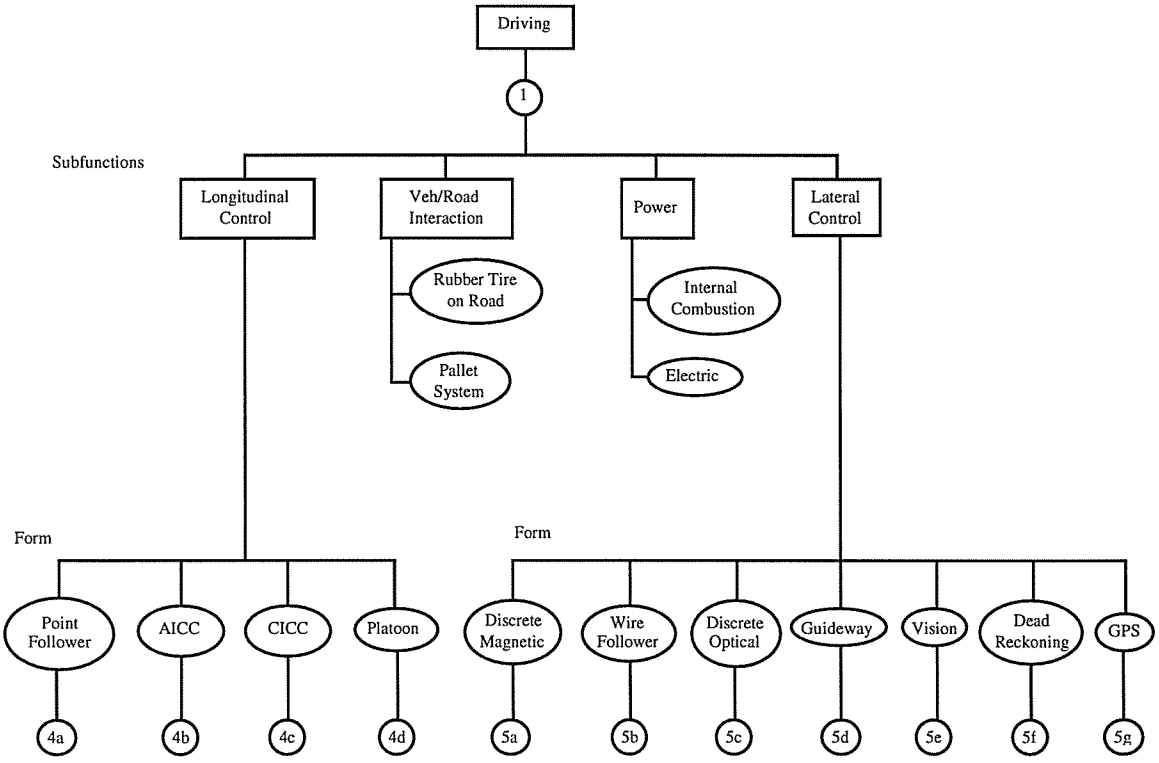

Figure A-2: Driving Function Overview.

Longitudinal Connection List

1 Driving Function to Lateral and Longitudinal Subfunctions

2 Structural Support Function to Subfunctions

3 Traffic Control Function to Subfunctions

4 Longitudinal Control form to Systems

5 Lateral Control form to Systems

6 Point Follower Emergency Systems to Subsystems

7 Point Follower Communication Systems to Physical Components

8 Point Follower Actuation Systems to Physical Components

9 Point Follower Sensing Systems to Physical Components

10 AICC Emergency Systems to Subsystems

11 AICC Communication Systems to Physical Components

12 AICC Actuation Systems to Physical Components

13 AICC Sensing Systems to Physical Components

14 CICC Emergency Systems to Subsystems

15 CICC Communication Systems to Physical Components

16 CICC Actuation Systems to Physical Components

17 CICC Sensing Systems to Physical Components

18 Platoon Emergency Systems to Subsystems

19 Platoon Communication Systems to Physical Components

20 Platoon Actuation Systems to Physical Components

21 Platoon Sensing Systems to Physical Components

22 Vehicle Sensing to Physical Components

23 Vehicle Status Sensing to Physical Components

96 Point-Follower Computation to Components

97 AICC Computation to Components

98 CICC Computation to Components

99 Platoon Computation to Components

Figure A-3: Longitudinal Control Connection List.

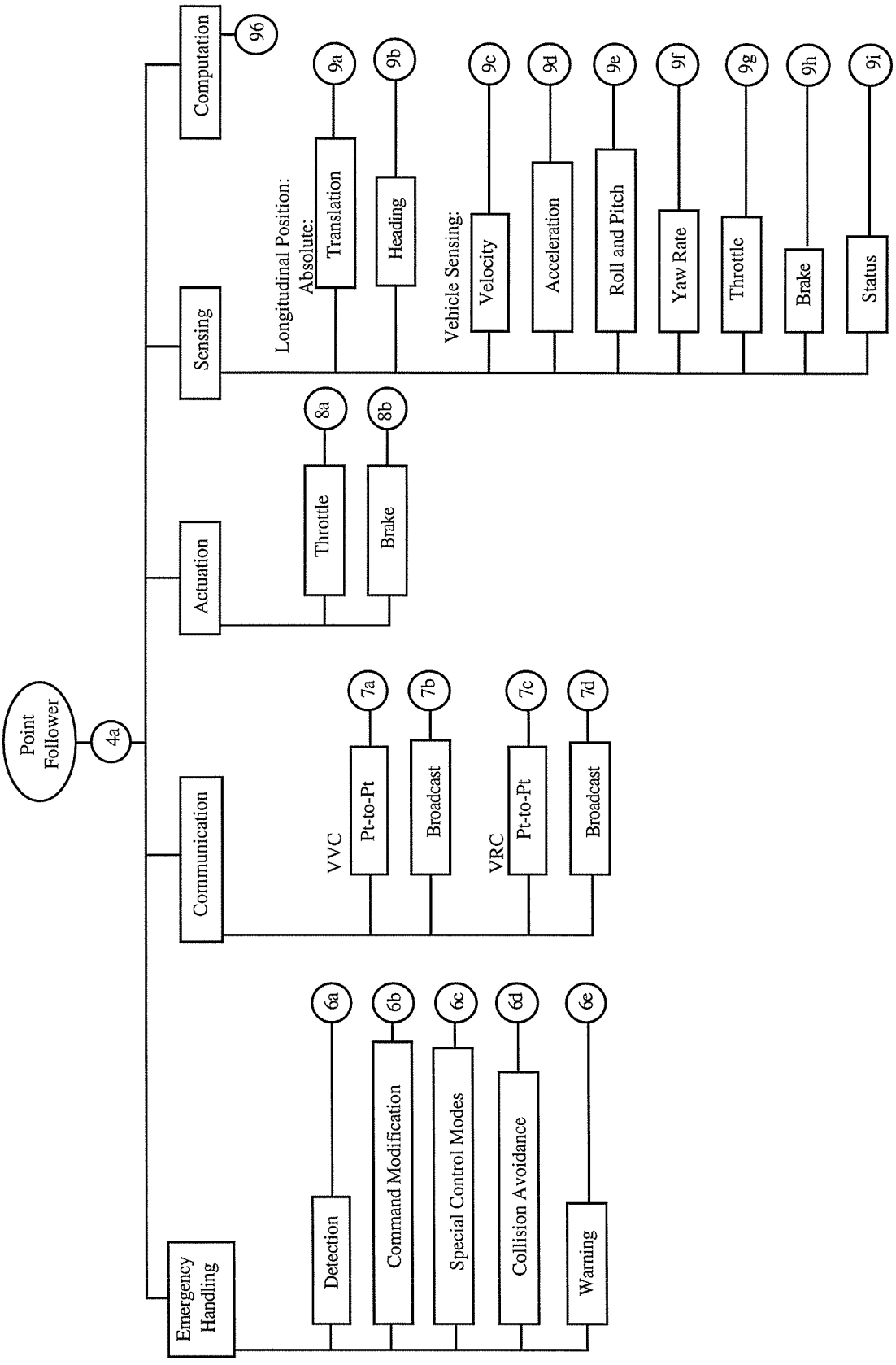

Figure A-4: Point-Follower Control Form.

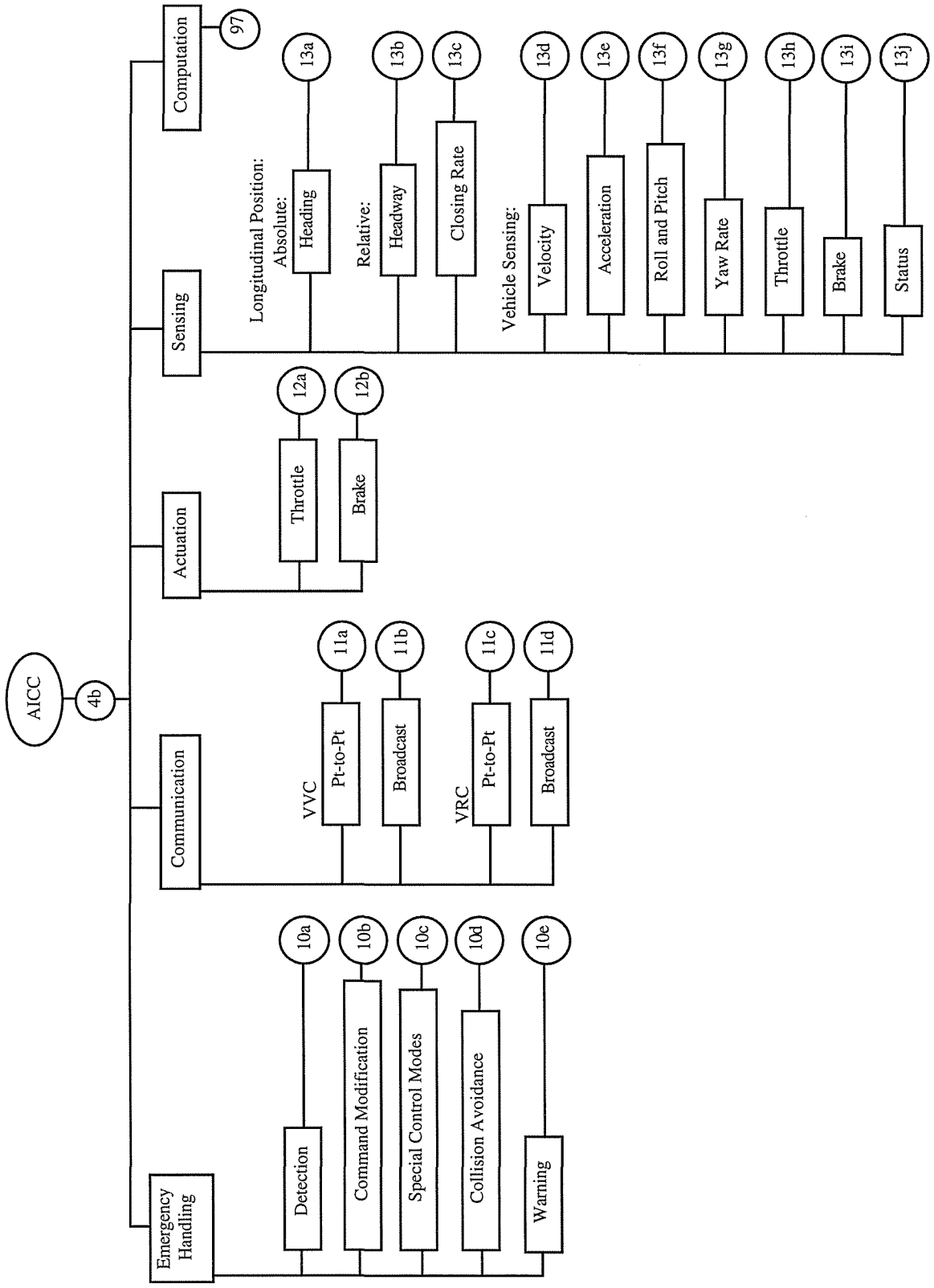

Figure A-5: Autonomous Intelligent Cruise Control (AICC) Form.

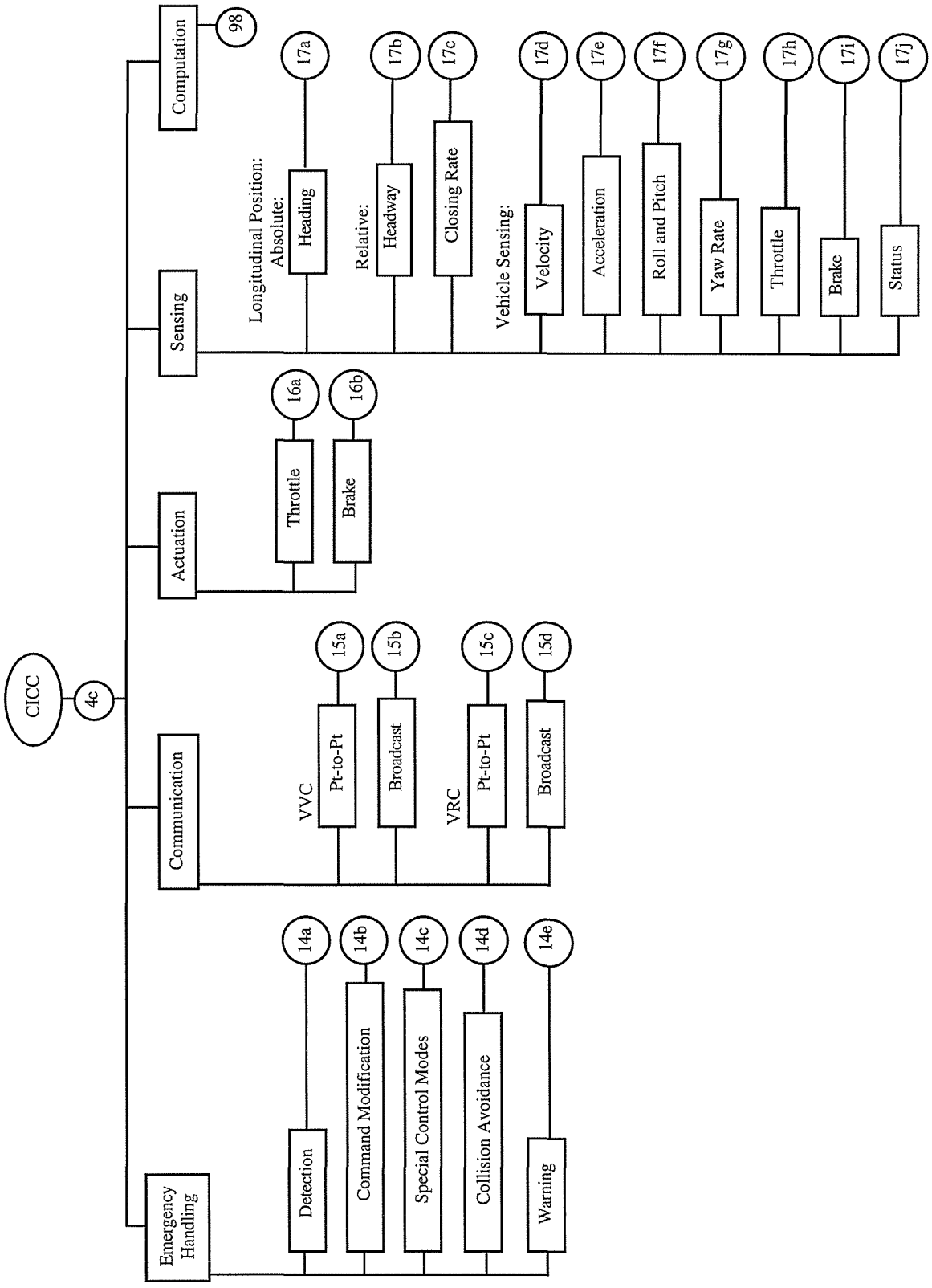

Figure A-6: Cooperative Intelligent Cruise Control (CICC) Form.

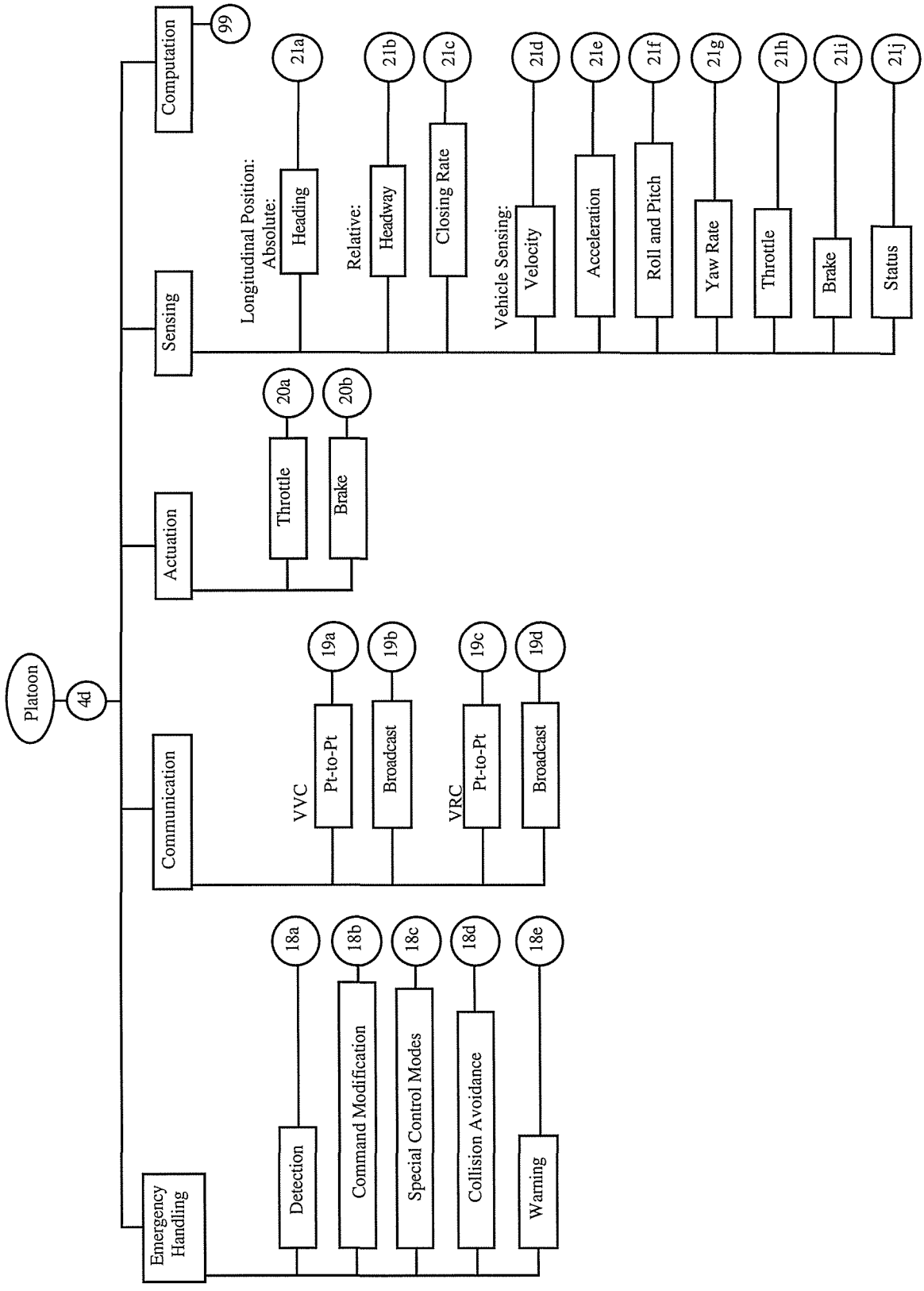

Figure A-7: Platooning Control Form.

Code	Approach
0	None
1	Point-Follower
2	AICC
3	CICC
4	Platooning
5	Other

Table A-1: Longitudinal Control Form Code.

Code	Approach
0	None
1	Long-Range Radar
2	Other

Table A-2: Emergency Detection Code: Obstacle Detection.

Code	Approach
0	None
1	Rain Detector
2	Snow Detector
3	Visibility Sensor
4	Pavement Temperature Sensor
5	Other

Table A-3: Emergency Detection Code: Weather.

Code	Approach
0	None
1	Inspection
2	Ice Detector
3	Other

Table A-4: Emergency Detection Code: Road Surface.

Code	Approach
0	None
1	Error Detecting Code
2	Communication Protocols
3	Detection Filter using Residuals
4	Voting Scheme
5	Other

Table A-5: Emergency Detection Code: Communication Loss.

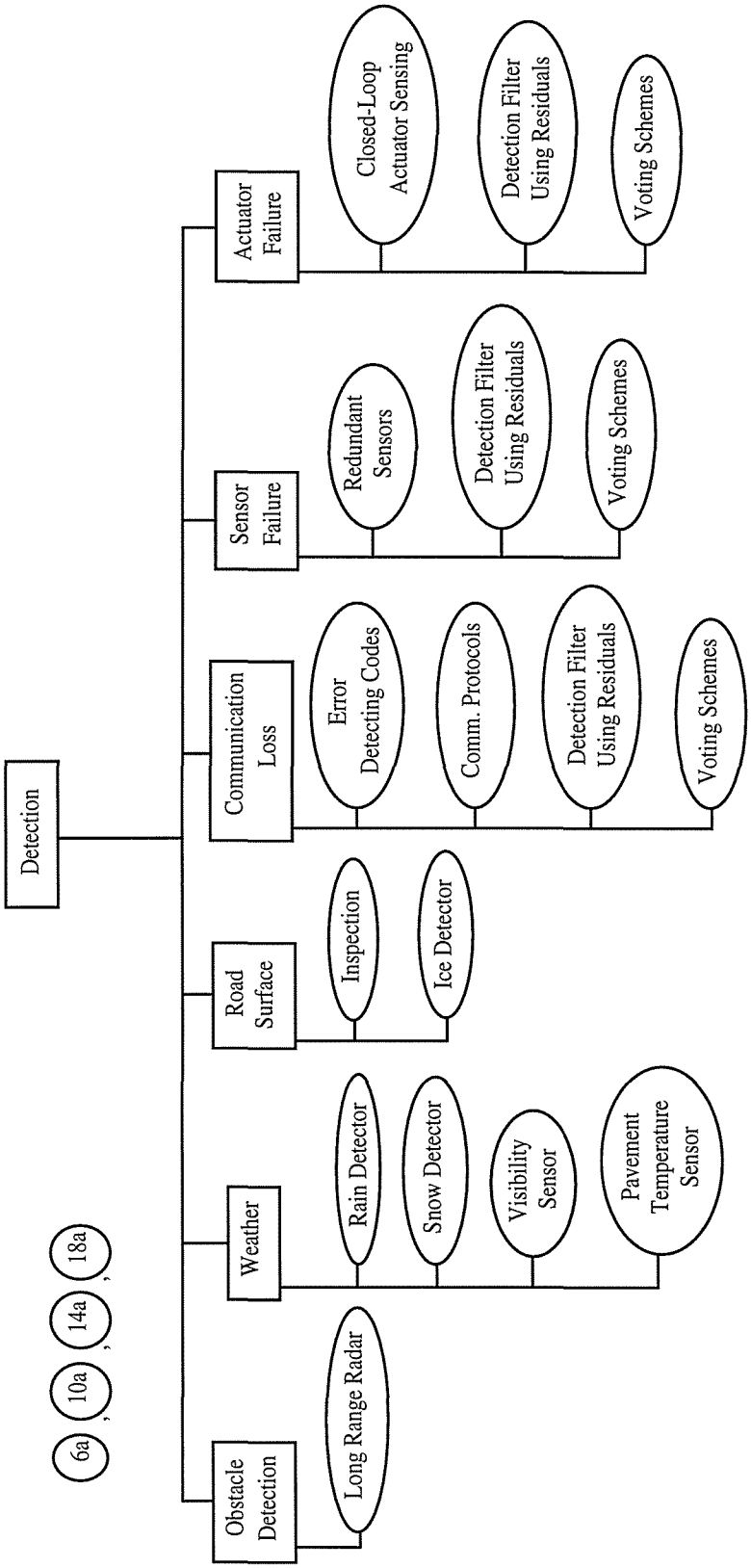

Figure A-8: Emergency Detection for All Longitudinal Forms.

Code	Approach
0	None
1	Redundant Sensors
2	Detection Filter using Residuals
3	Voting Scheme
4	Other

Table A-6: Emergency Detection Code: Sensor Failure.

Code	Approach
0	None
1	Closed-Loop Actuator Sensing
2	Detection Filter using Residuals
3	Voting Scheme
4	Other

Table A-7: Emergency Detection Code: Actuator Failure.

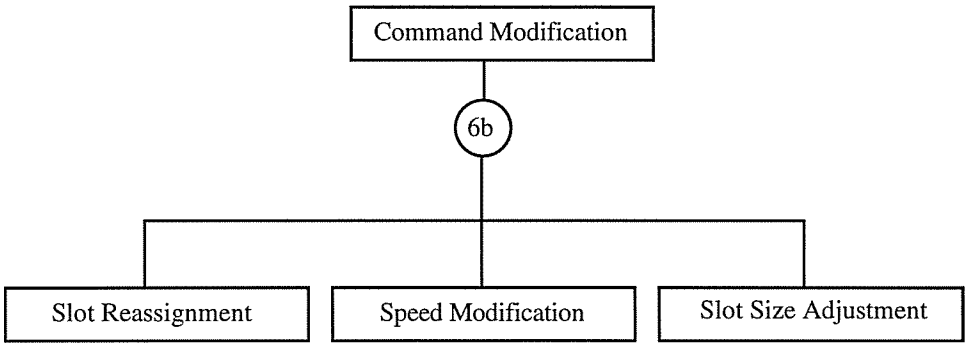

Figure A-9: Point-Follower Command Modification.

