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Authors:
Dr. J.E. Korteling
and
Maj. P.J.H.M. van der Burgt

Functional specifications driving simulator Mercedes 290 GD

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Authors: Dr. J.E. Korteling and Maj. P.J.H.M. van der Burgt

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SUMMARY

In order to increase the efficiency and the quality of the driver training on the Mercedes 290 GD, the Royal Dutch Ground Forces consider to employ driving simulators. Starting point is the notion that simulators may be used in a cost-effective way if they are focussed on the training of basic skills to drivers without driving experience. The present report provides the conclusive version of the functional specifications, or user requirements, for such a system. These pertain to a low-cost simulator with a modest computer-generated outside image supplemented with simplified mirror information. The outside image is controlled and activated by a head tracker such that the potential visual field is quite large, without having to put extreme demands to the capacity of the image generator, given a sufficient resolution. There is a sound system in which the amplitude, sound and rhythm of the various sound sources correlate with driving speed, motor rotations, and eventually motor load. The system includes vibrations but mechanical motion cuing is simple. Control forces and required displacements of controls resemble those of the real vehicle. The interior of the cabin should be an exact replication of the original Mercedes 290 GD cabin. Finally, requirements are provided concerning the driving environment, other traffic, the vehicle-environment model, and the instructor facilities, i.e., automatic instruction, performance measurement, feedback and the processing of student data.

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TNO Human Factors Research Institute
Soesterberg, The Netherlands

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TNO Technische Menskunde
Soesterberg

Functionele specificaties rijsimulator Mercedes 290 GD

J.E. Korteling en P.J.H.M. van der Burgt

SAMENVATTING

Om de efficiëntie van de militaire rijopleiding tot chauffeur op de lichte vrachtauto (Mercedes 290 GD) te vergroten en de kwaliteit van de opleiding te verhogen wordt door de Koninklijke Landmacht overwogen rijsimulatoren in te zetten. Uitgangspunt hierbij is de gedachte dat simulatoren kosten-effectief kunnen worden ingezet als ze gericht worden op het trainen van basisvaardigheden aan chauffeurs zonder rijervaring. Het onderhavige rapport geeft de functionele specificaties, ook wel gebruikerseisen genoemd, voor een dergelijk systeem. Deze betreffen een low-cost simulator met een eenvoudig computer-gegenereerd buitenbeeld aangevuld met vereenvoudigde spiegel-informatie. Het buitenbeeld wordt met behulp van een head tracker aangestuurd, waardoor het potentieel visuele veld vrij groot is, zonder dat daarbij–gegeven een voldoend hoge resolutie–extreem hoge eisen aan de capaciteit van de beeldgenerator hoeven te worden gesteld. Er is een geluidsysteem waarbij de sterkte, klankkleur en ritmes van verschillende geluidbronnen op realistische wijze samenhangen met snelheid, motortoerental en eventueel motorbelasting. Er is eenvoudige mechanische bewegingscuing met trillingen. Bedieningskrachten en benodigde verplaatsing van bedieningsmiddelen komen overeen met die van het werkelijke voertuig. Het interieur van de bestuurderscabine moet grotendeels een exacte replica zijn van de Mercedes 290 GD cabine. Tot slot worden er eisen gegeven ten aanzien van de rijomgeving, ander verkeer, het voertuig-omgeving model, en de instructiefaciliteiten, i.e., automatische instructie, prestatiemeting, terugkoppeling en verwerking van leerling-gegevens.

1 INTRODUCTION

1.1 Background

Every year the Training Center for Transport, Traffic and Driver Education (Opleidingscentrum voor Vervoer, Verkeer en Rijopleidingen, OCVVR) of the Royal Netherlands Ground Forces (RNLA) trains about 3000 military subjects to drive light trucks and about 6000 to drive heavy trucks. These courses require a large amount of equipment and personnel, they are a burden to the environment and they cause traffic inconvenience for the people living in the neighborhood. To avoid such problems, the use of driving simulators is being considered (among other things). It is expected that by a well-considered use of driving simulators, a part of the truck driver training can be more efficient and at least as effective as the existing training, without the drawbacks mentioned above.

The question whether, and in which way, simulators can in principle be used in military driver's training programs is complex. Within the limits of the evolving simulator techniques, a large number of possibilities exist for the way driving simulators can be used. To deploy simulators in an optimal way, the RNLA has ordered the TNO Human Factors Research Institute to carry out a pilot study, based on which an inventory of the possibilities of application of training simulators in driver courses could be drawn up (Korteling & Van Randwijk, 1991).