Code	Approach
0	None
1	Slot Reassignment
2	Speed Modification
3	Slot Size Adjustment
4	Other

Table A-8: Command Modification: Point-Follower.

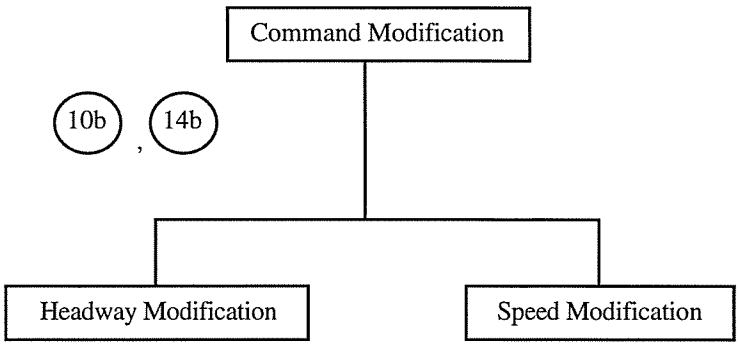

Figure A-10: AICC and CICC Command Modification.

Code	Approach
0	None
1	Headway Modification
2	Speed Modification
3	Other

Table A-9: Command Modification: AICC and CICC.

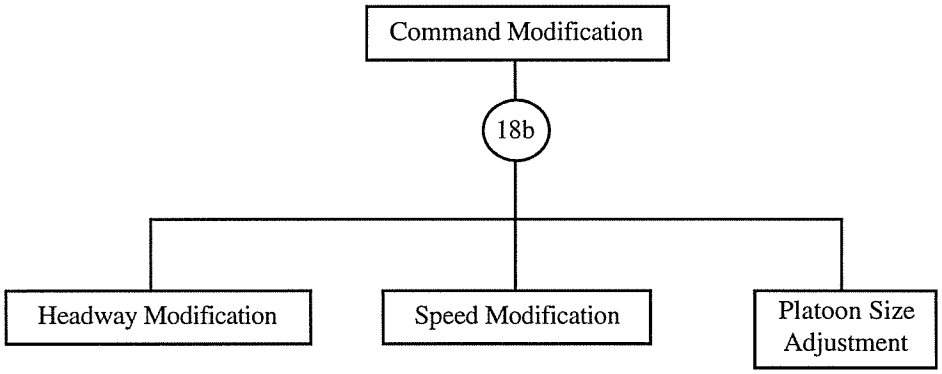

Figure A-11: Platooning Command Modification.

Code	Approach
0	None
1	Headway Modification
2	Speed Modification
3	Platoon Size Adjustment
4	Other

Table A-10: Command Modification: Platooning.

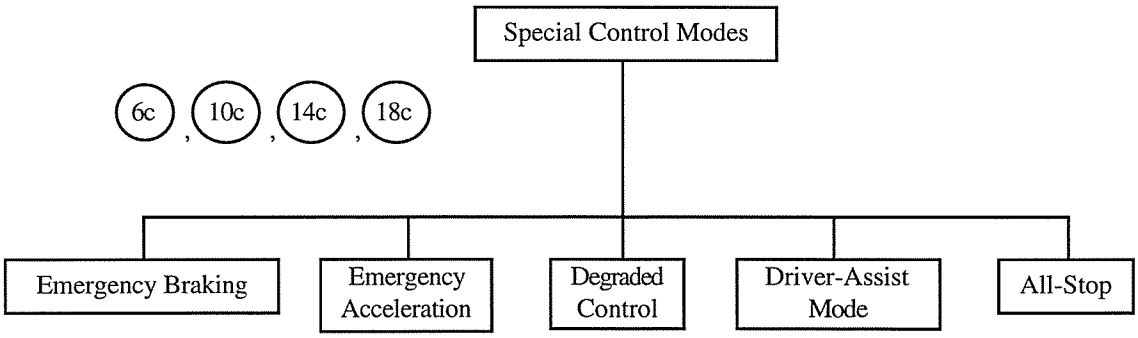

Figure A-12: Special Control for All Longitudinal Forms.

Code	Approach
0	None
1	Emergency Braking
2	Emergency Acceleration
3	Degraded Control
4	Driver-Assist Mode
5	All-Stop
6	Other

Table A-11: Special Control Code: All Longitudinal Forms.

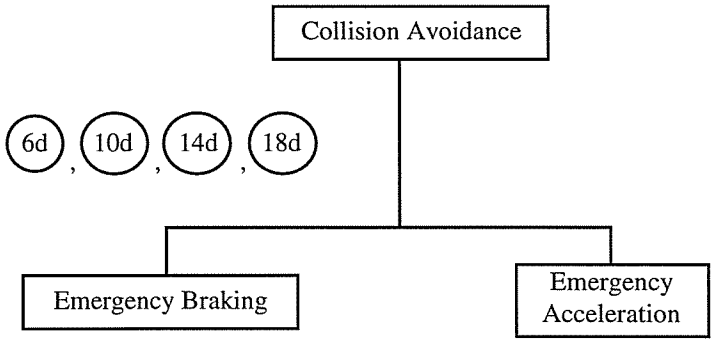

Figure A-13: Collision Avoidance for All Longitudinal Forms.

Code	Approach
0	None
1	Emergency Braking
2	Emergency Acceleration
3	Other

Table A-12: Collision Avoidance Code: All Longitudinal Forms.

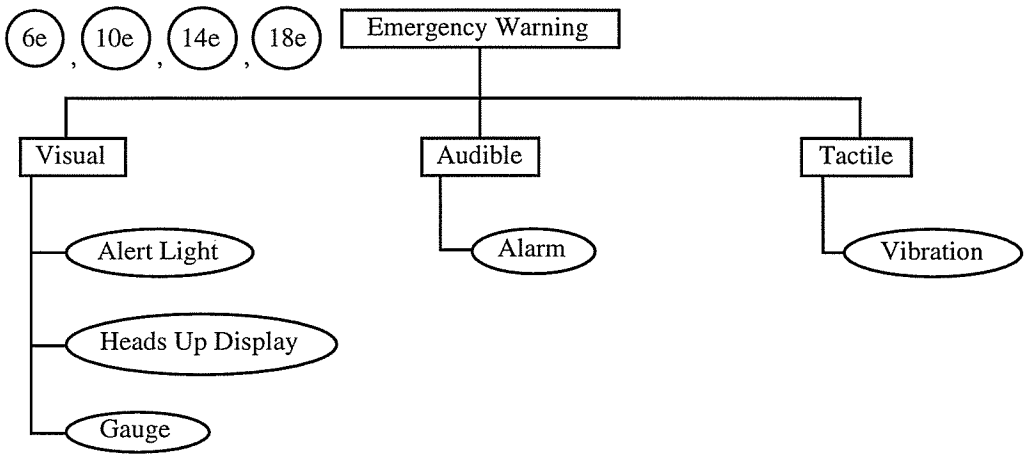

Figure A-14: Emergency Warning for All Longitudinal Forms.

Code	Approach
0	None
1	Alert Light
2	Heads-Up Display
3	Gauge
4	Other

Table A-13: Visual Emergency Warning Code: All Longitudinal Forms.

Code	Approach
0	None
1	Alarm
2	Other

Table A-14: Audible Emergency Warning Code: All Longitudinal Forms.

Code	Approach
0	None
1	Vibration
2	Other

Table A-15: Tactile Emergency Warning Code: All Longitudinal Forms.

Code	Item
0	None
1	Infrared Transceiver
2	Ultrasonic Transceiver
3	Other

Table A-16: Longitudinal Control Vehicle-to-Vehicle Communication Code: Point-to-Point.

Code	Item
0	None
1	Microwave Transceiver
2	Radio Frequency Transceiver
3	Other

Table A-17: Longitudinal Control Vehicle-to-Vehicle Communication Code: Broadcast.

Code	Item
0	None
1	Infrared Transceiver
2	Ultrasonic Transceiver
3	Other

Table A-18: Longitudinal Control Vehicle-to-Roadside Communication Code: Point-to-Point.

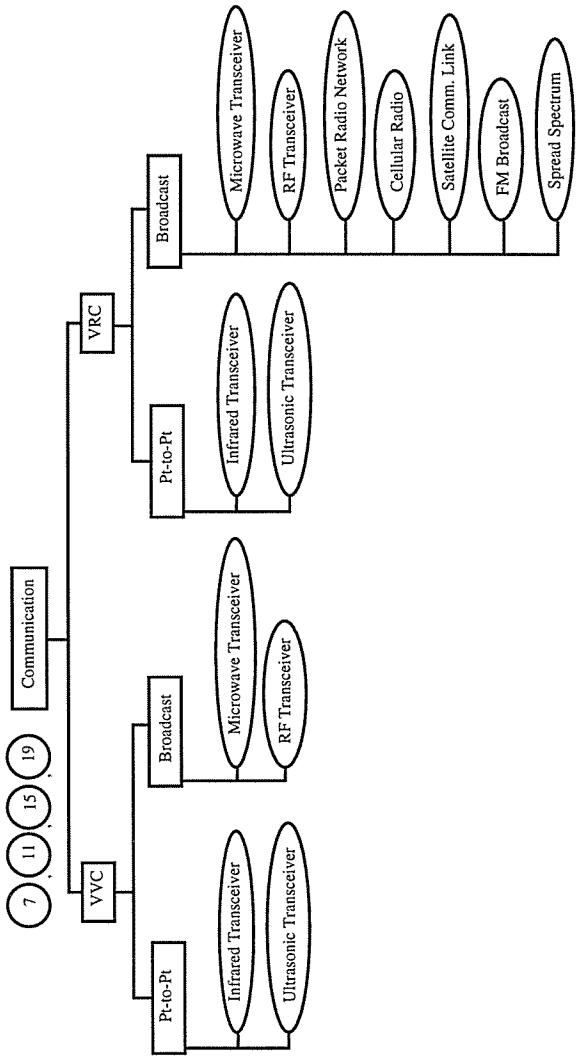

Figure A-15: Communications for All Longitudinal Forms.

Code	Item
0	None
1	Microwave Transceiver
2	Radio Frequency Transceiver
3	Packet Radio Network
4	Cellular Radio
5	Satellite Communication Link
6	FM Broadcast
7	Spread Spectrum Technology
8	Other

Table A-19: Longitudinal Control Vehicle-to-Roadside Communication Code: Broadcast.

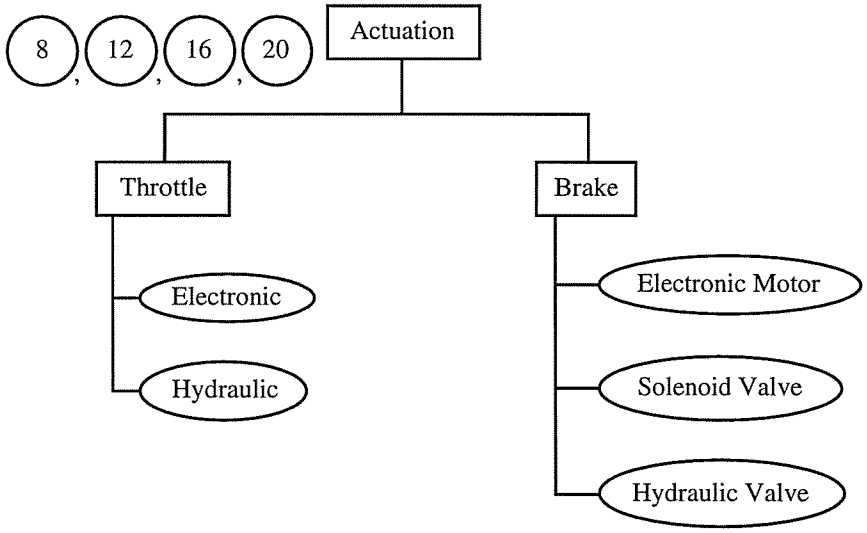

Figure A-16: Actuation for All Longitudinal Forms.

Code	Item
0	None
1	Electronic Actuator
2	Hydraulic Actuator
3	Other

Table A-20: Longitudinal Control Throttle Actuator Code.

Code	Item
0	None
1	Electronic Motor
2	Solenoid Valve
3	Hydraulic Valve
4	Other

Table A-21: Longitudinal Control Brake Actuator Code.

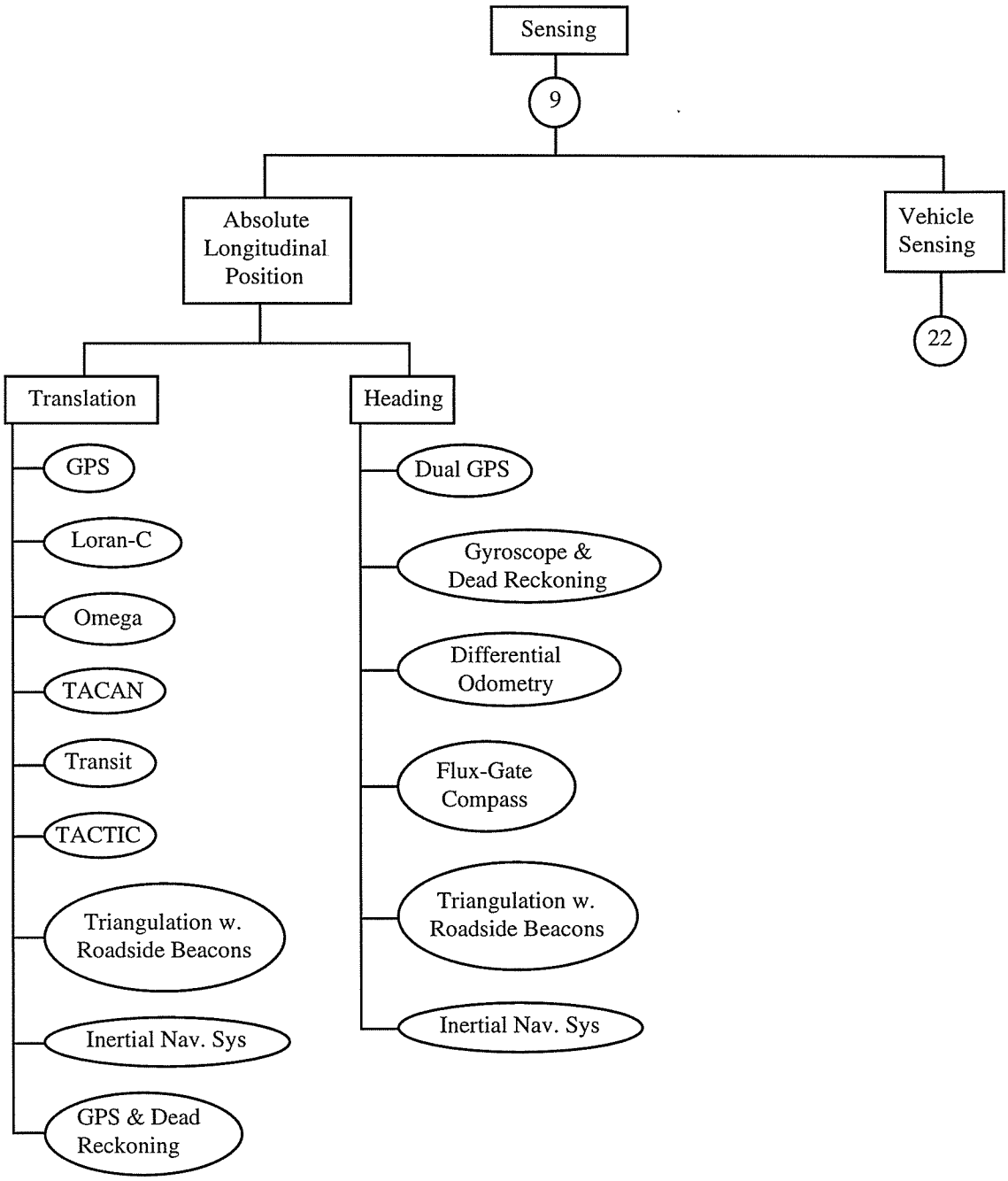

Figure A-17: Point-Follower Sensing.

Code	Item
00	None
01	GPS
02	Loran-C
03	Omega
04	Inertial Navigation System
05	TACAN
06	Transit
07	TACTIC
08	Triangulation w. Roadside Beacons
09	GPS and Dead-Reckoning
10	Other

Table A-22: Longitudinal Control Absolute Position (Translation) Sensing: Point-Follower.

Code	Item
0	None
1	Dual GPS
2	Gyroscope and Dead Reckoning
3	Differential Odometry
4	Flux-Gate Compass
5	Triangulation w. Roadside Beacons
6	Inertial Navigation System
7	Other

Table A-23: Longitudinal Control Absolute Position (Heading) Sensing: All Longitudinal Forms.

Code	Item
00	None
01	SONAR (Audio Frequency)
02	SONAR (Ultrasonic Frequency)
03	Microwave Radar (S-Band)
04	Microwave Radar (X-Band)
05	Microwave Radar (Ka-Band)
06	Millimeter Wave Radar
08	Single Point Laser Ranger
09	1-d Scanning Ladar
10	Triangulation using Stereo Disparity
11	Structured Light Triangulation
12	Active Triangulation
13	Known Target Size Triangulation
14	GPS with Communication
15	Triangulation with Roadside Beacons
16	Other

Table A-24: Longitudinal Control Headway Sensing: AICC, CICC, and Platooning.

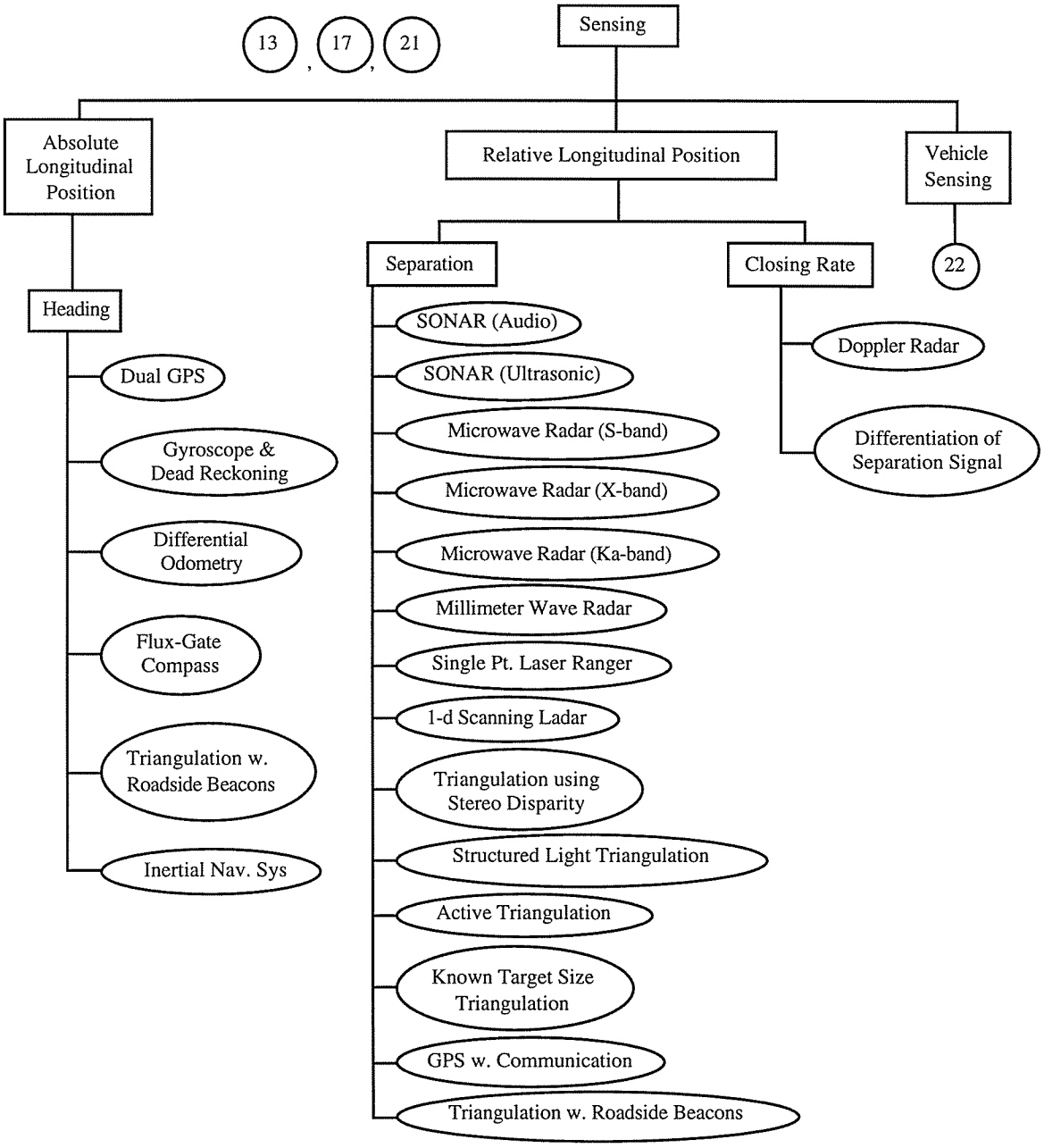

Figure A-18: AICC, CICC, and Platoon Sensing.

Code	Item
0	None
1	Doppler Radar
2	Differentiation of Distance Signal
3	Other

Table A-25: Longitudinal Control Headway Closing Rate Sensing: AICC, CICC, and Platooning.

Code	Item
00	None
01	Speedometer
02	Doppler Odometer
03	Tachometer
04	Pole Counter
05	Wheel Encoder w. Differentiation
06	Wheel Encoder w. Timing of Pulses
07	Non-Contact Optical Sensor
08	GPS
09	Inertial Navigation System
10	Timing of Discrete Mag. Marker Pulses
11	Other

Table A-26: Longitudinal Control Vehicle Sensing: Velocity.

Code	Item
0	None
1	Sprung-Mass Inertial Accelerometer
2	Solid-State Accelerometer
3	Velocity Signal Differentiation
4	Other

Table A-27: Longitudinal Control Vehicle Sensing: Acceleration.

Code	Item
0	None
1	Inertial Navigation System
2	Gyroscope
3	Inclinometer
4	Dual GPS
5	Other

Table A-28: Longitudinal Control Vehicle Sensing: Roll/Pitch.

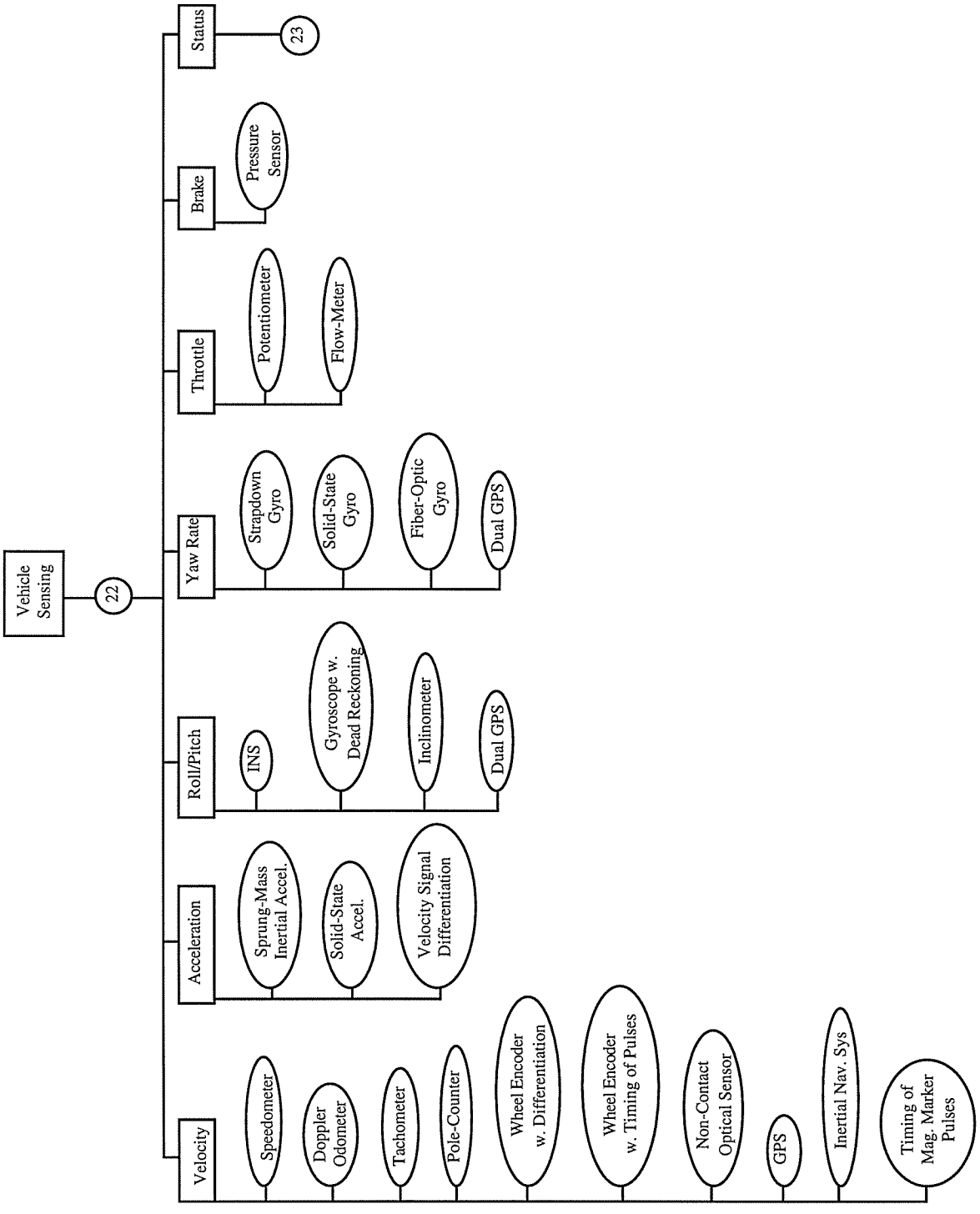

Figure A-19: Vehicle Sensing for All Longitudinal Forms.

Code	Item
0	None
1	Strapdown Gyroscope
2	Solid-State Gyroscope
3	Fiber-Optic Gyroscope
4	Dual GPS
5	Other

Table A-29: Longitudinal Control Vehicle Sensing: Yaw Rate.

Code	Item
0	None
1	Potentiometer
2	Flow-Meter
3	Other

Table A-30: Longitudinal Control Vehicle Sensing: Throttle.

Code	Item
0	None
1	Pressure Sensor
2	Other

Table A-31: Longitudinal Control Vehicle Sensing: Brake.

Code	Item
0	None
1	Pressure Sensor
2	Other

Table A-32: Longitudinal Control Status Sensing: Tire Pressure.

Code	Item
0	None
1	Standard Fuel Sensor
2	Other

Table A-33: Longitudinal Control Status Sensing: Fuel Level.

Code	Item
0	None
1	Thermocouple
2	Other

Table A-34: Longitudinal Control Status Sensing: Oil Temperature.

Code	Item
0	None
1	Thermocouple
2	Other

Table A-35: Longitudinal Control Status Sensing: Engine Temperature.

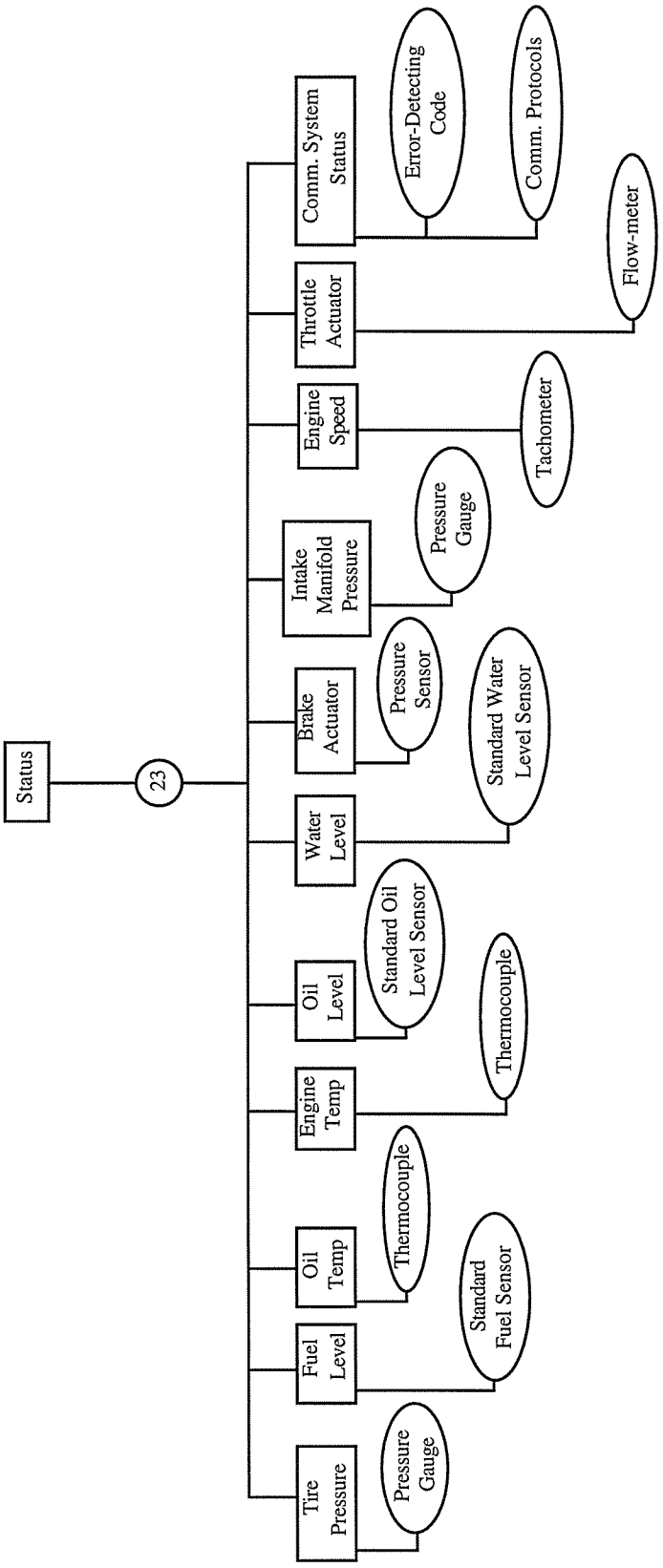

Figure A-20: Vehicle Status Sensing for All Longitudinal Forms.

Code	Item
0	None
1	Standard Oil Level Sensor
2	Other

Table A-36: Longitudinal Control Status Sensing: Oil Level.

Code	Item
0	None
1	Standard Water Level Sensor
2	Other

Table A-37: Longitudinal Control Status Sensing: Water Level.

Code	Item
0	None
1	Pressure Sensor
2	Other

Table A-38: Longitudinal Control Status Sensing: Brake Actuator.

Code	Item
0	None
1	Pressure Sensor
2	Other

Table A-39: Longitudinal Control Status Sensing: Intake Manifold Pressure.

Code	Item
0	None
1	Tachometer
2	Other

Table A-40: Longitudinal Control Status Sensing: Engine Speed.

Code	Item
0	None
1	Flow-Meter
2	Other

Table A-41: Longitudinal Control Status Sensing: Throttle Actuator.

Code	Item
0	None
1	Error-Detecting Code
2	Communication Protocols
3	Other

Table A-42: Longitudinal Control Status Sensing: Communication System.

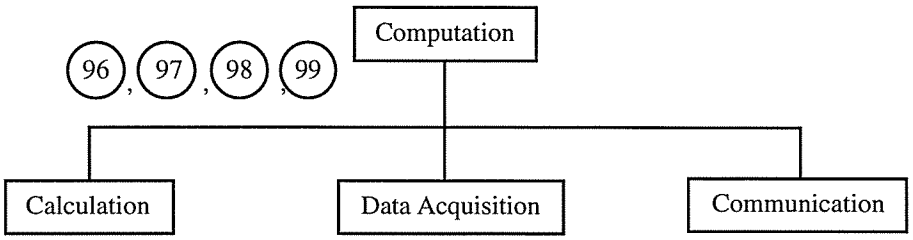

Figure A-21: Computation for All Longitudinal Forms.

Code	Item
0	None
1	Calculation
2	Data Acquisition
3	Communication
4	Other

Table A-43: Longitudinal Control Computation Code: All Longitudinal Forms.

Appendix B: Lateral Control

(24) Discrete Magnetic Emergency Systems to Subsystems

(25) Discrete Magnetic Communication Systems to Physical Components

(26) Discrete Magnetic Actuation Systems to Physical Components

(27) Discrete Magnetic Sensing Systems to Physical Components

(28) Wire Follower Emergency Systems to Subsystems

(29) Wire Follower Communication Systems to Physical Components

(30) Wire Follower Actuation Systems to Physical Components

(31) Wire Follower Sensing Systems to Physical Components

(32) Discrete Optical Emergency Systems to Subsystems

(33) Discrete Optical Communication Systems to Physical Components

(34) Discrete Optical Actuation Systems to Physical Components

(35) Discrete Optical Sensing Systems to Physical Components

(36) Guideway Emergency Systems to Subsystems

(37) Guideway Communication Systems to Physical Components

(38) Guideway Actuation Systems to Physical Components

(39) Guideway Sensing Systems to Physical Components

(40) Vision System Emergency Systems to Subsystems

(41) Vision System Communication Systems to Physical Components

(42) Vision System Actuation Systems to Physical Components

(43) Vision System Sensing Systems to Physical Components

(44) Dead Reckoning Emergency Systems to Subsystems

(45) Dead Reckoning Communication Systems to Physical Components

(46) Dead Reckoning Actuation Systems to Physical Components

(47) Dead Reckoning Sensing Systems to Physical Components

(48) GPS Emergency Systems to Subsystems

(49) GPS Communication Systems to Physical Components

(50) GPS Actuation Systems to Physical Components

(51) GPS Sensing Systems to Physical Components

(52) Discrete Radar Emergency Systems to Subsystems

(53) Discrete Radar Communication Systems to Physical Components

(54) Discrete Radar Actuation Systems to Physical Components

(55) Discrete Radar Sensing Systems to Physical Components

(56) Status Sensing to Components

Figure B-1: Lateral Control Connection List, Part 1.

57 Discrete Magnetic Computation to Subsystems

58 Wire Follower Computation to Subsystems

59 Discrete Optical Computation to Subsystems

60 Guideway Computation to Subsystems

61 Vision System Computation to Subsystems

62 Dead Reckoning Computation to Subsystems

63 GPS Computation to Subsystems

64 Discrete Radar Computation to Subsystems

Figure B-2: Lateral Control Connection List, Part 2.

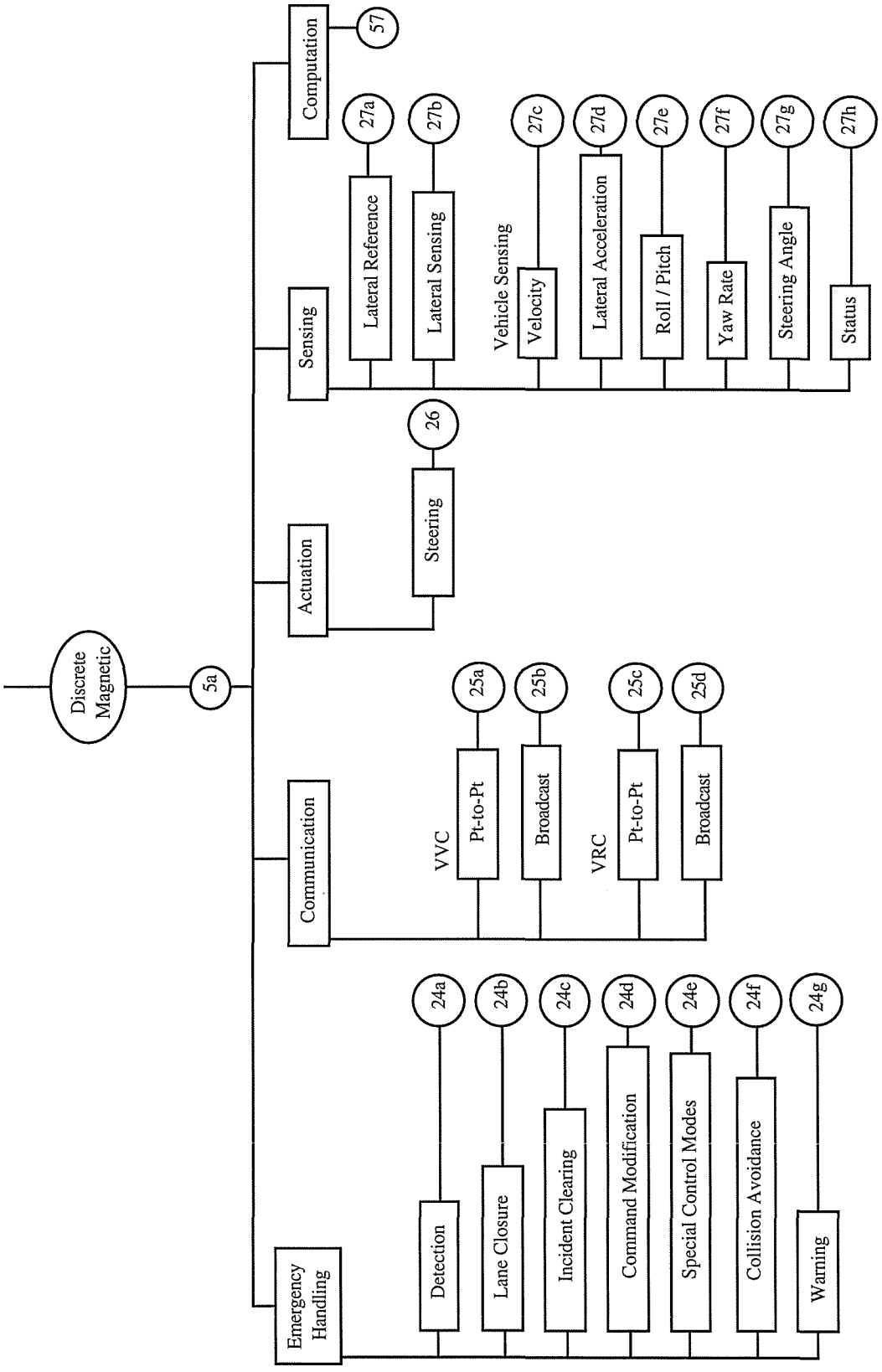

Figure B-3: Discrete Magnetic Lateral Control.

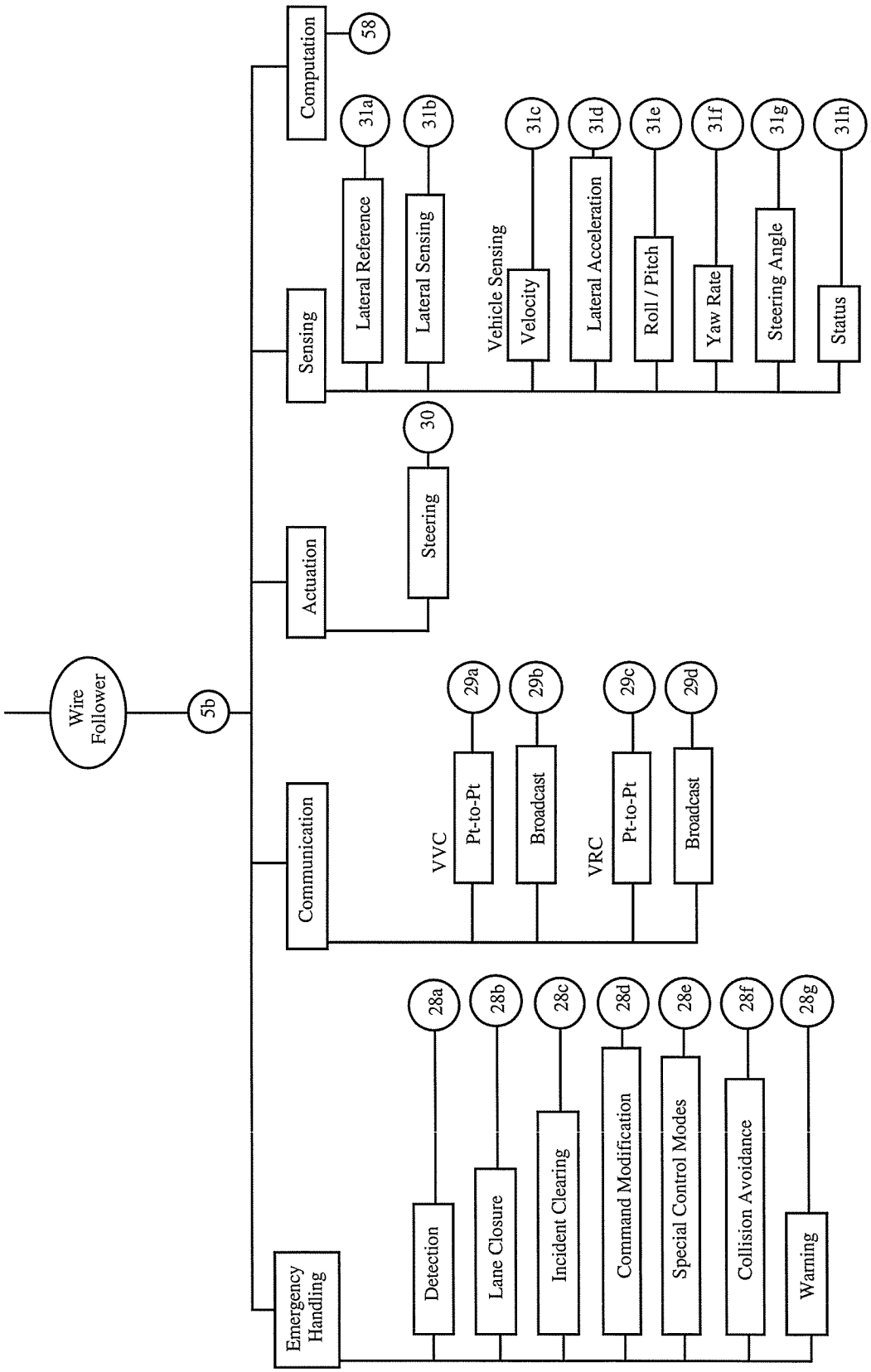

Figure B-4: Wire Follower Lateral Control.

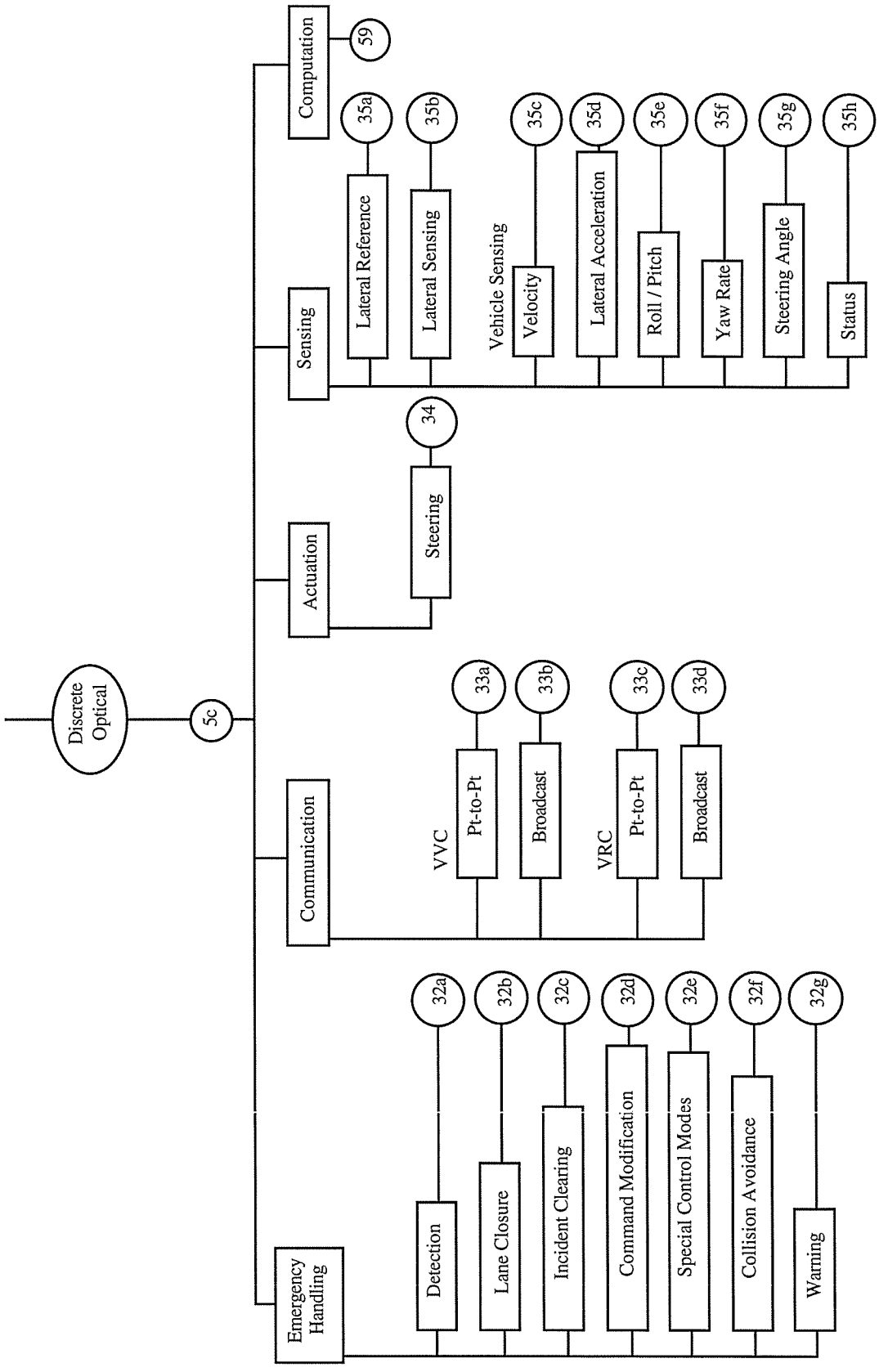

Figure B-5: Discrete Optical Lateral Control.

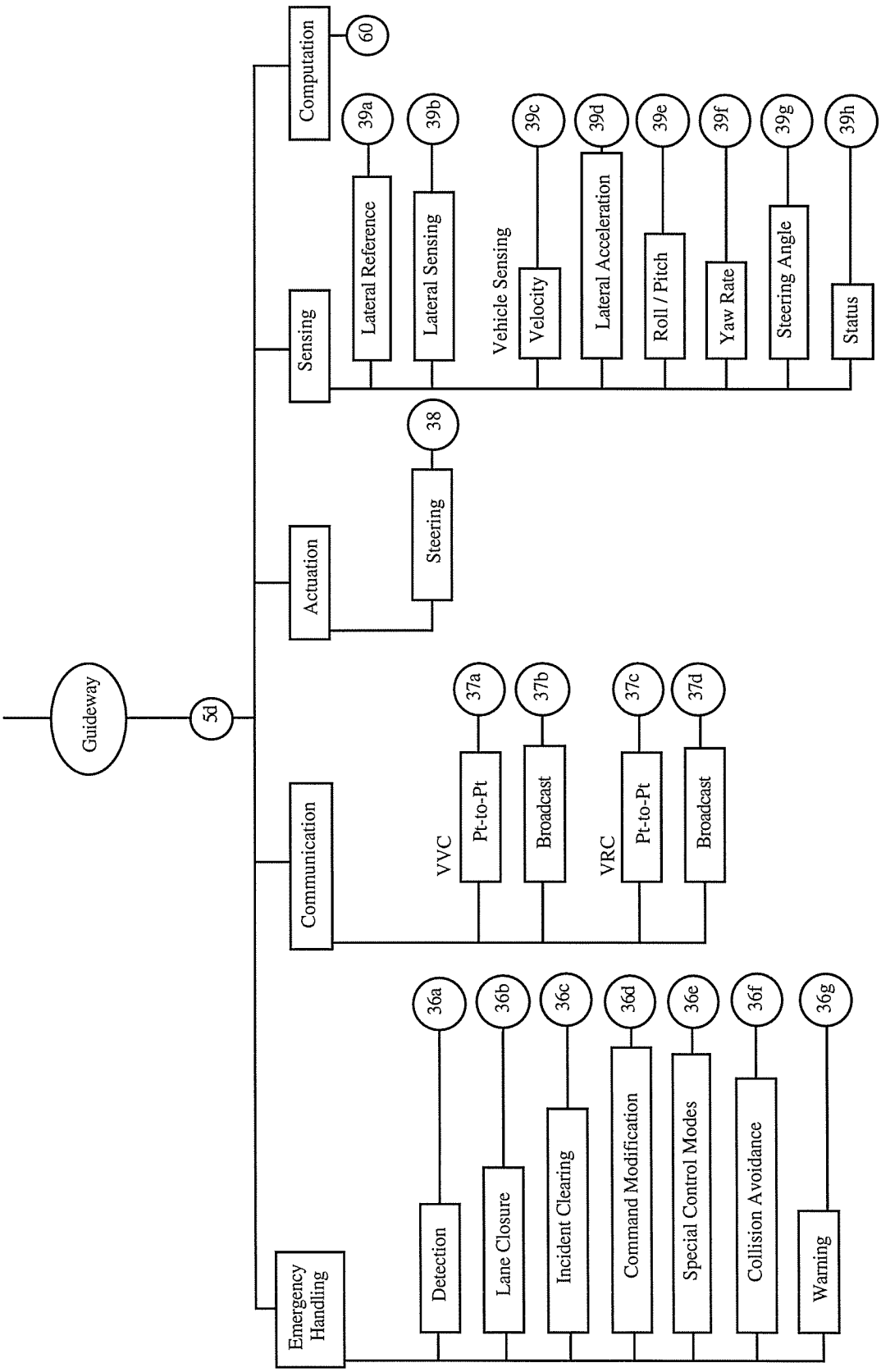

Figure B-6: Guideway Lateral Control.