This study took into account the base level of the incoming students, the training goals and the time and mileage needed to achieve each training goal, the state-of-the-art of available technology and the driving task as a complex perceptual-motor task (with relatively few cognitive and procedural aspects). It resulted in functional specifications for a restricted simulator that can be used for the training of the basic aspects of driving (the most elementary partial tasks) and a number of traffic-insight aspects. Based on registration of the time needed for each part of the task in the present driving courses, and on estimates of the learning benefits and the training efficiency of the simulator, it is now assumed that about 16 such systems will be sufficient to take care of approximately 40% of the drivers courses[1].

The present functional specifications are primarily based on the results of the study of Korteling and Van Randwijk (1991). These functional specifications have been sent to 11 major manufacturers of simulators or simulator-components in the form of a previous draft modified by the DMKL. The manufacturers were invited to offer non-committal proposals, i.e., a Request For Information (RFI). This RFI yielded positive reactions from 4 manufacturers. An evaluation of these reactions (Korteling & Van der Burgt, 1994) showed that the offers were based on existing high-performance systems meant to teach entire practical drivers courses, including special circumstances. The possibilities to adapt these systems to the specific requirements of the RNLA in a meaningful way were limited. Furthermore, these systems were so expensive that a cost-effective use of them was impossible. Therefore it was decided to consult, in a second RFI, manufacturers that are particularly engaged in the

[1] At the time this report was written, a potential of 6000 trainees was assumed, whereas at present this potential is estimated at about half this number. Therefore, only 16 simulators are needed, instead of 30.

development of low-cost systems. The present report provides the functional specifications for this second RFI.

1.2 Training goals

Given the relatively low exploitation costs of the Mercedes 250 GD, the basic assumption is that only limited-scale simulations (i.e. no full-scale simulations) can be cost-effective. Such a limited-scale simulation system should only provide for the possibility to train basic skills of the practical drivers course [i.e., with full transfer of training (100%) *and* with high training effectiveness (> 0.70)]. This means that only students who do not possess a civil drivers license (B category) are eligible for training in the driving simulator. Below, for each cluster of training goals the percentage of partial tasks that can (and must) be trained effectively with this circumscribed simulator cluster is indicated. The first task clusters should be trained almost exclusively on the simulator, whereas the subsequent clusters need not, or hardly, can be trained on the simulator.

1 Starting, pulling up, stopping (90%)
2 Control of the accelerator pedal, braking (80%)
3 Special operations (50%)
4 Changing gears (70%)
5 Steering on straight roads and in wide bends (50%)
6 Steering in sharp bends and at crossroads (25%)
7 Participation in traffic (35%)
8 Driving in rough terrain (0%).

A further specification of these training goals, their feasibility on the basis of simulator training, and the time and mileage needed for each training goal can be found in Appendices 2 and 3 of the Korteling and Van Randwijk (1991) report.

The training effectiveness on the simulator compared to practical training (TER) increases by the ability to create or adapt traffic situations and driving conditions at will. In this way, the training program can be tuned optimally to the instruction that is needed, which means that different parts of the driving task can be practiced separately, in a well-chosen order, and with a systematically-varied difficulty. Because driving performance can be recorded automatically and objectively, simulators offer better feedback opportunities. Driving under special circumstances, such as fog, slipperiness, darkness and unexpected maneuvers of other traffic participants can also be practiced at will (Korteling, 1991). For task clusters that relate to vehicle control, the relative effectiveness of simulator training is mainly enhanced by the possibility to control and manipulate road and weather conditions. The surplus value of simulators for task clusters that relate to the participation in traffic concerns mainly the possibility to manipulate traffic situations and behavior of other traffic participants at will. Therefore, less time will be lost by driving to the desired location, task performance can be practiced easily and fast several times in succession, and one does not depend on the coincidental behavior of other traffic participants that accidentally pass by.

The effectiveness of simulator training, compared to practical training is hampered because it is impossible to simulate all relevant information in a completely realistic way. The limitations for simulator training in task clusters related to vehicle control are mainly caused by insufficient mechanical motion information (moving-base) and an incomplete outside image (mirrors). The relatively small image angle, the absence of simultaneous front and side view as well as large numbers of other traffic participants constitute the most significant limitations on training effectiveness in the task clusters that involve traffic participation. The perception of depth (at short viewing distances) will be difficult in the absence of stereopsis (binocular parallax) and monocular parallax. The latter point can in principle be solved by a head-tracking device, though.