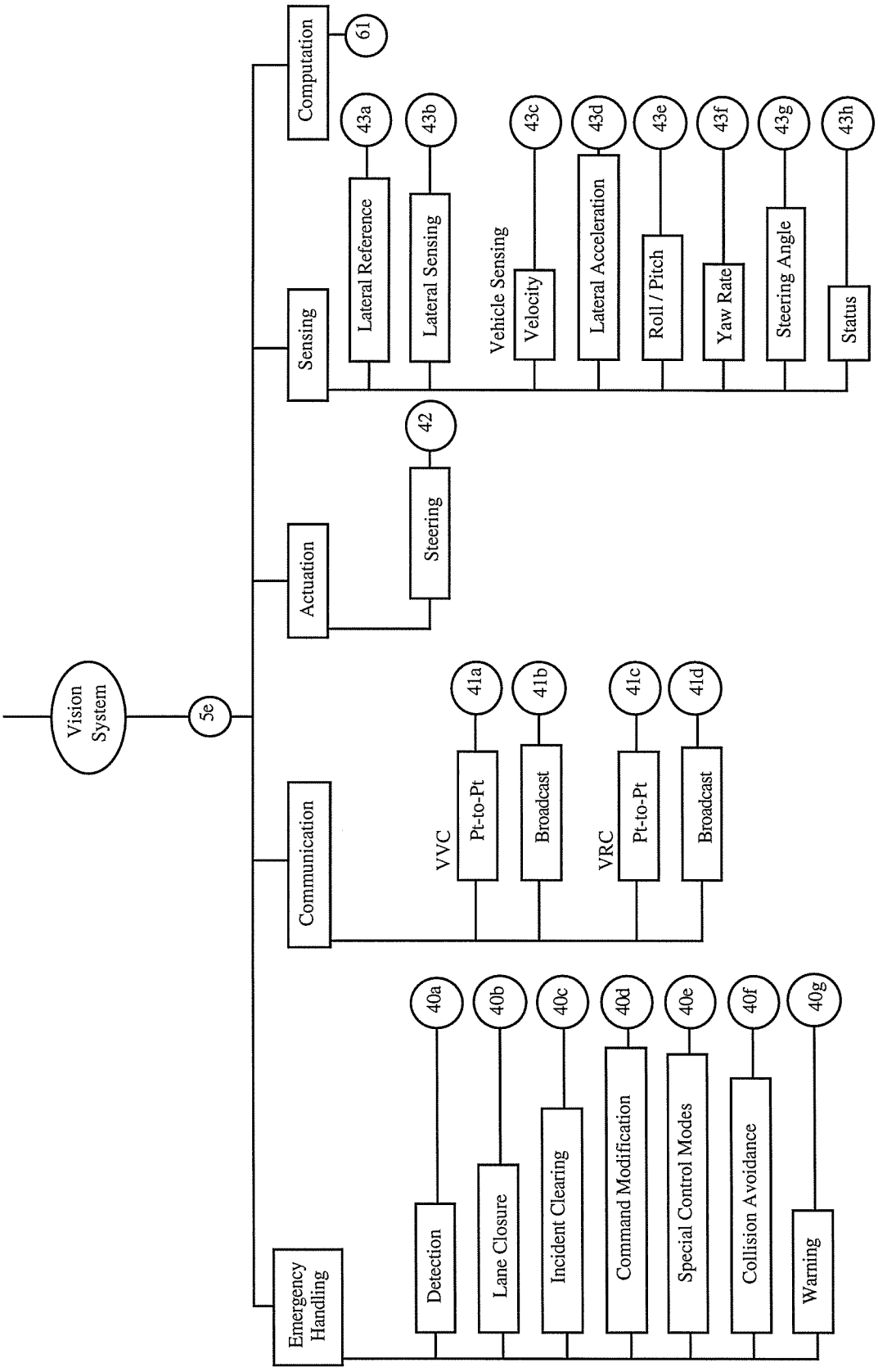

Figure B-7: Vision System Lateral Control.

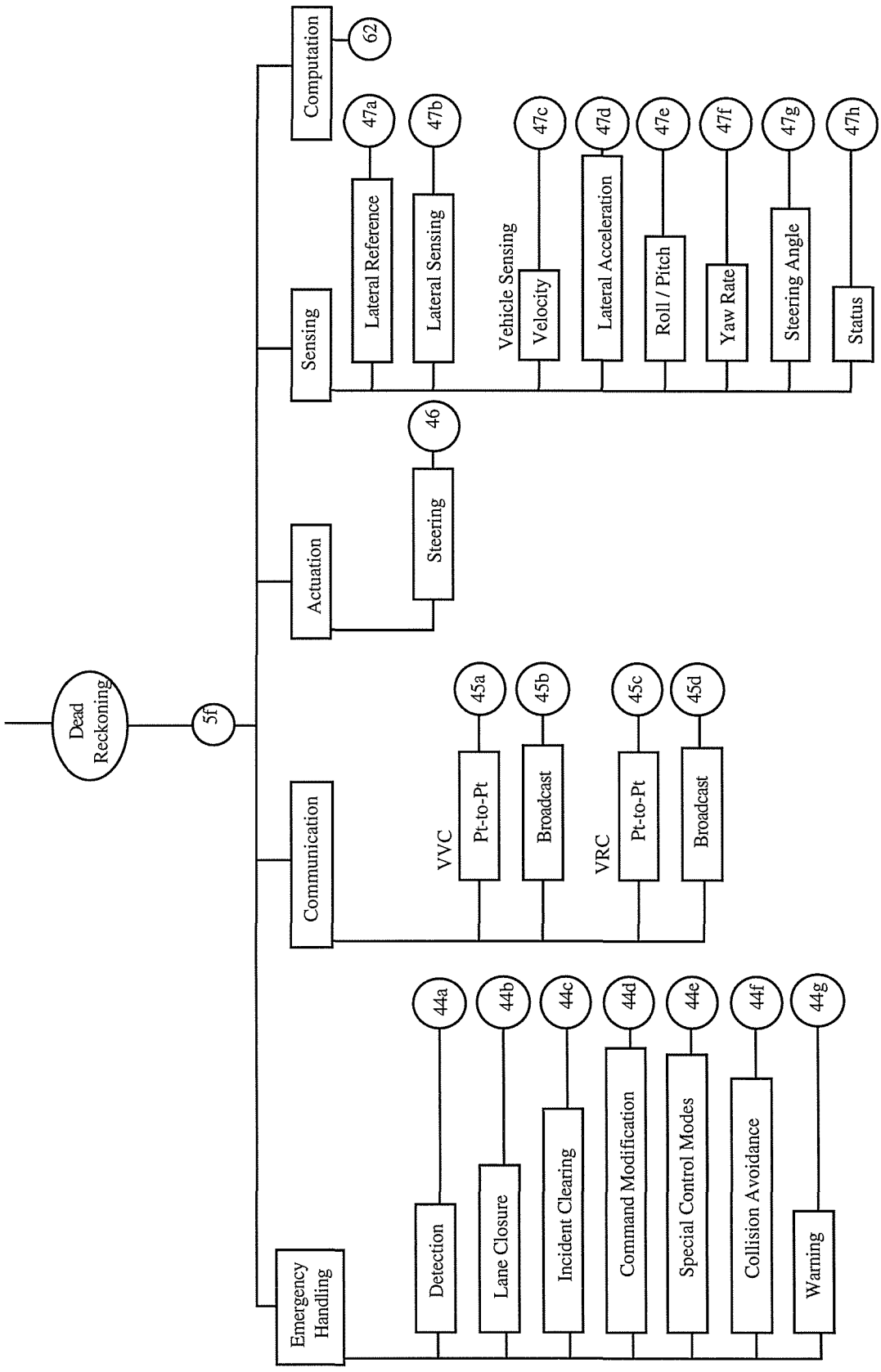

Figure B-8: Dead Reckoning Lateral Control.

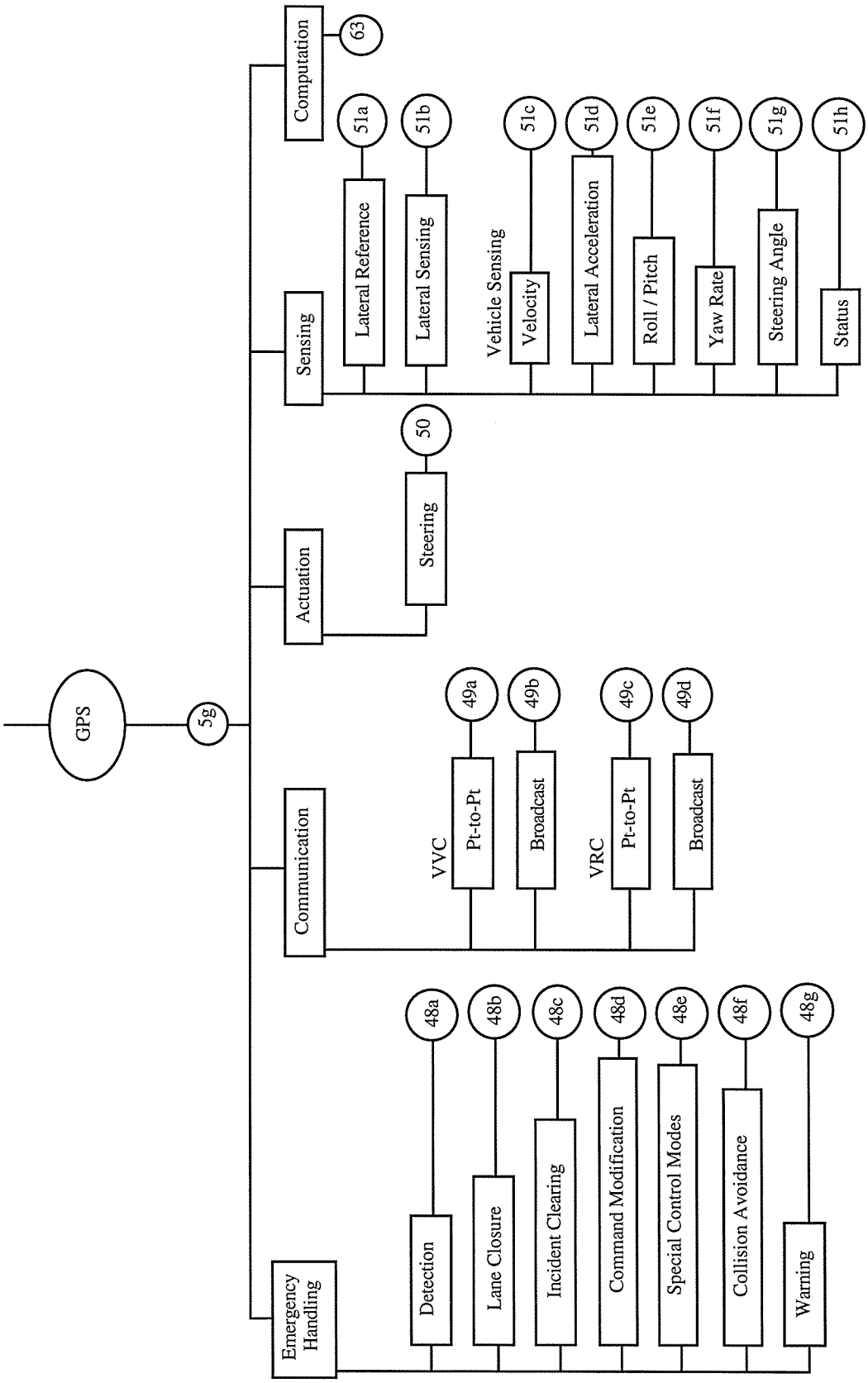

Figure B-9: GPS Lateral Control.

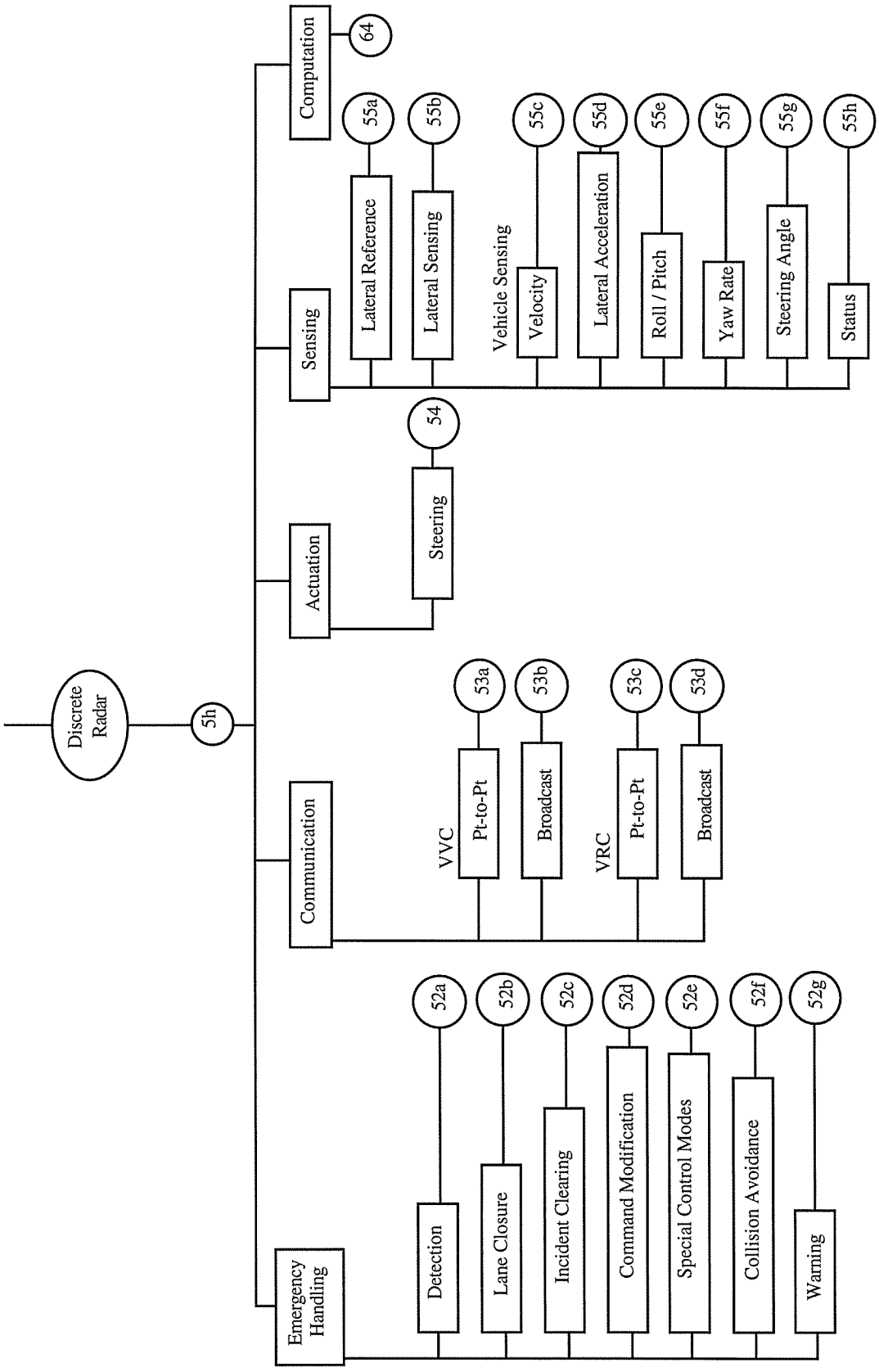

Figure B-10: Discrete Radar Lateral Control.

Code	Approach
0	None
1	Discrete Magnetic
2	Wire Follower
3	Discrete Optical
4	Guideway
5	Vision System
6	Dead Reckoning
7	GPS
8	Discrete Radar
9	Other

Table B-1: Lateral Control Form Code.

Code	Approach
0	None
1	Long-Range Radar
2	Other

Table B-2: Emergency Detection Code: Obstacle Detection.

Code	Approach
0	None
1	Rain Detector
2	Snow Detector
3	Visibility Sensor
4	Pavement Temperature Sensor
5	Other

Table B-3: Emergency Detection Code: Weather.

Code	Approach
0	None
1	Inspection
2	Ice Detector
3	Other

Table B-4: Emergency Detection Code: Road Surface.

Code	Approach
0	None
1	Error Detecting Code
2	Communication Protocols
3	Detection Filter using Residuals
4	Voting Scheme
5	Other

Table B-5: Emergency Detection Code: Communication Loss.

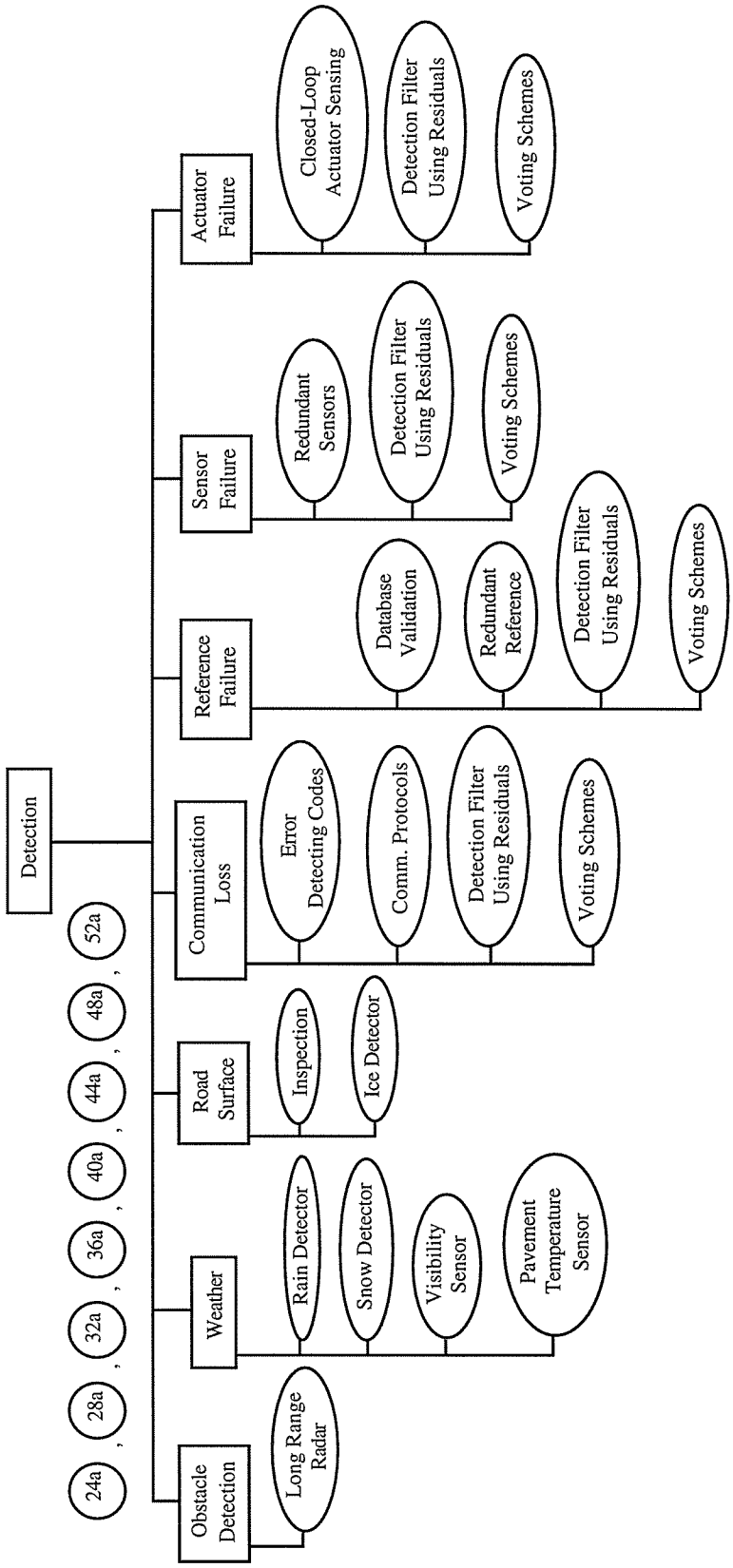

Figure B-11: Emergency Detection for All Lateral Forms.

Code	Approach
0	None
1	Database Validation
2	Redundant Reference
3	Detection Filter using Residuals
4	Voting Scheme
5	Other

Table B-6: Emergency Detection Code: Reference Failure.

Code	Approach
0	None
1	Redundant Sensors
2	Detection Filter using Residuals
3	Voting Scheme
4	Other

Table B-7: Emergency Detection Code: Sensor Failure.

Code	Approach
0	None
1	Closed-Loop Actuator Sensing
2	Detection Filter using Residuals
3	Voting Scheme
4	Other

Table B-8: Emergency Detection Code: Actuator Failure.

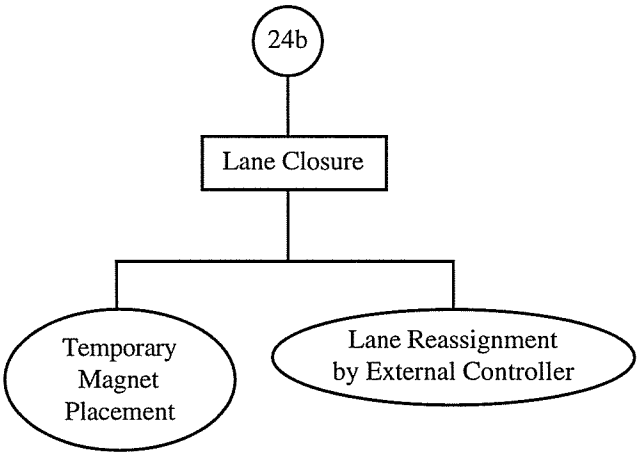

Figure B-12: Lane Closure for Discrete Magnetic Lateral Control.

Code	Approach
0	None
1	Temporary Magnet Placement
2	Lane Reassignment by External Controller
3	Other

Table B-9: Lane Closure Code: Discrete Magnetic Lateral Control.

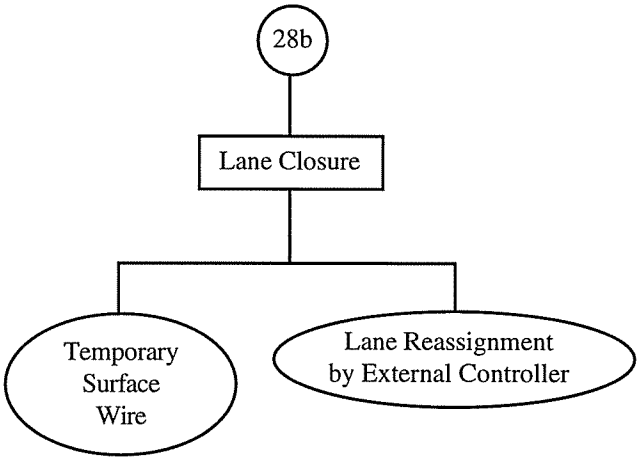

Figure B-13: Lane Closure for Wire Follower Lateral Control.

Code	Approach
0	None
1	Temporary Surface Wire
2	Lane Reassignment by External Controller
3	Other

Table B-10: Lane Closure Code: Wire Follower Lateral Control.

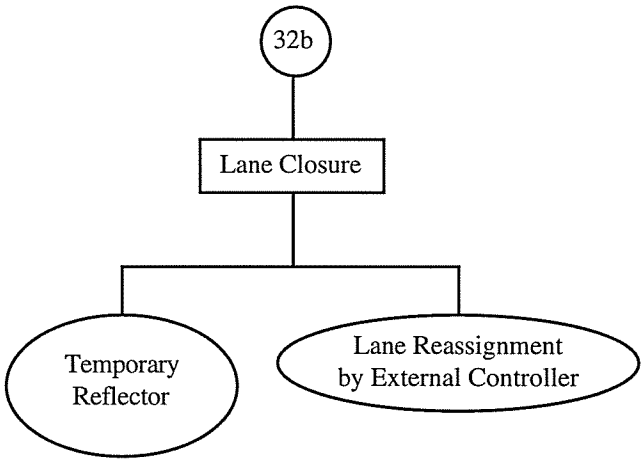

Figure B-14: Lane Closure for Discrete Optical Lateral Control.

Code	Approach
0	None
1	Temporary Reflector Placement
2	Lane Reassignment by External Controller
3	Other

Table B-11: Lane Closure Code: Discrete Optical Lateral Control.

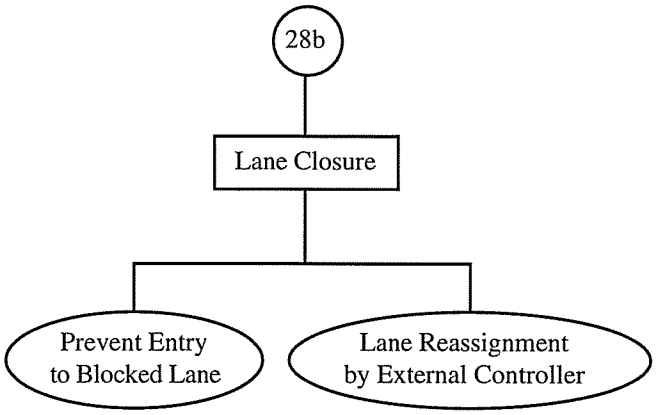

Figure B-15: Lane Closure for Guideway Lateral Control.

Code	Approach
0	None
1	Upstream Entry Prevention
2	Lane Reassignment by External Controller
3	Other

Table B-12: Lane Closure Code: Guideway Lateral Control.

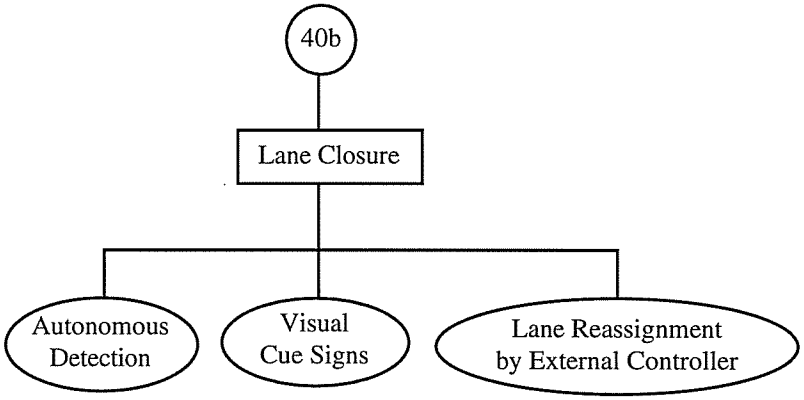

Figure B-16: Lane Closure for Vision System Lateral Control.

Code	Approach
0	None
1	Autonomous Visual Detection
2	Visual Cue Signs
3	Lane Reassignment by External Controller
4	Other

Table B-13: Lane Closure Code: Vision System Lateral Control.

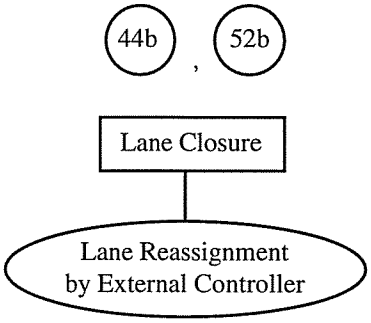

Figure B-17: Lane Closure for Dead Reckoning and Discrete Radar Lateral Control.

Code	Approach
0	None
1	Lane Reassignment by External Controller
2	Other

Table B-14: Lane Closure Code: Dead Reckoning and Discrete Radar Lateral Control.

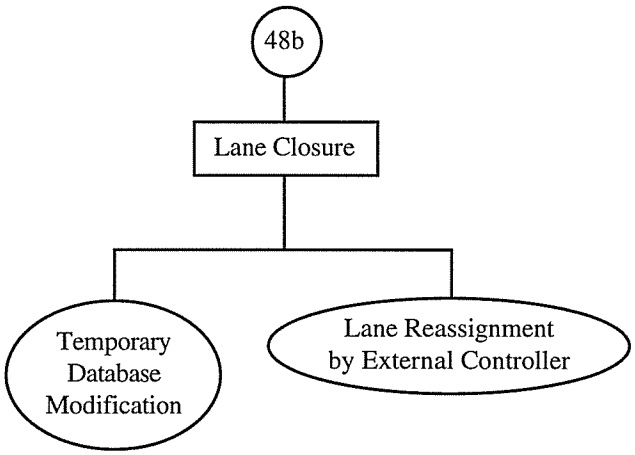

Figure B-18: Lane Closure for GPS Lateral Control.

Code	Approach
0	None
1	Temporary Database Modification
2	Lane Reassignment by External Controller
3	Other

Table B-15: Lane Closure Code: GPS Lateral Control.

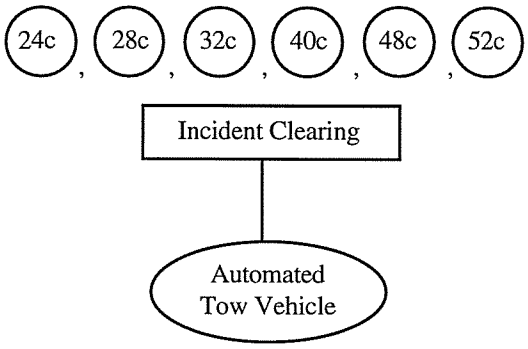

Figure B-19: Incident Clearing for All Lateral Control Forms Except Dead Reckoning and Guideway.

Code	Approach
0	None
1	Automated Tow Vehicle
2	Other

Table B-16: Incident Clearing Code: All Lateral Control Forms Except Dead Reckoning and Guideway.

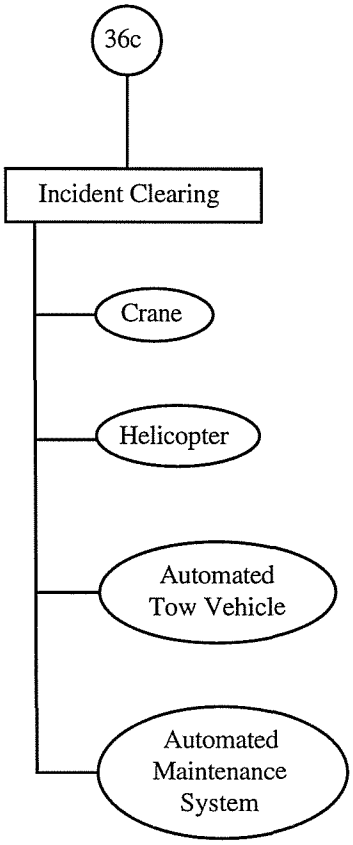

Figure B-20: Incident Clearing for Guideway Lateral Control.

Code	Approach
0	None
1	Crane
2	Helicopter
3	Automated Tow Vehicle
4	Automated Maintenance System
5	Other

Table B-17: Incident Clearing Code: Guideway Lateral Control.

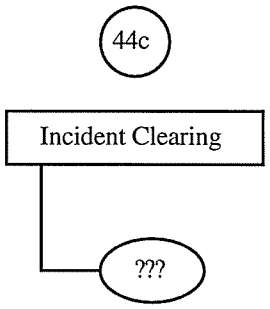

Figure B-21: Incident Clearing for Dead Reckoning Lateral Control.

Code	Approach
0	None
1	Unknown
2	Other

Table B-18: Incident Clearing Code: Dead Reckoning Lateral Control.

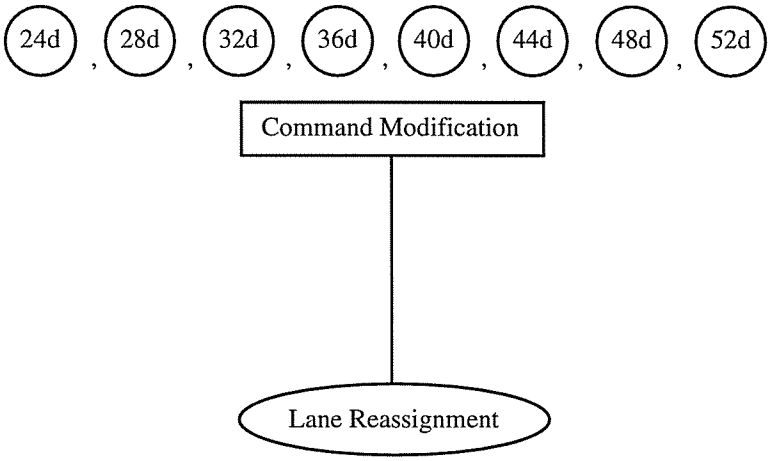

Figure B-22: Command Modification for All Forms of Lateral Control.

Code	Approach
0	None
1	Lane Reassignment
2	Other

Table B-19: Command Modification Code: All Forms of Lateral Control.

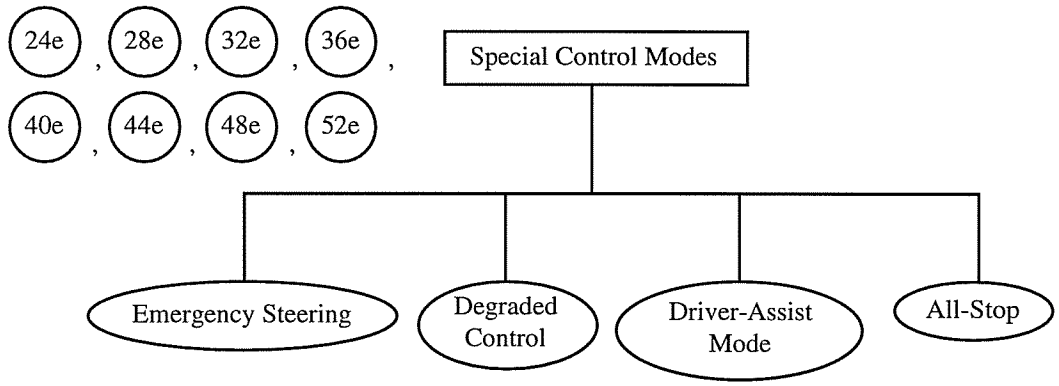

Figure B-23: Special Control Modes for All Forms of Lateral Control.

Code	Approach
0	None
1	Emergency Steering
2	Degraded Control
3	Driver-Assist Mode
4	All-Stop
5	Other

Table B-20: Special Control Mode Code: All Forms of Lateral Control.

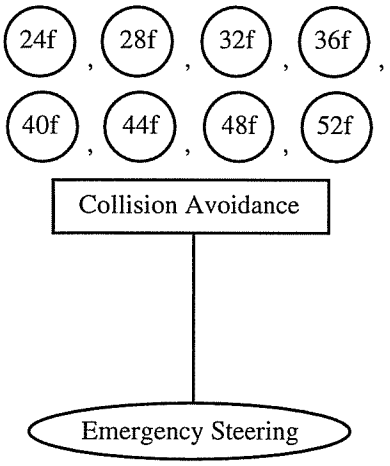

Figure B-24: Collision Avoidance for All Forms of Lateral Control.

Code	Approach
0	None
1	Emergency Steering
2	Other

Table B-21: Collision Avoidance Code: All Forms of Lateral Control.

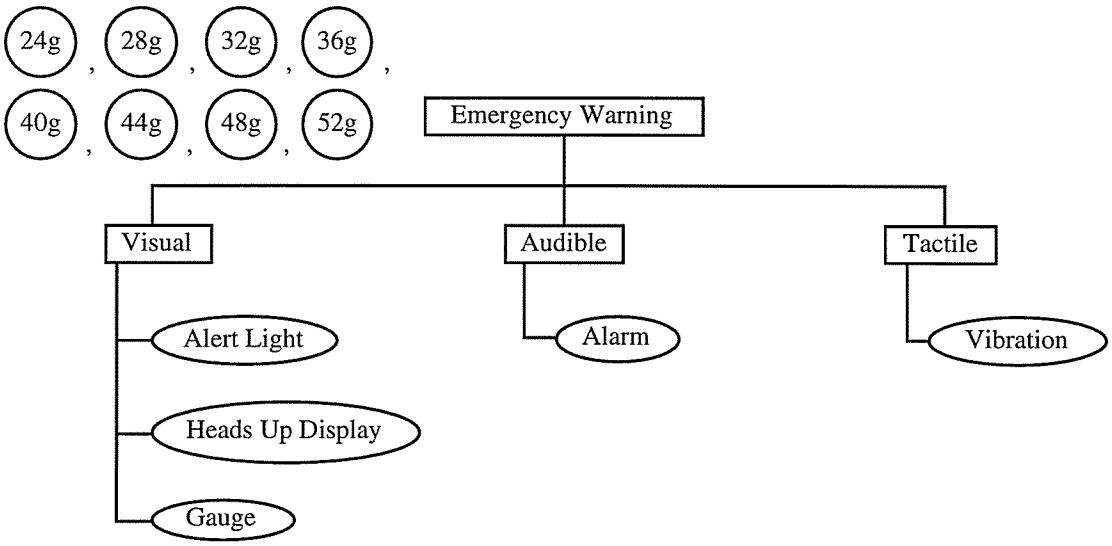

Figure B-25: Emergency Warning for All Forms of Lateral Control.

Code	Approach
0	None
1	Alert Light
2	Heads-Up Display
3	Gauge
4	Other

Table B-22: Visual Emergency Warning Code: All Forms of Lateral Control.

Code	Approach
0	None
1	Alarm
2	Other

Table B-23: Audible Emergency Warning Code: All Forms of Lateral Control.

Code	Approach
0	None
1	Vibration
2	Other

Table B-24: Tactile Emergency Warning Code: All Forms of Lateral Control.

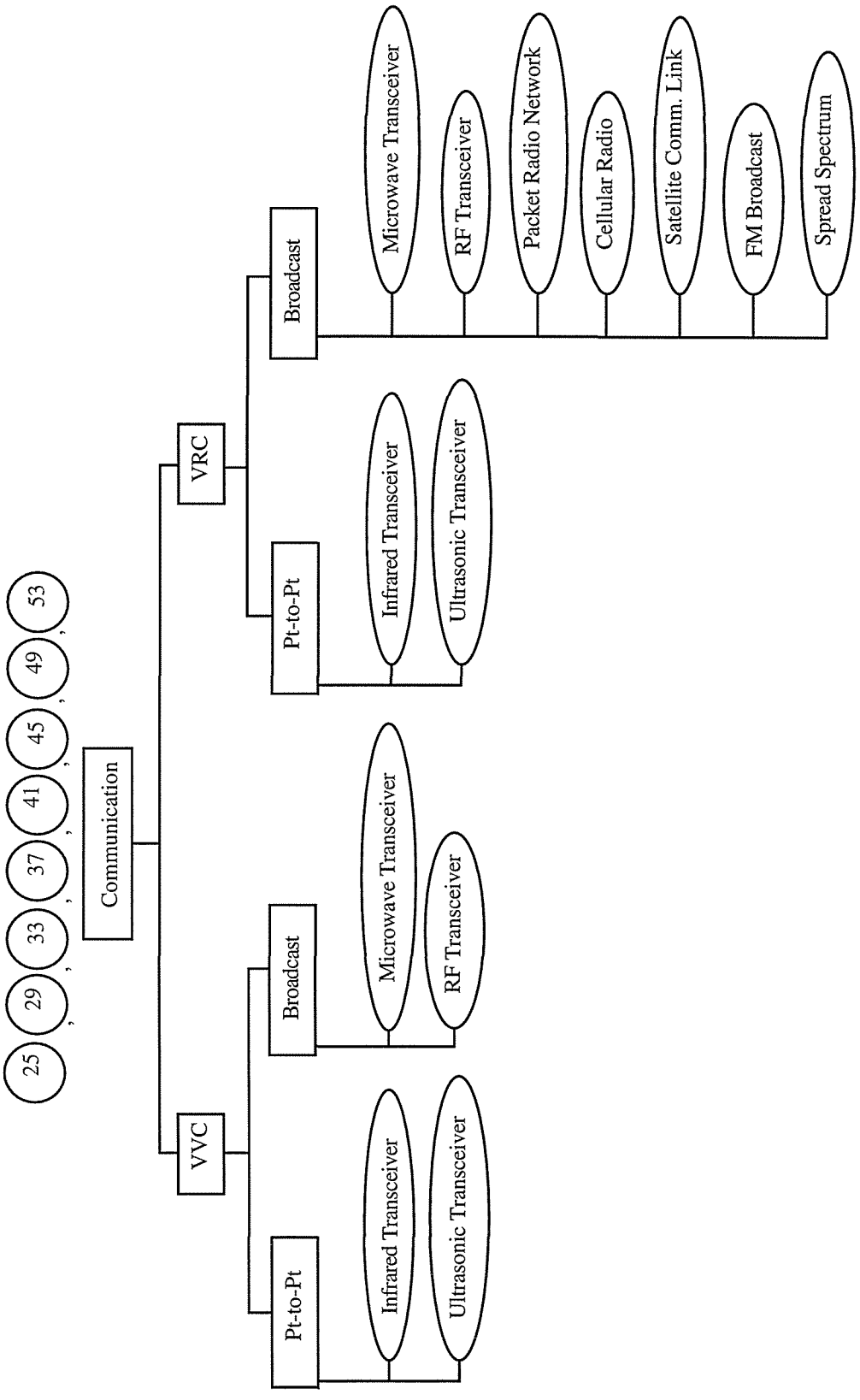

Figure B-26: Communications for All Forms of Lateral Control.

Code	Item
0	None
1	Infrared Transceiver
2	Ultrasonic Transceiver
3	Other

Table B-25: Lateral Control Vehicle-to-Vehicle Communication Code: Point-to-Point.

Code	Item
0	None
1	Microwave Transceiver
2	Radio Frequency Transceiver
3	Other

Table B-26: Lateral Control Vehicle-to-Vehicle Communication Code: Broadcast.

Code	Item
0	None
1	Infrared Transceiver
2	Ultrasonic Transceiver
3	Other

Table B-27: Lateral Control Vehicle-to-Roadside Communication Code: Point-to-Point.

Code	Item
0	None
1	Microwave Transceiver
2	Radio Frequency Transceiver
3	Packet Radio Network
4	Cellular Radio
5	Satellite Communication Link
6	FM Broadcast
7	Spread Spectrum Technology
8	Other

Table B-28: Lateral Control Vehicle-to-Roadside Communication Code: Broadcast.

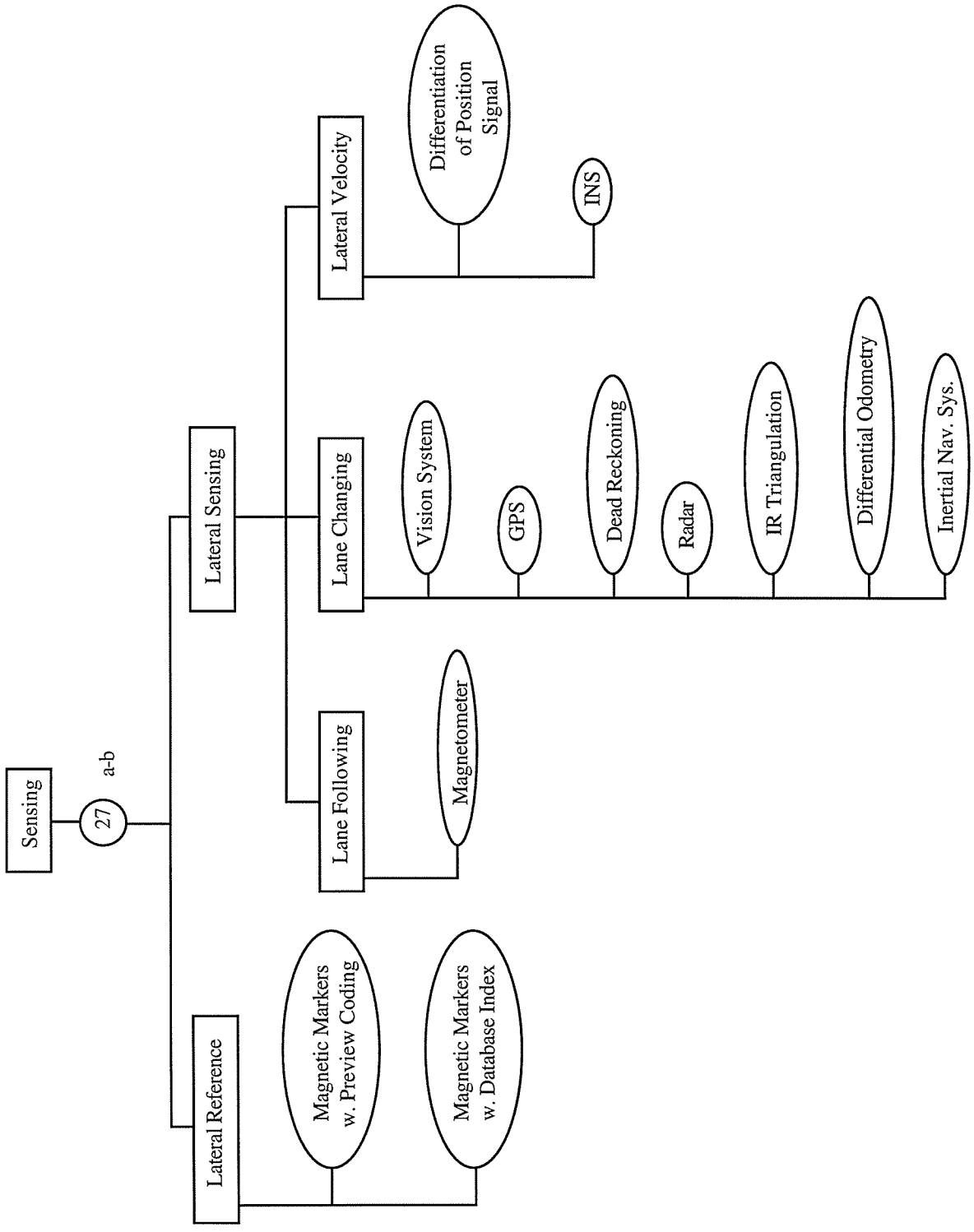

Figure B-27: Lateral Sensing for Discrete Magnetic Lateral Control.

Code	Item
0	None
1	Magnetic Marker w. Preview Coding
2	Magnetic Marker w. Database Reference
3	Other

Table B-29: Lateral Reference Code: Discrete Magnetic Control.

Code	Item
0	None
1	Magnetometer
2	Other

Table B-30: Lateral Lane Following Sensor Code: Discrete Magnetic Control.

Code	Item
0	None
1	Vision System
2	GPS
3	Dead Reckoning
4	Radar
5	Infrared Triangulation
6	Differential Odometry
7	Inertial Navigation System
8	Other

Table B-31: Lateral Lane Changing Sensor Code: All Forms of Lateral Control.

Code	Item
0	None
1	Differentiation of Position Signal
2	Inertial Navigation System
3	Other

Table B-32: Lateral Velocity Sensor Code: Discrete Magnetic Control.

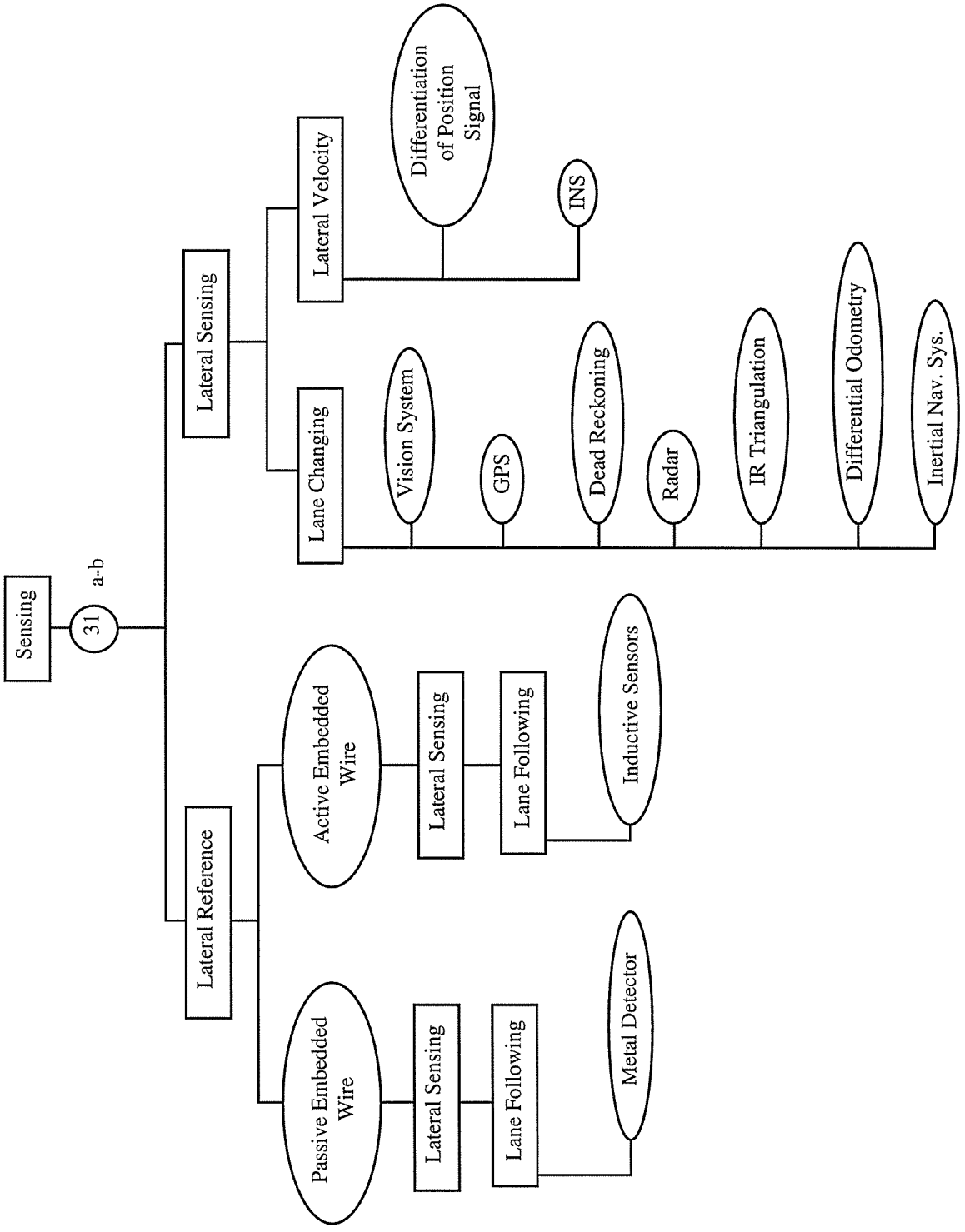

Figure B-28: Lateral Sensing for Wire Follower Lateral Control.