1.3 General remarks

1 Industry and training organizations are invited to provide provisional information regarding their capability to provide a driving simulator for the above training purposes and a price indication.

2 The term driving simulator denotes a replica (form, fit, and function) of the frontal interior and frontal windshield frame of the Mercedes 290 GD cabin, including assembled equipment and computer programs necessary to represent the vehicle in driving operations, a visual system providing real-time out-of-the-window view, a control force system, a sound system, instruction facilities, and a motion system which provides at least vibration cues.

3 The simulator will be evaluated in those areas that are essential to completing the drivers training goals as outlined above. The simulator will be subjected to validation tests and to subjective expert evaluations. Validation tests are used to compare simulator and vehicle data objectively to ensure that they agree within certain tolerances. Relative responses of the visual system, the vehicle displays and the motion system shall be coupled closely to provide integrated sensory information.

4 The information below is intended to give an outline of the requirements. For each item in this list of functional requirements, industry is requested to state whether or not they comply, how compliance is achieved, or in what way a deviation is proposed.

5 Definitions:
The word “shall” or “must” in the text below expresses a *mandatory minimal requirement* of the specification. Departure from such a requirement is not permitted without a formal agreement between industry and consumer.
The word “should” in the text expresses a *recommendation* or *advice* with regard to the implementation of the specification. The customer expects such recommendations or advice to be followed unless reasons are stated for not doing so.

6 Apart from the visual databases, the project is in principle considered as a “turn-key” project, i.e. the simulators should be ready for use when delivered or made available.

7 Costs related to extras that add to the minimal requirements shall be separately indicated.

2 IMAGE SYSTEM AND VISUAL ENVIRONMENT

2.1 Image system

1 The driving simulator shall have a display system that presents sufficient information to be able to perform spatial (orientational) functions adequately. Less value is attached to the visibility of small details.

2 The display should be sufficiently in order to cover the hood of the car over its entire width, including protrusions that may act as points of reference, for lateral and longitudinal all at the same time.

3 The vertical viewing angle shall be wide enough to display the surface of the road from about 4 m in front of the car, while traffic signs should be visible from about 10 m in front of the car.

4 The display system shall not engender noticeable depth (or height) illusions as is often encountered when objects close to the observer are displayed by collimated images. Therefore, projection rather than collimation is preferred.

5 The image content/complexity and resolution shall be high enough to represent a sufficient number of common objects seen by traffic participants in sufficient detail to be recognized.

6 Motion information of objects shall be presented, given critical and for participation in traffic relevant combinations of velocity, distance en object sizes. For example, the optical looming (expansion) of a cyclist, moving with a speed of 3 m/s on a crossroad at 20 m from the intersection, should be clearly visible to the observer (car driver) located at 100 m of the intersection and driving with a speed of 14 m/s (Time-To-Contact in this case is 7.2 s). Such critical conditions require a resolution of at least 20 lines/degree.

7 The processing speed of the image generator shall be sufficient to yield smooth images when simulating driving speeds of up to 80 km/h.

8 The system should be able to realistically emulate various weather and lighting conditions (fog, dusk, darkness).

9 Complete backward visibility by way of one or more mirrors is not necessary. However, because of the importance of using mirrors in car driving, at least a cheap, stripped form of information presented by mirrors shall be provided (see Chapter 5).

10 Lateral visibility is necessary to train traffic insight, i.e. the ability to quickly get an overview of all kinds of traffic situations. It is not necessary for this peripheral information to be visible continuously. The presence of images to the front and to the side of the vehicle can be controlled by the driver by means of a head tracker (not necessarily a helmet-mounted display). For this aim a minimum and an improved option are provided below.

Minimum option

A 1-channel system with a simple head tracker and three monitors with a horizontal angle of about 3×40°. By means of head movements one of these three monitors is activated discretely. This minimum variant can be improved by using a somewhat better head tracker which controls the presented horizontal visual angle of 40° on the three monitors continuously. The image shifts continuously with the head tracker and thus does not jump discretely from monitor to monitor.