Code	Item
0	None
1	Active Embedded Wire
2	Passive Embedded Wire
3	Other

Table B-33: Lateral Reference Code: Wire Follower Control.

Code	Item
0	None
1	Metal Detector
2	Other

Table B-34: Lateral Lane Following Sensor Code: Passive Wire Follower Control.

Code	Item
0	None
1	Inductive Sensor
2	Other

Table B-35: Lateral Lane Following Sensor Code: Active Wire Follower Control.

Code	Item
0	None
1	Differentiation of Position Signal
2	Inertial Navigation System
3	Other

Table B-36: Lateral Velocity Sensor Code: Wire Follower Control.

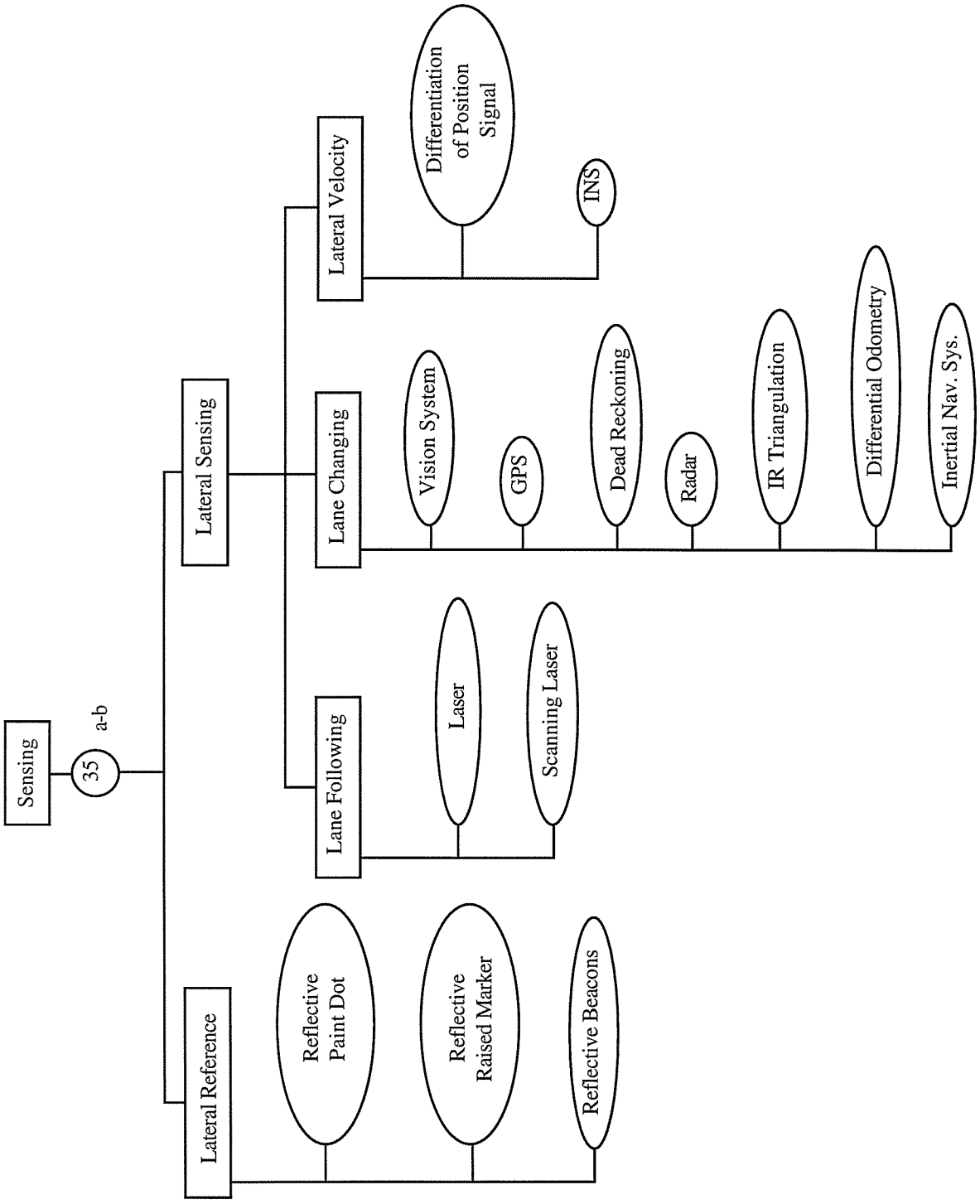

Figure B-29: Lateral Sensing for Discrete Optical Lateral Control.

Code	Item
0	None
1	Reflective Paint Dots
2	Reflective Raised Markers
3	Reflective Beacons
4	Other

Table B-37: Lateral Reference Code: Discrete Optical Control.

Code	Item
0	None
1	Laser Array
2	Scanning Laser
3	Other

Table B-38: Lateral Lane Following Sensor Code: Discrete Optical Control.

Code	Item
0	None
1	Differentiation of Position Signal
2	Inertial Navigation System
3	Other

Table B-39: Lateral Velocity Sensor Code: Discrete Optical Control.

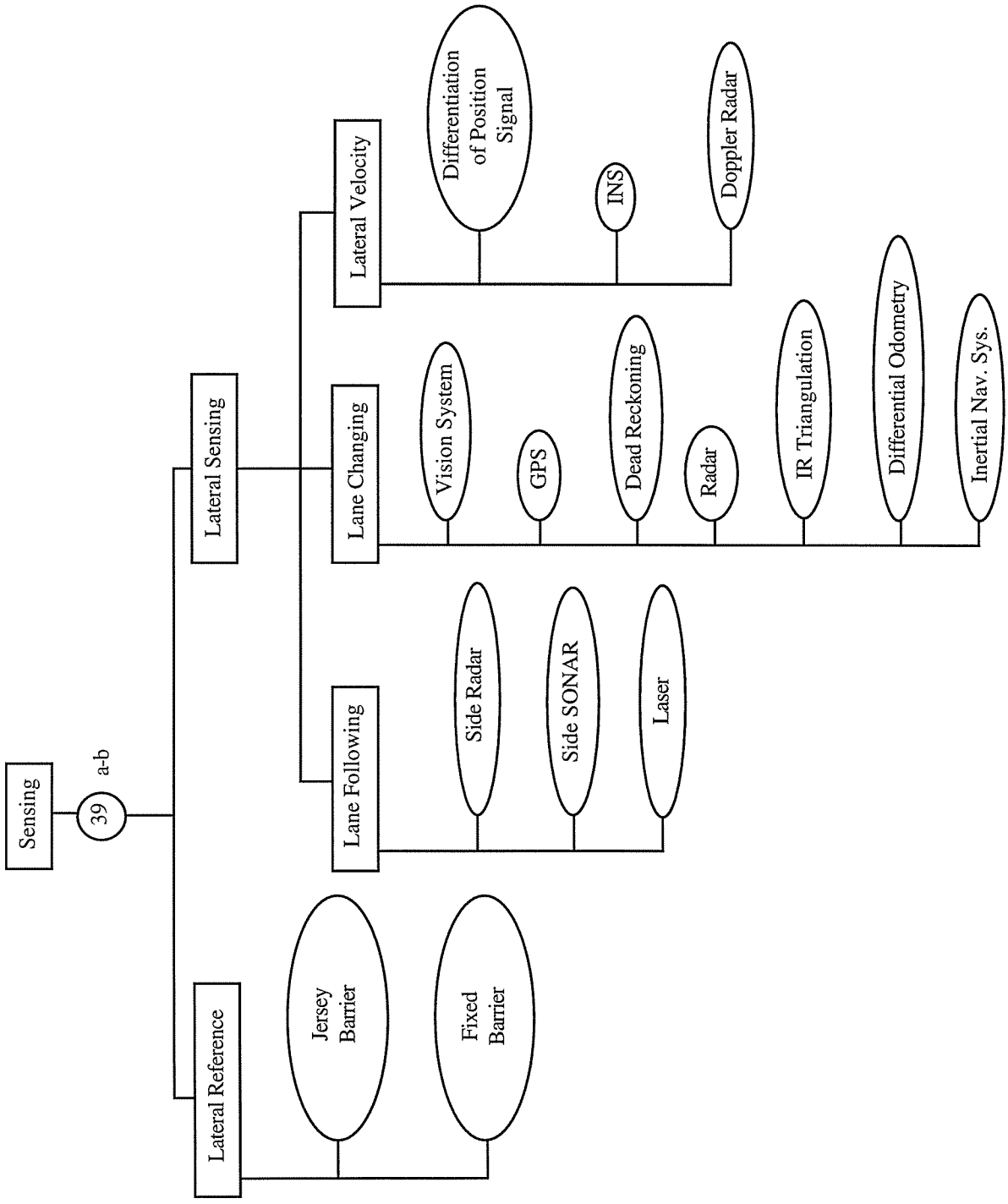

Figure B-30: Lateral Sensing for Guideway Lateral Control.

Code	Item
0	None
1	Jersey Barrier
2	Fixed Barrier
3	Other

Table B-40: Lateral Reference Code: Guideway Control.

Code	Item
0	None
1	Side Radar
2	Side SONAR
3	Laser
4	Other

Table B-41: Lateral Lane Following Sensor Code: Guideway Control.

Code	Item
0	None
1	Differentiation of Position Signal
2	Inertial Navigation System
3	Doppler Radar
4	Other

Table B-42: Lateral Velocity Sensor Code: Guideway Control.

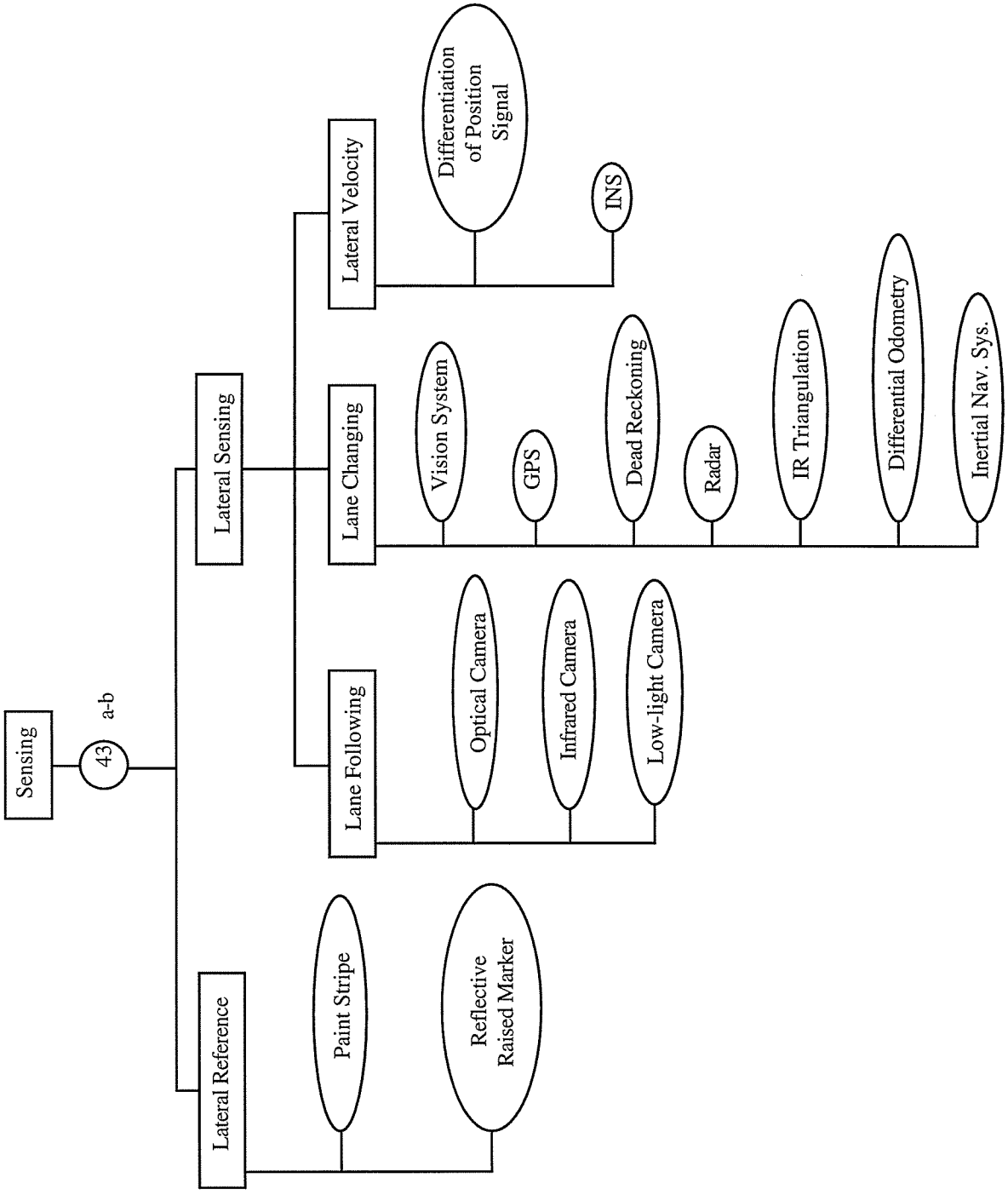

Figure B-31: Lateral Sensing for Vision System Lateral Control.

Code	Item
0	None
1	Paint Stripe
2	Reflective Raised Marker
3	Other

Table B-43: Lateral Reference Code: Vision System Control.

Code	Item
0	None
1	Optical Camera
2	Infrared Camera
3	Low-light Camera
4	Other

Table B-44: Lateral Lane Following Sensor Code: Vision System Control.

Code	Item
0	None
1	Differentiation of Position Signal
2	Inertial Navigation System
3	Other

Table B-45: Lateral Velocity Sensor Code: Vision System Control.

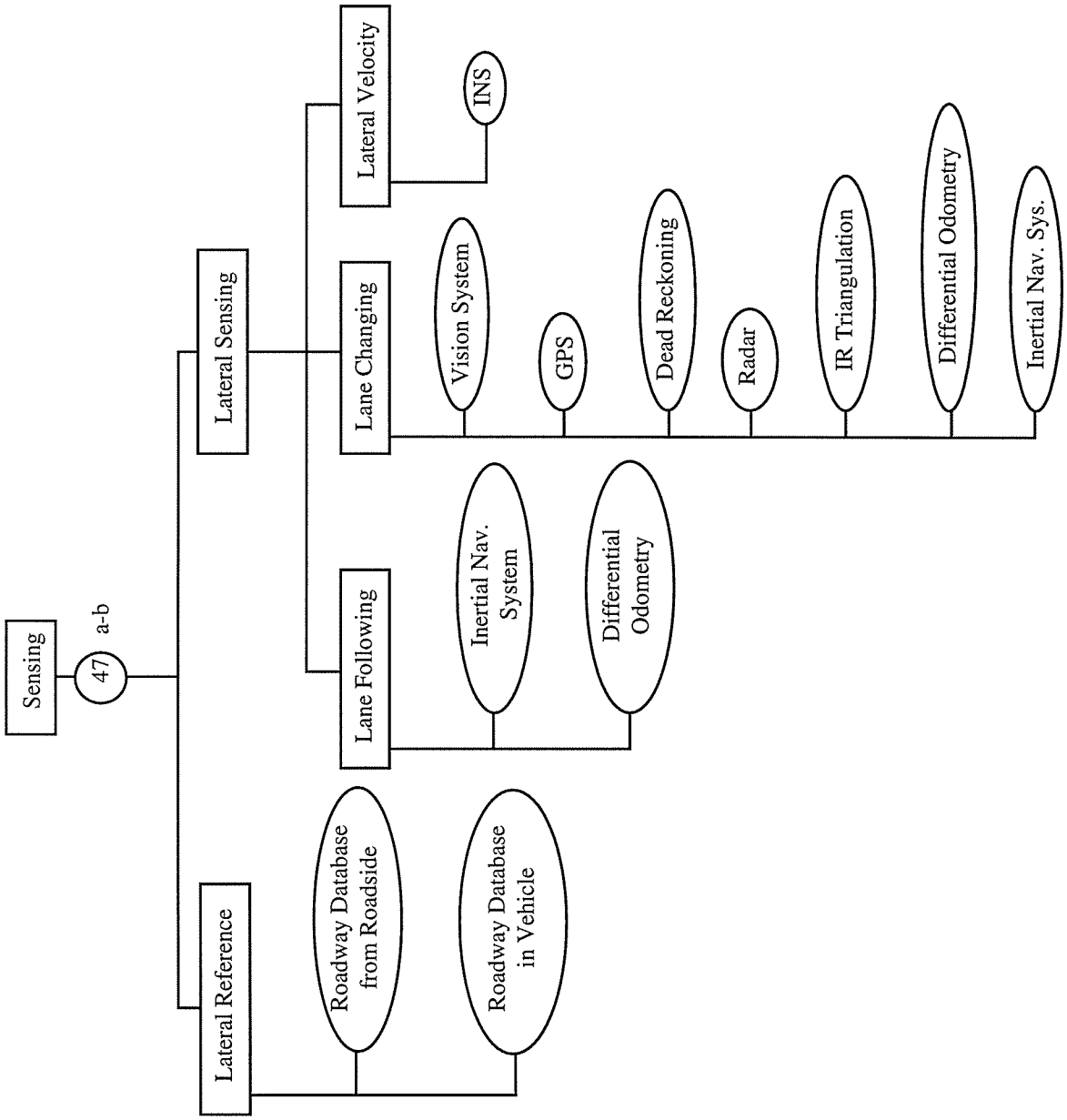

Figure B-32: Lateral Sensing for Dead Reckoning Lateral Control.

Code	Item
0	None
1	Roadway Database from Roadside
2	Roadway Database in Vehicle
3	Other

Table B-46: Lateral Reference Code: Dead Reckoning Control.

Code	Item
0	None
1	Inertial Navigation System
2	Differential Odometry
3	Other

Table B-47: Lateral Lane Following Sensor Code: Dead Reckoning Control.

Code	Item
0	None
1	Inertial Navigation System
2	Other

Table B-48: Lateral Velocity Sensor Code: Dead Reckoning Control.

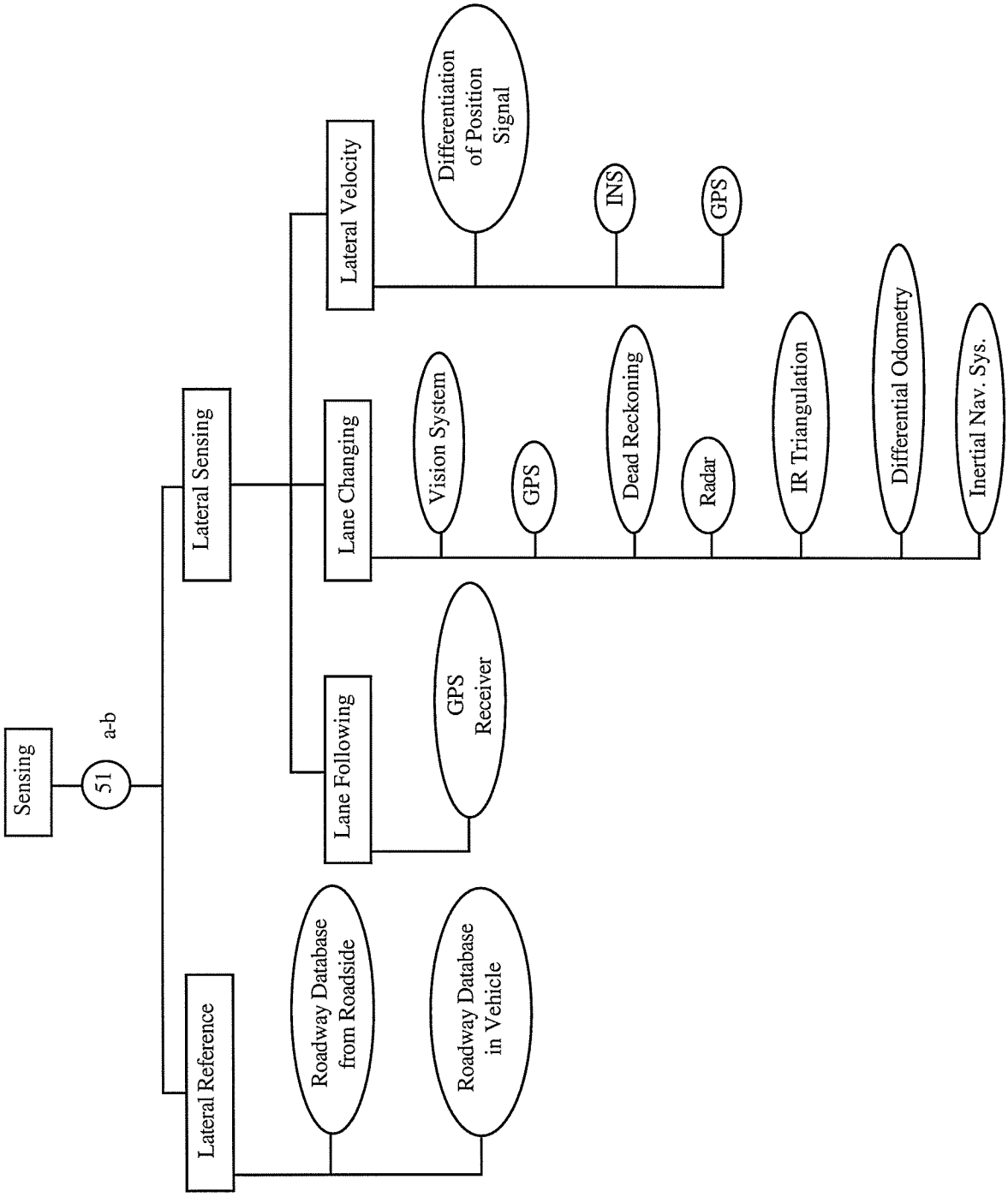

Figure B-33: Lateral Sensing for GPS Lateral Control.

Code	Item
0	None
1	Roadway Database from Roadside
2	Roadway Database in Vehicle
3	Other

Table B-49: Lateral Reference Code: GPS Control.

Code	Item
0	None
1	GPS Receiver
2	Other

Table B-50: Lateral Lane Following Sensor Code: GPS Control.

Code	Item
0	None
1	Differentiation of Position Signal
2	Inertial Navigation System
3	GPS
4	Other

Table B-51: Lateral Velocity Sensor Code: GPS Control.

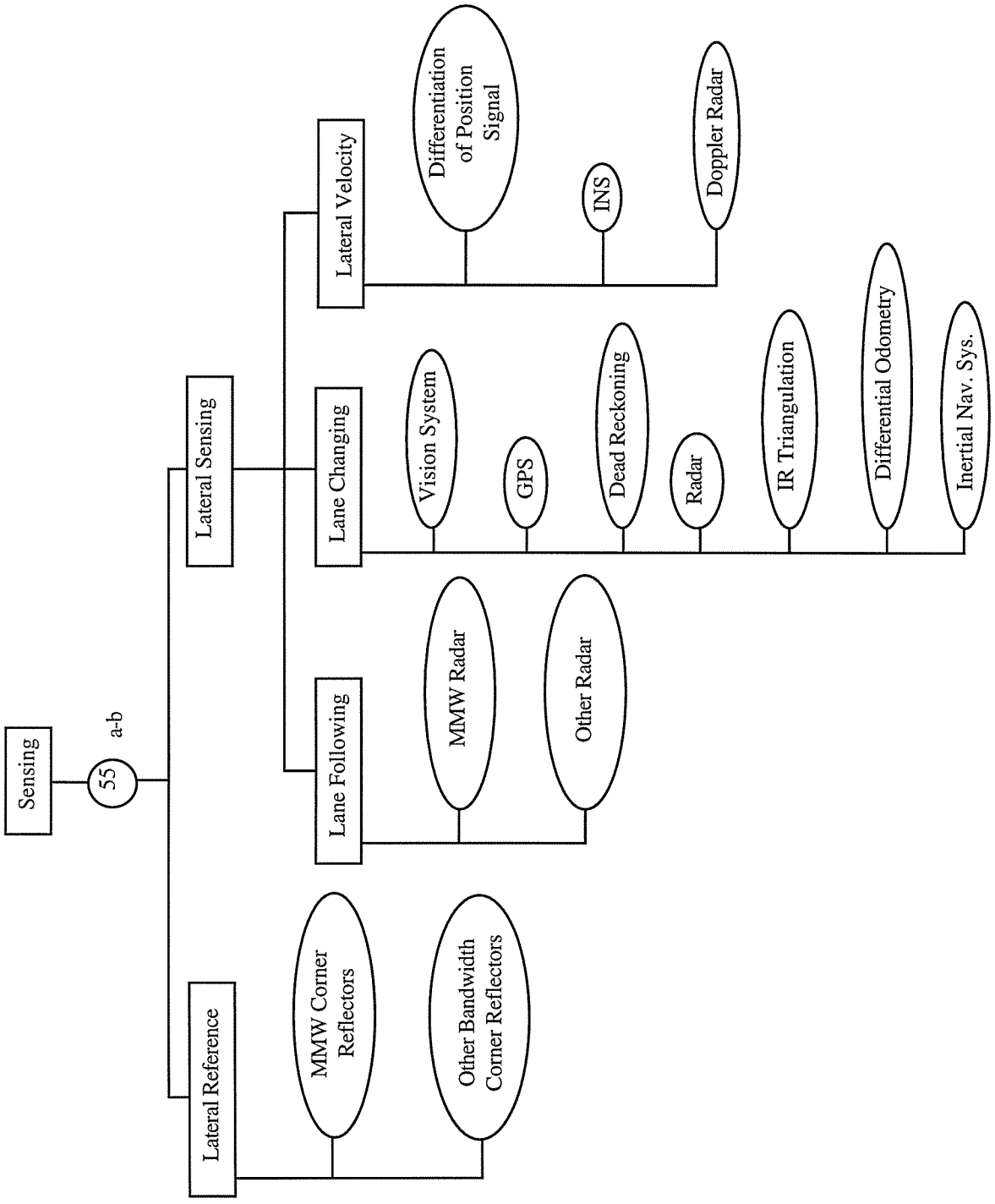

Figure B-34: Lateral Sensing for Discrete Radar Lateral Control.