Improved option

The image activated by the head tracker is shown in high resolution and the remaining areas in low resolution. Hence, this is an addition with respect to the first option, namely by attaching two areas of "secondary-interest". Analogous to option 1, the (primary) area-of-interest image can be controlled discretely or continuously over the three displays by the head tracker.

− An important advantage of using a head tracker is that it may be used to judge and improve the trainees looking behavior, which enables the instructor to give him feedback on failure. Moreover, the drill to look sideways will be enhanced (especially with option 1). When the system has a good (and affordable) head tracking system at its disposal, it will be possible to offer depth cues based on head-motion parallax as well.

− Using the head tracker, information in the mirrors can be displayed without demanding more processing capacity of the image generator.

11 The visual information shall respond to abrupt longitudinal and rotational inputs from the driver's position within 100 milliseconds of time, but not before the time, when the vehicle would respond under the same conditions.

12 Information concerning the following parameters should be (quantitatively) indicated: visual angles and resolution from the drivers point of view, eye-screen distance, contrast ratio, number of luminance steps, update frequency, refresh rate, delay on discrete control input, anti aliasing, number of channels, number of polygons/channel, pixel fill rate, number of detail levels, number of texture patterns, transparent polygons, shading, light points.

2.2 Environmental demands

The training environment shall be modelled by the RNLA itself or by an external provider in close consultation with the users at the RNLA. The following driving conditions shall be modelled both visually and (if applicable) mechanically:

Paved roads (RONA categories I and III-VIII, see Appendix 2) containing:

1 obstacles to be passed
2 narrow passages, bridges, tunnels, fly-overs, road narrowings
3 merge, exit, lane change and priority situations
4 curbstones, speed ramps
5 slopes

6 traffic engineering provisions, such as the most common signs, signals, reflector posts and road markings (including priority markings, zebra intersections, stop signs)
7 traffic lights and railway intersections

8 delineations fitting to the road category
9 straight road sections
10 curves (mainly shallow ones) with various (realistic) arc lengths and several different and varying curvatures (transition arcs)
11 crossroads and a roundabout
12 especially the RONA categories V-VIII shall be represented frequently
13 it should be possible to train driving on visual signals given by a marshaller.

The roads shall confirm to the Dutch regulations (RONA etc.) concerning width, delineation, signals, markings and other road design aspects.

2.3 Other traffic

The simulator shall contain models of a restricted number of other traffic participants which behave in such way that the driver is forced to take decisions concerning future maneuvers. It is not mandatory to simulate busy traffic situations. Other traffic includes the following elements:
1 pedestrians and cyclists at intersections
2 transverse traffic at several priority situations
3 traffic shall be such that complications emerge with respect to passing by, merging, exiting, and filtering (e.g. agricultural vehicles)
4 traffic situations and corresponding complications should be linked to the computer based instruction program "TRAFFIC THEORY", which is being developed by the OCVVR of the RNLA in cooperation with HFRI (Van den Bosch, Van Berlo & Van der Burgt, 1995; Van Berlo & Riemersma, 1994)
5 the numbers of traffic participants (actors) and their degree of autonomy and interactivity shall be indicated.

2.4 Modelling requirements

Given the systems limitations, visual information should be presented as efficiently as possible. When modelling de simulated training environment, one should be guided by the following general principles:
1 Along all roads there should be several vertical and horizontal structures, such as houses, trees, hedges, farmland, ditches, fences and bushes. At every road section at least some of the above should be present at both sides of the road.
2 Objects should be visualized using their most representative and typical colors, sizes and shapes (i.e. prototypes).
3 Object density (amount) is more important than object detail. Hence, one should use a lot of schematically modelled objects rather than a few detailed objects (this only holds for CGI).
4 Frequently occurring objects should be distributed such that per unit of distance, both along the road and transverse to it, an approximately equal amount of objects of each kind is visible.

5 Identical objects (reflector posts, lampposts, a discontinuous center line) are to be positioned at regular intervals near the vehicle's path.
6 Horizontal curves should be marked by means of regularly positioned vertical structures (e.g. reflector posts).
7 With the exception of reflector posts along the road or elements at long distances (e.g., the horizon), objects in the field should be positioned at varying distances from the road. The same holds for trees in groves.
8 Separate objects at different transverse distances of the road shall have a distinct color, brightness, or texturing.
9 Long, horizontally outstretched objects (walls, banks, dikes, fences, or ditches) shall have vertical discontinuities (breakers, marks, changes in color or intensity, edges, etc.) at regular intervals.
10 Objects which are at longer transverse distances shall be displayed in more light, faded colors, and with less contrast, preferably through simulated haze or fog effects.
11 In normal visibility conditions, the horizon should always be visible; at least 20% of the total horizontal field.
12 If a large segment of the horizon is visible, at least one “anchor” point shall be in sight, e.g., church tower, water tower, broadcasting mast.

2.5 Training trajectory

1 The simulated training environment must be precisely adjusted to a to-be-specified training trajectory in which components of the driving task (subtasks) are arranged in an optimal order and difficulty.
2 Starting points and short connecting roads at well-chosen points shall enable the instructor to repeat certain parts of a lesson in an efficient way.
3 The training environment must be flexible, i.e., easy to change as changing training needs and new didactical or logistic requirements demand so.
4 If the training environment is externally provided, the RNLA must have at its disposal modelling facilities to change the training environment according to needs.
5 The amount of continuously available terrain (...km × ...km) should be indicated.

3 MECHANICAL MOTION

A *moving base* system is not absolutely necessary. Inexpensive solutions, however, will be seriously taken into account. When such a system is offered, it shall have the following characteristics:
1 The position of the driver with respect to the axes of rotation of the simulator cabin should match reality.
2 Preferably, only transient accelerations and decelerations, e.g., those which occur during the onsets of speed increase or decrease, emergency braking, driving on slopes, sharp bends normal, and gear shifts or errors should be generated. Sustained mechanical accelerations need not to be presented.

3 The motion system shall run synchronously with the image system and the sound system with correct relative intensities. It shall not be slower than the image projection.
4 The mechanical motion information should respond to abrupt longitudinal and rotational inputs from the driver's position within 100 milliseconds of time, but not before the time, when the vehicle would respond under the same conditions.
5 Motion cues perceived by the driver as a consequence of hitting an object should be a function of the simulated driving speed.
6 Delay and wash-out specifications shall be provided, as well as specifications concerning movement speed and range.
7 Extra costs following from the specified motion system shall be indicated.

A *vibration system* masks the absence of mechanical movement. If a fixed-base system is chosen, vibration feedback should be given. Such a system should at least provide vibration information, that is related to the frequency and amplitude of motor vibrations, through the seat (and possibly through control apparatus). Other sources of vibration (surface of the road, gearbox) do not have to be present in naturalistic way. The following requirements are given for a vibration system:
1 A vibration system shall at least provide through the seat (and possibly through the controls) the vibration information that is related to the frequency of motor (revolutions) and road surface vibrations when driving.
2 The system should provide through the main controls the vibration information that is related to the frequency of motor (revolutions) and road surface vibrations when driving.
3 The system should reflect the frequency of motor revolutions when standing still.
4 The system should provide information about the condition of the road surface.
5 Extra costs following from the specified vibration system shall be indicated.

4 CONTROL LOADING

To achieve the first five clusters of learning goals it is essential that control force and displacement (force-distance diagram) of the break, gas and gear pedals, the gear box and the steering wheel match those of the actual vehicle in similar circumstances. The reaction of different control mechanisms when they are let go should match reality. Possible dependence on driving speed of control force should also be implemented in the simulator. The following requirements are given involve the force, position, and motion characteristics and relationships of the controls.
1 The forces, positions, and motions of controls (braking pedal, clutch, accelerator pedal, gears and steering wheel) and switches shall correspond to the real vehicle.
2 The reactions of various controls (steering wheel, pedals, clutch) when released shall correspond to reality.
3 If loading depends of driving-speed (steering wheel), this shall also be implemented.
4 Control forces should vary in a realistic way with the following surface conditions: dry, wet, icy.

5 VEHICLE SYSTEMS

The following demands are to be fulfilled by the control environment:

1 The interior of the driver's cabin shall be an exact replica of the Mercedes 250 GD from window to the drivers seat, but with the exception of the co-driver's seat.

2 The functioning of the controls, switches, displays, and further systems (seat belts, seat adjustment) shall be identical to those of the real vehicle, with the exception of windscreen wipers, windscreen washer, heater, ventilator, and fire extinguisher.

3 If the real vehicle contains objects between the head (eye) of the student-driver and the image presented, which may act as points of reference, for longitudinal and lateral position of the Mercedes, these objects shall be mounted or depicted at the correct position. The complete width of the bonnet must be visible, if not in the image, then along the lower edge of the image.