Code	Item
0	None
1	Millimeter Wave (MMW) Corner Reflectors
2	Other Bandwidth Corner Reflectors
3	Other

Table B-52: Lateral Reference Code: Discrete Radar Control.

Code	Item
0	None
1	MMW Radar
2	Other Radar
3	Other

Table B-53: Lateral Lane Following Sensor Code: Discrete Radar Control.

Code	Item
0	None
1	Differentiation of Position Signal
2	Inertial Navigation System
3	Doppler Radar
4	Other

Table B-54: Lateral Velocity Sensor Code: Discrete Radar Control.

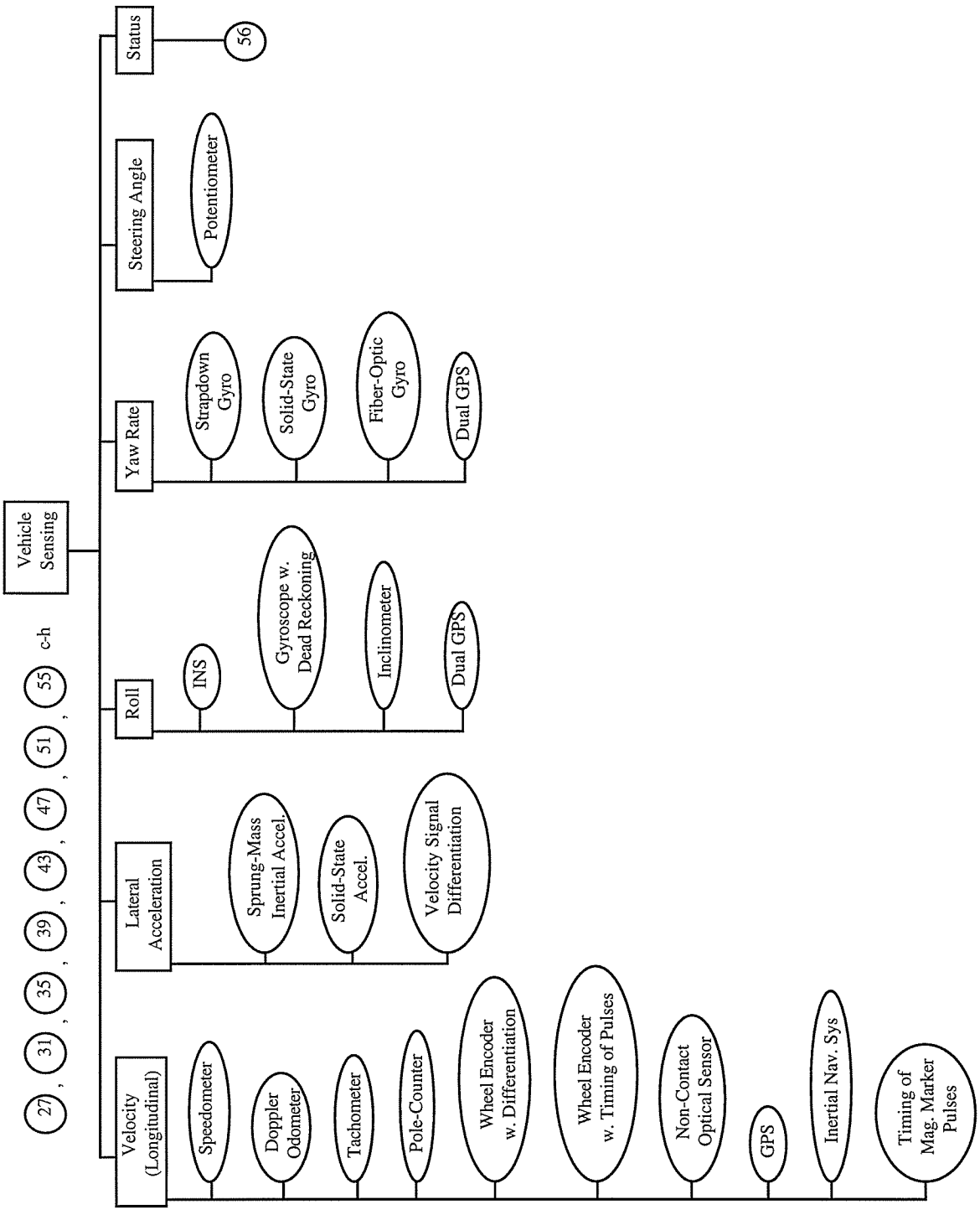

Figure B-35: Vehicle Sensing for All Forms of Lateral Control.

Code	Item
00	None
01	Speedometer
02	Doppler Odometer
03	Tachometer
04	Pole Counter
05	Wheel Encoder w. Differentiation
06	Wheel Encoder w. Timing of Pulses
07	Non-Contact Optical Sensor
08	GPS
09	Inertial Navigation System
10	Timing of Discrete Mag. Marker Pulses
11	Other

Table B-55: Lateral Control Vehicle Sensing: Longitudinal Velocity.

Code	Item
0	None
1	Sprung-Mass Inertial Accelerometer
2	Solid-State Accelerometer
3	Velocity Signal Differentiation
4	Other

Table B-56: Lateral Control Vehicle Sensing: Lateral Acceleration.

Code	Item
0	None
1	Inertial Navigation System
2	Gyroscope
3	Inclinometer
4	Dual GPS
5	Other

Table B-57: Lateral Control Vehicle Sensing: Roll.

Code	Item
0	None
1	Strapdown Gyroscope
2	Solid-State Gyroscope
3	Fiber-Optic Gyroscope
4	Dual GPS
5	Other

Table B-58: Lateral Control Vehicle Sensing: Yaw Rate.

Code	Item
0	None
1	Potentiometer
2	Other

Table B-59: Lateral Control Vehicle Sensing: Steering Angle.

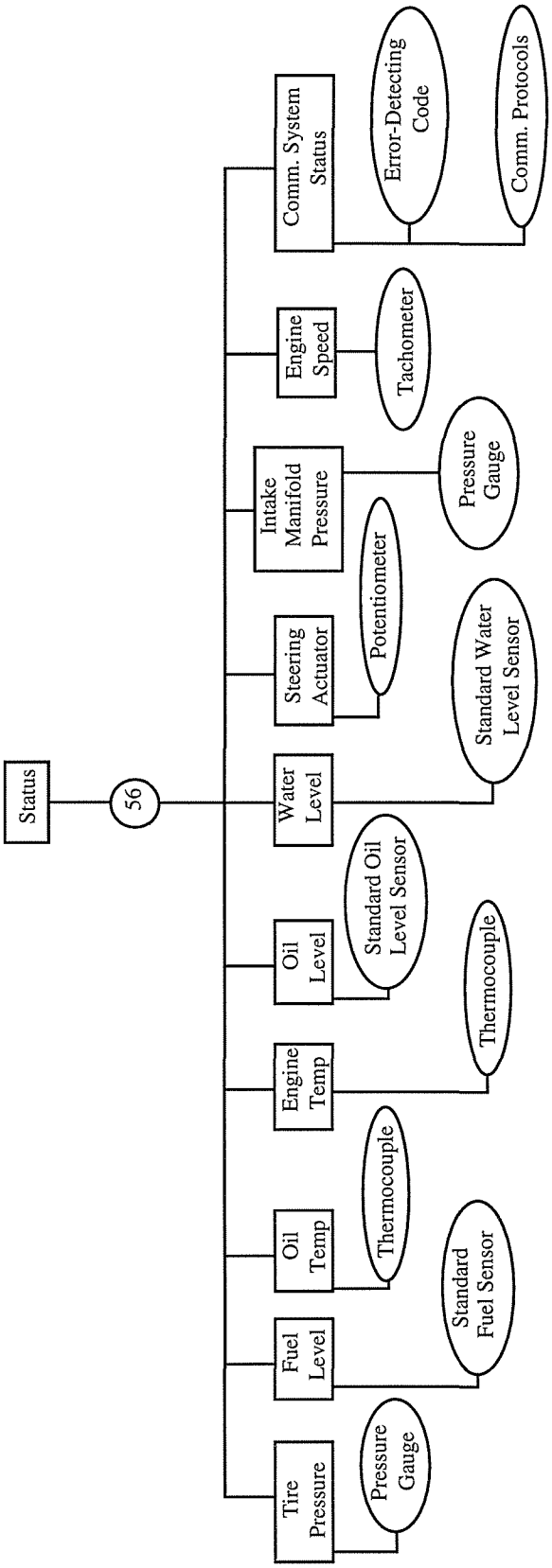

Figure B-36: Status Sensing for All Forms of Lateral Control.

Code	Item
0	None
1	Pressure Sensor
2	Other

Table B-60: Lateral Control Status Sensing: Tire Pressure.

Code	Item
0	None
1	Standard Fuel Sensor
2	Other

Table B-61: Lateral Control Status Sensing: Fuel Level.

Code	Item
0	None
1	Thermocouple
2	Other

Table B-62: Lateral Control Status Sensing: Oil Temperature.

Code	Item
0	None
1	Thermocouple
2	Other

Table B-63: Lateral Control Status Sensing: Engine Temperature.

Code	Item
0	None
1	Standard Oil Level Sensor
2	Other

Table B-64: Lateral Control Status Sensing: Oil Level.

Code	Item
0	None
1	Standard Water Level Sensor
2	Other

Table B-65: Lateral Control Status Sensing: Water Level.

Code	Item
0	None
1	Potentiometer
2	Other

Table B-66: Lateral Control Status Sensing: Steering Actuator.

Code	Item
0	None
1	Pressure Sensor
2	Other

Table B-67: Lateral Control Status Sensing: Intake Manifold Pressure.

Code	Item
0	None
1	Tachometer
2	Other

Table B-68: Lateral Control Status Sensing: Engine Speed.

Code	Item
0	None
1	Error-Detecting Code
2	Communication Protocols
3	Other

Table B-69: Lateral Control Status Sensing: Communication System.

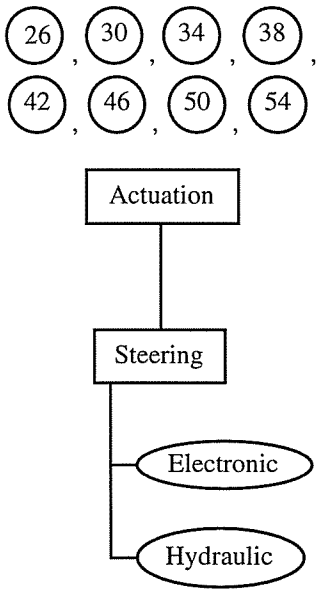

Figure B-37: Actuation for All Forms of Lateral Control.

Code	Item
0	None
1	Electronic Actuator
2	Hydraulic Actuator
3	Other

Table B-70: Lateral Control Steering Actuator Code: All Lateral Forms.

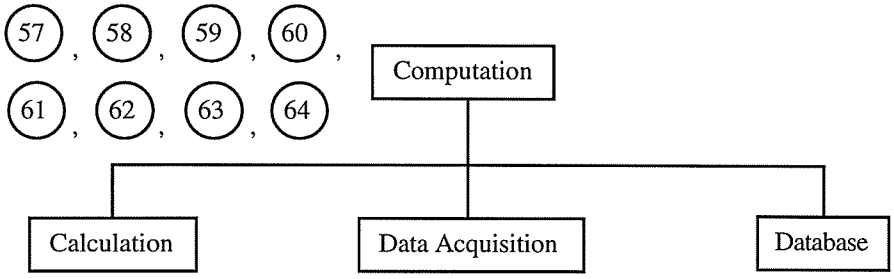

Figure B-38: Computation for All Forms of Lateral Control.

Code	Item
0	None
1	Calculation
2	Data Acquisition
3	Communication
4	Other

Table B-71: Lateral Control Computation Code: All Lateral Forms.

Appendix C: Vehicle / Road Interaction and Power Source

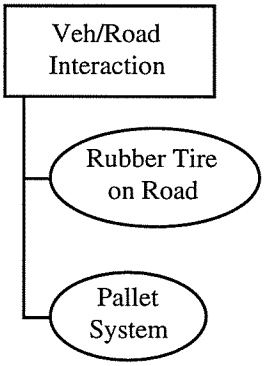

Figure C-1: Vehicle / Road Interaction.

Code	Approach
0	None
1	Rubber Tire on Road
2	Pallet System
3	Other

Table C-1: Vehicle / Road Interaction Code.

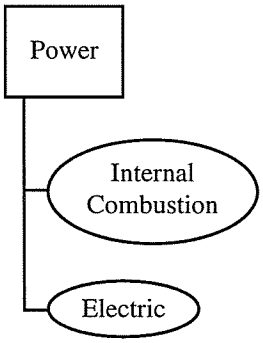

Figure C-2: Vehicle Power.

Code	Approach
0	None
1	Rubber Tire on Road
2	Pallet System
3	Other

Table C-2: Vehicle Power Code.

Appendix D: Structural Support

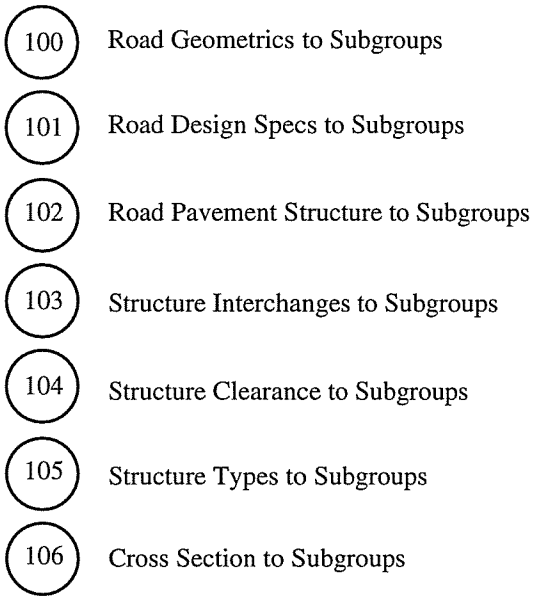

Figure D-1: Structural Support Connection List.

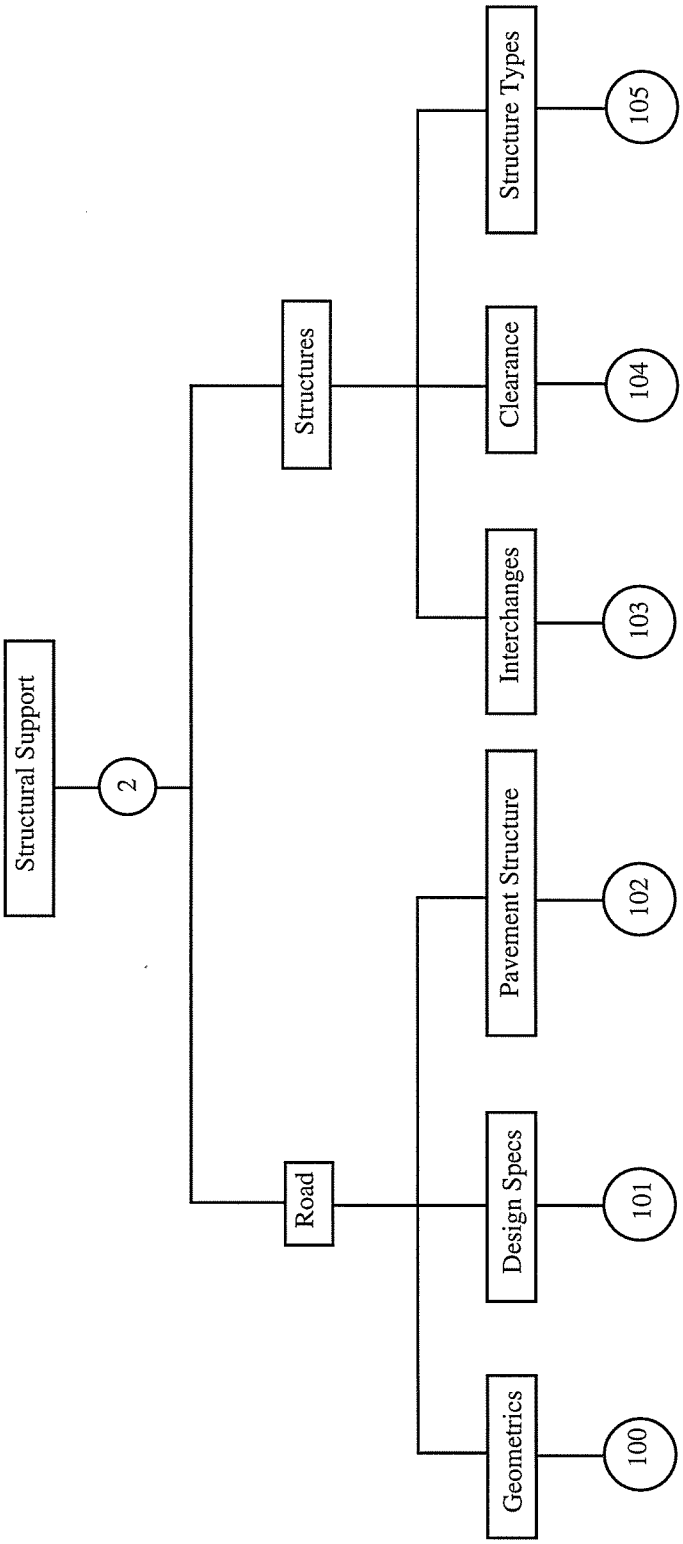

Figure D-2: Structural Support Overview.

Code	Distance (ft)
00	Unknown
01	< 125
02	125 - 150
03	151 - 200
04	201 - 250
05	251 - 300
06	301 - 360
07	361 - 430
08	431 - 500
09	501 - 580
10	581 - 660
11	661 - 750
12	751 - 840
13	841 - 930
14	> 930

Table D-1: Geometrics: Stopping Distance Code.

Code	Distance (ft)
00	Unknown
01	< 800
02	800 - 950
03	951 - 1100
04	1101 - 1300
05	1301 - 1500
06	1501 - 1650
07	1651 - 1800
08	1801 - 1950
09	1951 - 2100
10	2101 - 2300
11	2301 - 2500
12	2501 - 2600
13	2601 - 2700
14	> 2700

Table D-2: Geometrics: Passing Distance Code.

Code	Distance (ft)
0	Unknown
1	< 1000
2	1000 - 1100
3	1101 - 1200
4	> 1200

Table D-3: Geometrics: Decision Distance Code.

Code	Superelevation (feet/foot)
00	Unknown
01	Standard Crown
02	0.02
03	0.03
04	0.04
05	0.05
06	0.06
07	0.07
08	0.08
09	0.09
10	0.10
11	0.11
12	0.12
13	> 0.12

Table D-4: Geometrics: Superelevation Code.

Code	Form
0	Unknown
1	Curved
2	Straight

Table D-5: Geometrics: Curvature Form Code.

Code	Radius (ft)
0	Unknown
1	< 130
2	130 - 300
3	301 - 550
4	551 - 850
5	851 - 1150
6	1151 - 2100
7	2101 - 3900
8	> 3900

Table D-5: Geometrics: Curvature Form Code.

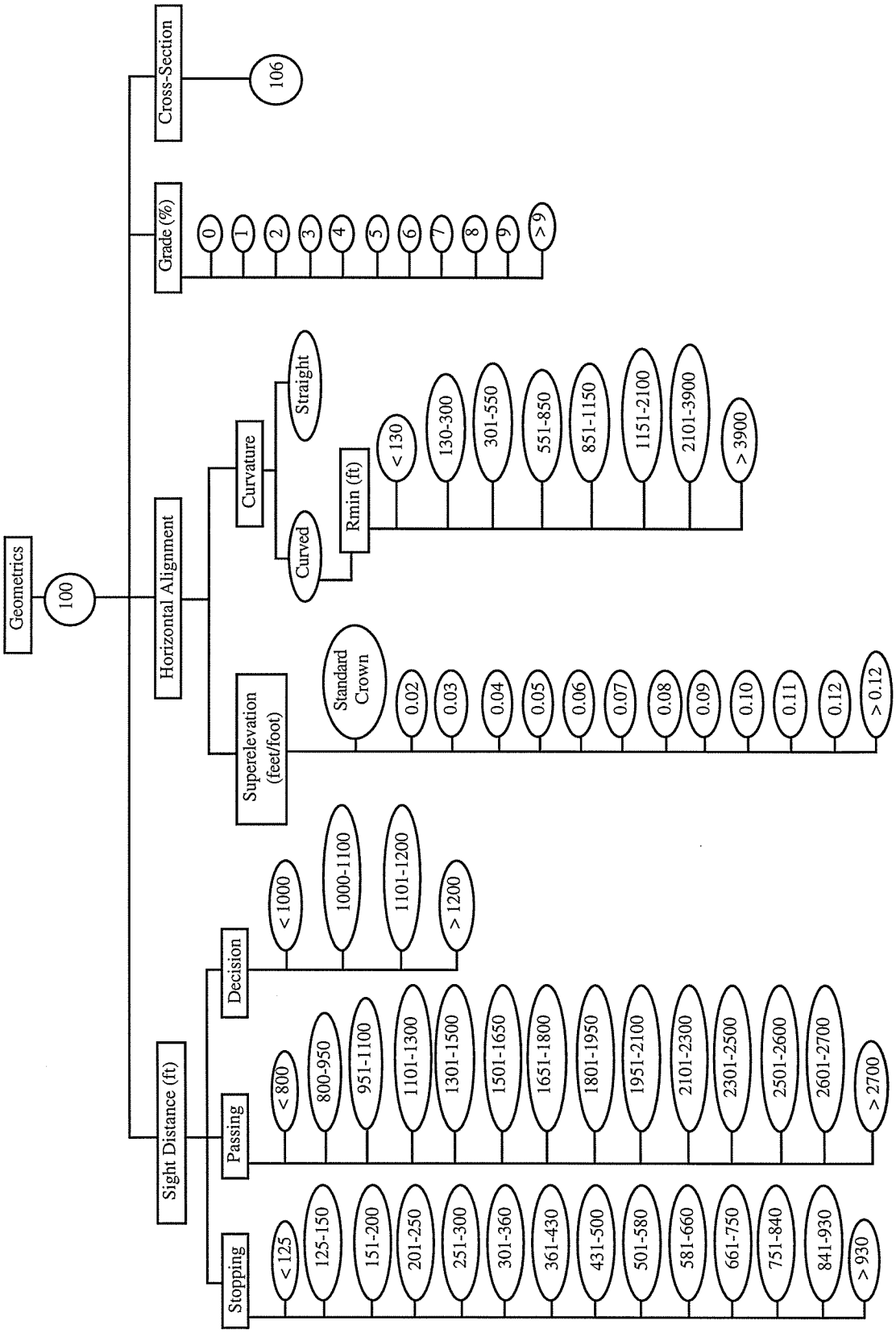

Figure D-3: Structural Support: Geometrics.

Code	Grade (%)
00	Unknown
01	0
02	1
03	2
04	3
05	4
06	5
07	6
08	7
09	8
10	9
11	> 9

Table D-6: Geometrics: Grade Code.

Code	Number of Lanes
0	Unknown
1	2
2	4
3	6
4	8
5	> 8
6	Other

Table D-7: Geometrics: Cross-Section: Directional Automated Lanes Code.

Code	Width (ft)
0	Unknown
1	< 6
2	6 - 8
3	8.1 - 10
4	10.1 - 12
5	> 12

Table D-8: Geometrics: Cross-Section: Automated Lane Width Code.

Code	Width (ft)
0	Unknown
1	< 2
2	2 - 4
3	4.1 - 6
4	6.1 - 8
5	8.1 - 10
6	> 10

Table D-9: Geometrics: Cross-Section: Left Shoulder Width Code.