4 Mirrors must be present at the same position and of the same shape as in the real vehicle. These mirrors need not necessary display the outside world image. In order to learn to use the mirrors, they shall depict at least a Go/no Go signal.

5 Faithfully shaped windscreen wipers shall be positioned or depicted at their usual place.

6 The simulator ambient lighting shall be dynamically consistent with the visual scene displayed

6 SOUND

The amplitude and frequency of noises and sounds shall be realistic. Sounds to be simulated shall be correctly related to speed and engine rotation speed for intensity, pitch, and timbre.
If appropriate, sounds should be correctly related to engine load for intensity, pitch, and timbre.
The sound effects shall reflect the following sources:

1 wind and wheels
2 engine
3 cabin resonance
4 changing gears.

These sources should be recognizable as for direction and character. The system should present special sounds when starting the engine, or when driving against obstacles (sound of crashing). If applicable, sound should be synchronized with image and mechanical motion.

7 VEHICLE BEHAVIOR

The movements of the vehicle through the training environment, as experienced by the student- driver through images, (possibly) mechanical motion, sounds, and other indicators, shall faithfully depend on the control actions and on the mechanical characteristics of the subsoil and objects touched (slopes, unevenness, resistance, curbs, sills, objects on or near the road). For example: with too little throttle when driving up a hill, the visual and mechanical acceleration shall be lower than normal, the sound of the engine shall be low and droning, possibly, the engine shall stall, which can be accompanied by fits and starts, like in the real vehicle. This kind of realistic behavior unquestionably applies for starting, pulling up, halting, control of the accelerator pedal and braking at low speeds (<55 km/h), changing gears, and driving up hills, steering on straight roads and in wide bends. Demands are less strict for other tasks (see § 1.2).

The display information shall respond to abrupt longitudinal and rotational inputs from the driver's position within 100 milliseconds of time, but not before the time, when the display would respond under the same conditions.

8 FACILITIES FOR THE INSTRUCTORS

In this stage, it is undetermined whether there should be a 1:1 or a higher (1:10) relation between instructor and student. Amongst others, this depends on the possibilities to computerize instructions and feedback about performance for reasonable costs (see Chapter 9).

8.1 General

1 All information displays and all controls for the instructor must be perceivable and operationable from one central point.
2 A good, ergonomically designed chair with adjustable back is necessary for carrying out the instructors task.
3 The chair should be positioned right in front of the instructor's image system.
4 Light emissions from the instructor operation station (IOS) shall not hinder the driver under any outside visual condition, nor have any impact on the visibility of the outside image.

8.2 Monitoring

1 The control panel shall be positioned such that the instructor can operate his instruction system and simultaneously is able to observe the actions of the trainee.
2 The instructor shall have at his disposal the same outside world image as the student, such that this image contains both the information to evaluate the driving behavior, and to drive on.
3 The outside world image should be positioned right in front of the instructor, and not higher than at eye height.
4 Displays should be placed central or more in the periphery depending on their importance.
5 All meters, instruments, and displays of the drivers cabin should be duplicated in a visible way on the instructors panel.

6 Due to de restrictions in the outside world information, the instructor should have additional means, with which he can perceive a right impression of the vehicle in relation to its immediate environment (for example “bird's-eye view”).

8.3 Operation

1 All switches, buttons, and levers, must be within hands reach.
2 At all times the instructor must be able to take over the control of the vehicle, controls for this shall be situated at the right place.
3 The instructor must be able to freeze situations, in which the eventual motion system returns into the neutral position. Afterwards, the training scenario shall be easy to continue.
4 The instructor shall have at his disposal a good, adjustable communications possibility (e.g. intercom) between the student and himself. The audibility of verbal communications between student and instructor must be optimal.
5 The workbench (with space for legs and feet underneath) shall have enough room for writing (filling in forms), and reading (instructors book).
6 The instructor must have at his disposal preprogrammed traffic scenarios (presence and behavior of other traffic) which are didactically considered (in which decisions must be made, and which teach something relevant concerning traffic participation. He shall be able to design and store training scenarios in advance of the simulator session and to activate these scenarios during training sessions. The scenario-operation procedures must be simple (selecting one of the alternatives with one push of a button). Similarly, exceptional and complicated circumstances must be easy to control.
7 The instructor must be able to easily select and set at least the position of the vehicle in the database and to manipulate the outside environment with respect to viewing conditions.
8 The instructor must be enabled to easily select and generate the most relevant vehicle malfunctions and to switch on and off all indicators/displays in the cabin (for example oil pressure). He must be able to adjust the fuel level. Disturbances enforced this way must be continuously visible on the instructor panel.
9 Selection and full recording and replay of parts of the training session should be possible. Reproduction of recorded parts must be possible (separately).

8.4 Administration

The simulator should be equipped with facilities for administration of:
1 student, class, platoon, driving school
2 certificate of theory exam.
3 training so far
4 lessons, hours, kilometers
5 PMF data (see Chapter 9).

This data should be presented in a comprehensible way by means of a monitor screen a printer.

9 AUTOMATED INSTRUCTION AND PERFORMANCE ASSESSMENT

For simulators, automation of components of the instructor's task is in principle possible. To which extent this may be implemented effectively depends on a large number of factors. In brief, this depends on the amount of knowledge on the driving task and possibilities concerning:

- exact defined measures for the quality of the driving behavior (per task)
- criteria for the different sorts of correct and fault behavior
- feedback systems and procedures adjusted to the registered driving behavior
- training modules which offer a training condition and accompanying instruction and feedback on the basis of selected training objectives
- a training model that makes a diagnosis on the basis of the registered driving behavior, on the basis of which it closes, repeats, or invokes new training modules (Korteling 1991).

For perceptual-motor tasks, like driving, one may expect that automated instruction is harder to realize than for more abstract tasks (procedures). An obvious form of automation is a system for Performance Measurement and Feedback (PMF), which measures in an automated and objective way performance along a predefined (test) route and provides feedback to the driver (and the instructor). Forms of performance measurement and feedback to be used are:

Immediate feedback on errors

1 Stopping the simulator.
2 Auditive signals (crashing sounds).
3 Visual signals (depicting comments in the image).

Delayed feedback and judgement

1 Debriefing forms.
2 Name of the student- driver and other relevant administrative items.
3 Judged tasks like: driving on straight roads, steering in wide bends, special actions etc..
4 Per task only the relevant tasks aspects like: course stability, speed/completion time, suppleness, changing gears
5 Per aspect a judgement which is normalized on the basis of a performance criterion. This judgement must be meaningful.
6 Per aspect a weight that indicates the relative importance of the judges' aspect.
7 Feedback about the things the student-driver did wrong.
8 A weighted judgement per task and possibly a weighted final judgement.

If a kind of PMF system, or automated instruction system can be delivered, extra costs following from the system shall be specified.

The debriefing form shall be formulated in easy, and for laymen understandable terms. These data are stored internally in the system, and the instructor shall be able to access these data through screen or printer. For general guidelines, see for instance Korteling (1991) and Korteling and Van den Bosch, 1995). For an example of more specific technical requirements for such a system, see Korteling and Padmos (1992).

10 MISCELLANEOUS

1 The student-driver and the instructors must not be disturbed by non-functional sounds like that of computers, fans, etc.
2 Simulators with a moving base system shall have an emergency stop, which shuts down the system and stops the cabin in a save position. This stop should be easily accessible for both the instructor, and the driver. This stop procedure shall automatically take place in case of a power failure and when somebody tries to enter or leave the cabin while the moving-base is active.
3 Inside the simulator, a hand-held fire extinguisher shall be provided.
4 Giving instructions in the simulator shall be that easy, that one week of training for instructing personnel is sufficient.
5 In addition to § 2.5, the manufacturer should train three instructors before delivery to the user.
6 The system shall not suffer from negative effects of mistreatment by student-drivers or instructors during instruction.
7 The training system shall be usable at least 99% of the total available instruction time in a year. For a simulator without a moving base system this shall be 99.8%.
8 Power supply to the simulator shall be in accordance with available public electrical power (220/380 Volts, 50 Hz, 1 or 3 phase). Industry shall provide information on power consumption and eventually consumption of other sources.
9 Information shall be given indicating the weight of the simulator and, in case of a moving-base, its weight and its maximum payload.
10 Cabin temperature shall be adjustable between 15°C en 20°C.
11 Manuals in Dutch language shall be provided in clear and easy understandable vocabulary.

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Dr. J.E. Korteling

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J.E. Korteling and P.J.H.M. van der Burgt

12. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

TNO Human Factors Research Institute
Kampweg 5
3769 DE SOESTERBERG

13. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

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