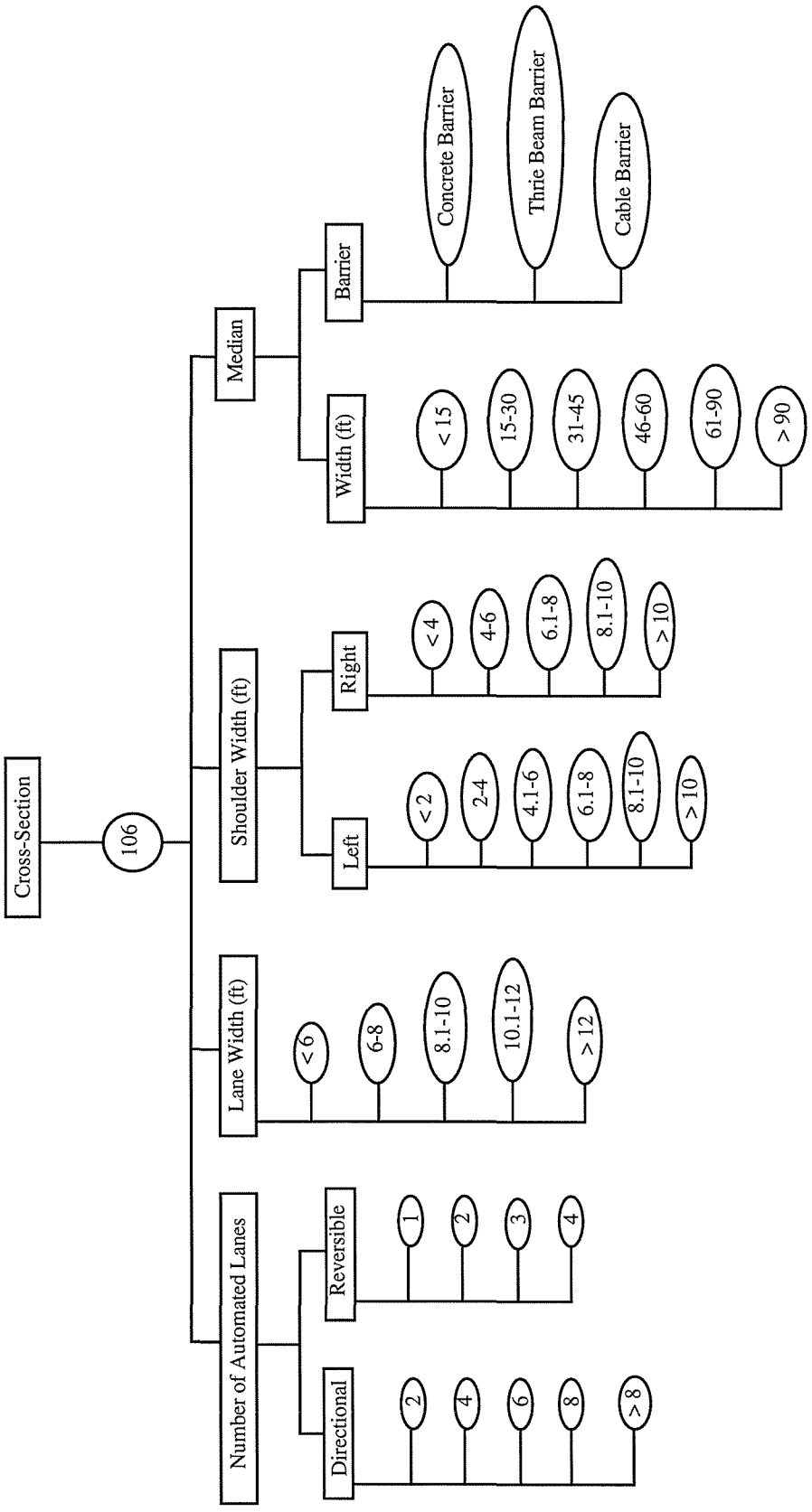

Figure D-4: Structural Support: Geometrics: Cross-Section.

Code	Width (ft)
0	Unknown
1	< 4
2	4 - 6
3	6.1 - 8
4	8.1 - 10
5	> 10

Table D-10: Geometrics: Cross-Section: Right Shoulder Width Code.

Code	Width (ft)
0	Unknown
1	< 15
2	15 - 30
3	31 - 45
4	46 - 60
5	61 - 90
6	> 90

Table D-11: Geometrics: Cross-Section: Median Width Code.

Code	Type
0	None
1	Concrete Barrier
2	Thrie Beam Barrier
3	Cable Barrier
4	Other

Table D-12: Geometrics: Cross-Section: Median Barrier Code.

Code	Design Speed (MPH)
0	Unknown
1	< 30
2	30 - 40
3	41 - 50
4	51 - 60
5	61 - 70
6	71 - 80
7	> 80

Table D-13: Design Specifications: Speed Code.

Code	Design Capacity (Veh/Lane/Hr)
0	Unknown
1	< 1000
2	1000 - 1200
3	1201 - 1800
4	1801 - 2400
5	2401 - 3000
6	3001 - 4000
7	4001 - 5000
8	5001 - 6000
9	> 6000

Table D-14: Design Specifications: Capacity Code.

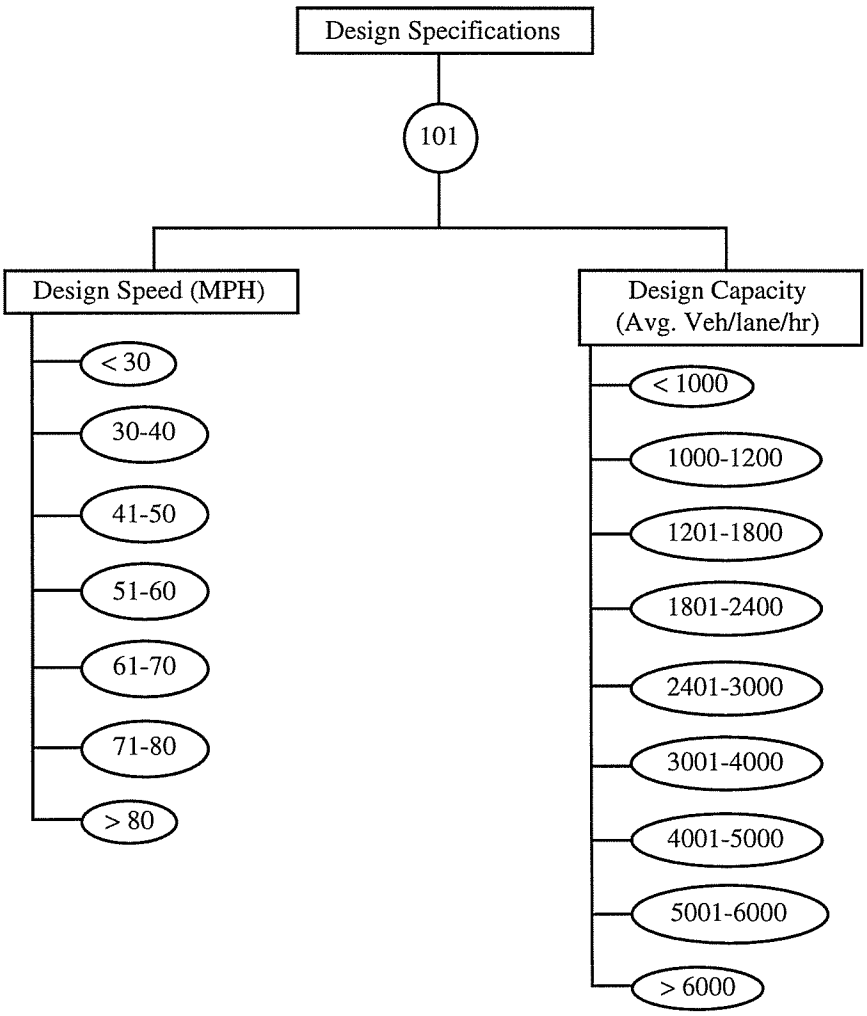

Figure D-5: Structural Support: Design Specifications.

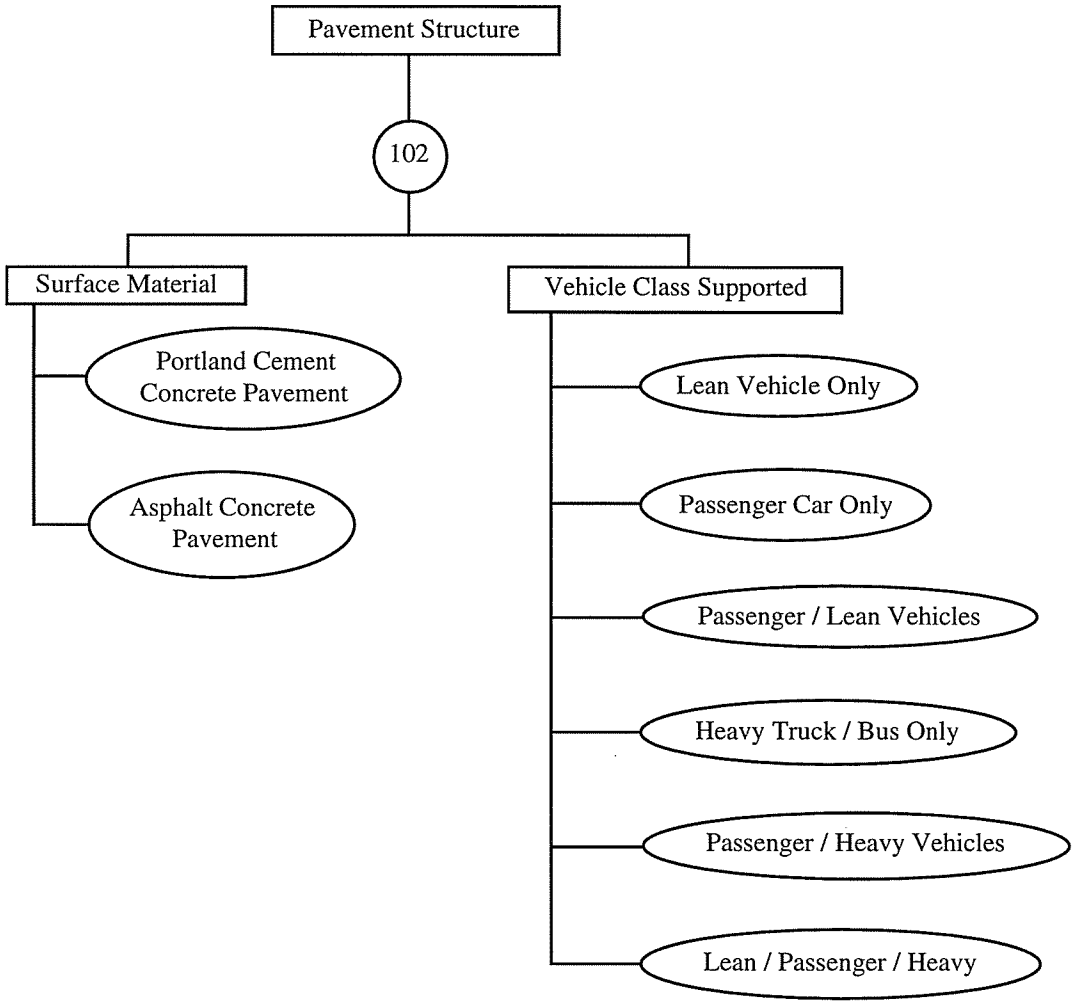

Figure D-6: Structural Support: Pavement Structure.

Code	Surface Material
0	Unknown
1	Portland Cement Concrete
2	Asphalt Concrete
3	Other

Table D-15: Pavement Structure: Surface Material Code.

Code	Vehicle Class
0	Unknown
1	Lean Vehicle Only
2	Passenger Car Only
3	Passenger Car and Lean Vehicles
4	Heavy Truck and Bus Only
5	Passenger Car and Heavy Vehicles
6	Lean / Passenger / Heavy Vehicles
7	Other

Table D-16: Pavement Structure: Vehicle Class Support Code.

Code	Type
00	None
01	Diamond
02	Split Diamond
03	Partial Cloverleaf
04	Cloverleaf
05	Cloverleaf with Collector-Distributor
06	Direct Connection
07	Trumpet
08	"T" Interchange
09	Scissor
10	Buttonhook
11	Left Side
12	Other

Table D-17: Interchanges: Interchange Type Code.

Code	Spacing (Miles)
0	Unknown
1	< 0.5
2	0.5 - 1
3	1.1 - 2
4	2.1 - 5
5	> 5

Table D-18: Interchanges: Interchange Spacing Code.

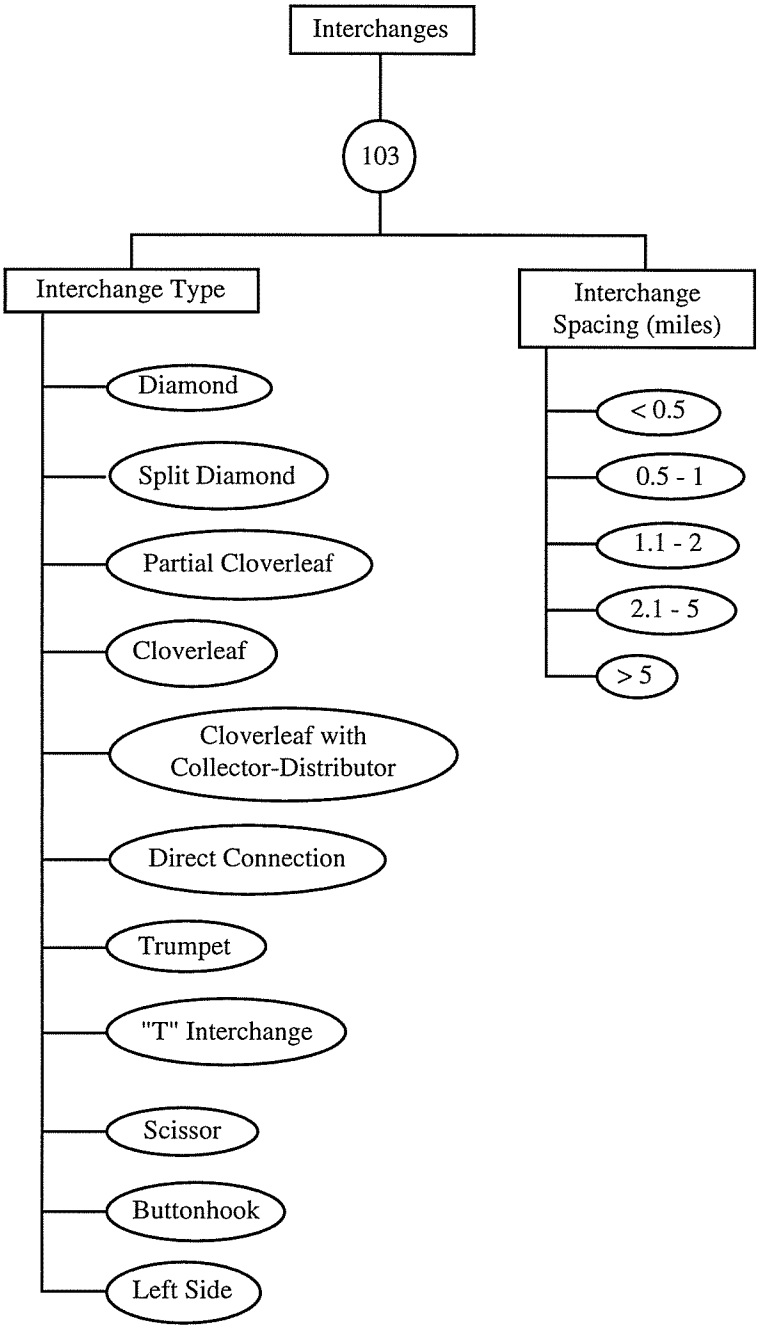

Figure D-7: Structural Support: Interchanges.

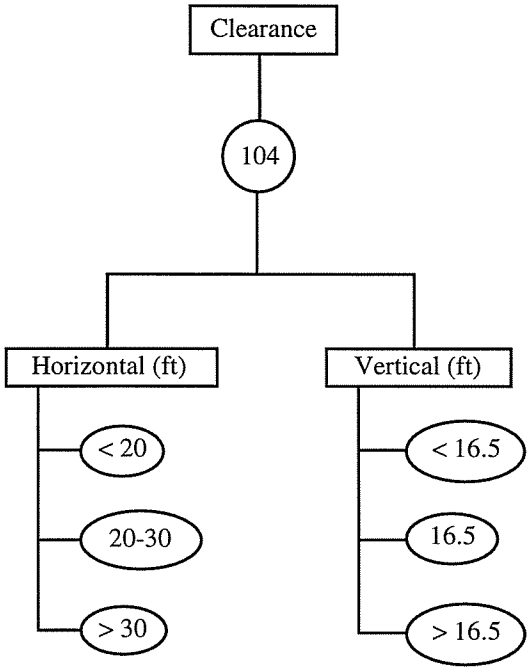

Figure D-8: Structural Support - Clearance.

Code	Clearance (ft)
0	Unknown
1	< 20
2	20 - 30
3	> 30

Table D-19: Clearance: Horizontal Code.

Code	Clearance (ft)
0	Unknown
1	< 16.5
2	16.5
3	> 16.5

Table D-20: Clearance: Vertical Code.

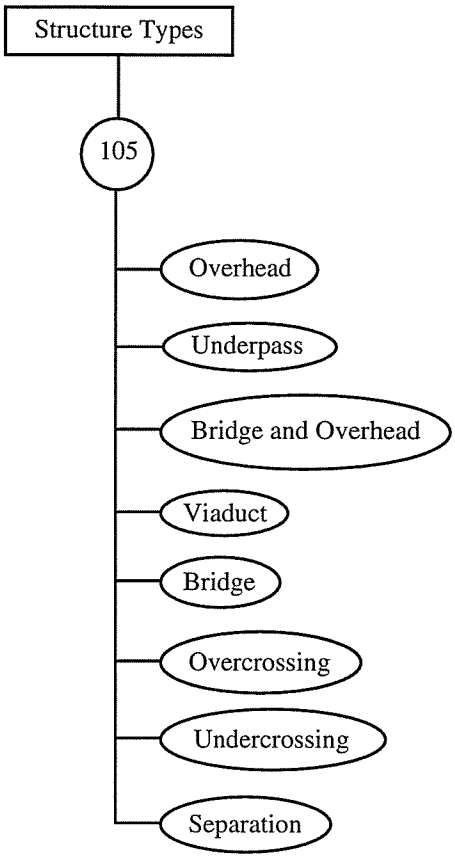

Figure D-9: Structural Support: Structure Type.

Code	Structure Type
0	None
1	Overhead
2	Underpass
3	Bridge and Overhead
4	Viaduct
5	Bridge
6	Overcrossing
7	Undercrossing
8	Separation
9	Other

Table D-21: Structure Type Code.

Appendix E: Traffic Regulation

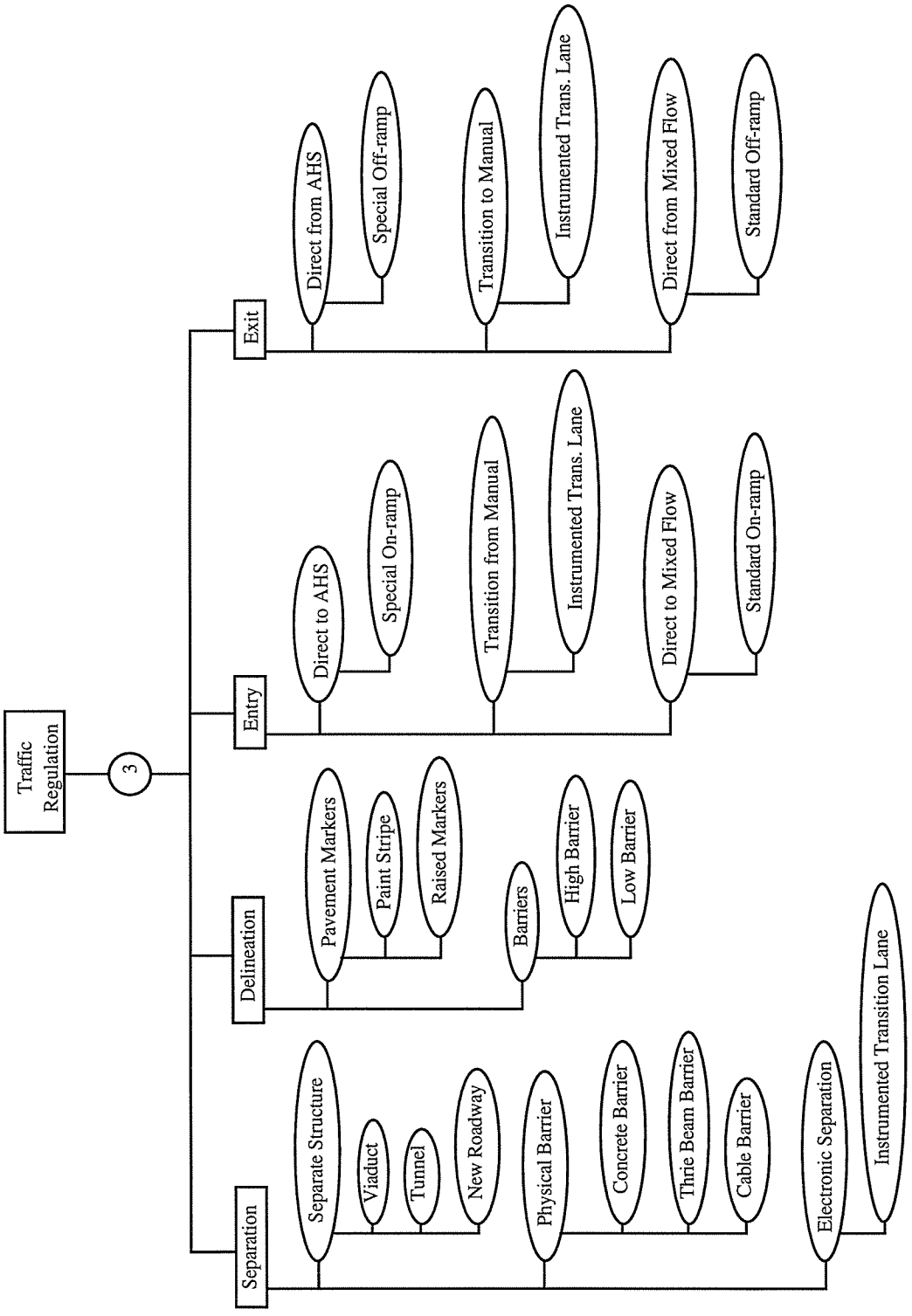

Figure E-1: Traffic Regulation.

Code	Form
0	None
1	Separate Structure
2	Physical Barrier
3	Electronic Barrier
4	Other

Table E-1: Traffic Regulation: Separation (AHS from Non-AHS) Form Code.

Code	Type
0	Unknown
1	Viaduct
2	Tunnel
3	New Roadway
4	Other

Table E-2: Traffic Regulation: Separate Structure Type Code.

Code	Type
0	Unknown
1	Concrete Barrier
2	Thrie Beam Barrier
3	Cable Barrier
4	Other

Table E-3: Traffic Regulation: Physical Barrier Type Code.

Code	Type
0	Unknown
1	Instrumented Transition Lane
2	Other

Table E-4: Traffic Regulation: Electronic Separation Type Code.

Code	Form
0	None
1	Pavement Markers
2	Barriers
3	Other

Table E-5: Traffic Regulation: Lane Delineation Form Code.

Code	Type
0	Unknown
1	Paint Stripe
2	Raised Markers
3	Other

Table E-6: Traffic Regulation: Lane Pavement Marker Type Code.

Code	Type
0	Unknown
1	High Barrier
2	Low Barrier
3	Other

Table E-7: Traffic Regulation: Lane Barrier Type Code.

Code	Form
0	Unknown
1	Direct to AHS
2	Transition from Manual
3	Direct to Mixed Flow
4	Other

Table E-8: Traffic Regulation: AHS Entry Form Code.

Code	Type
0	Unknown
1	Dedicated AHS On-Ramp
2	Other

Table E-9: Traffic Regulation: Direct Entry Type Code.

Code	Type
0	Unknown
1	Instrumented Transition Lane
2	Other

Table E-10: Traffic Regulation: Transition Entry Type Code.

Code	Type
0	Unknown
1	Standard On-Ramp
2	Other

Table E-11: Traffic Regulation: Mixed Flow Entry Type Code.

Code	Form
0	Unknown
1	Direct from AHS
2	Transition to Manual
3	Direct from Mixed Flow
4	Other

Table E-12: Traffic Regulation: AHS Exit Form Code.

Code	Type
0	Unknown
1	Dedicated AHS Off-Ramp
2	Other

Table E-13: Traffic Regulation: Direct Exit Type Code.

Code	Type
0	Unknown
1	Instrumented Transition Lane
2	Other

Table E-14: Traffic Regulation: Transition Exit Type Code.

Code	Type
0	Unknown
1	Standard Off-Ramp
2	Other

Table E-15: Traffic Regulation: Mixed Flow Exit Type Code.