# Design Considerations in Simulating Pedestrian Environments

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**ABSTRACT**

Pedestrian Simulation is a new area of safety and health research employing contemporary technology in a form traditionally used in areas of vehicular transportation, skill acquisition and defense. This paper discusses the design considerations of developing such a simulator, which provides scope for multi-modal research in the fields of safety, health and transportation. Predicated on documentation of actual field conditions, the PED-SIM is being developed to create simulated environments whereby the participant of the study responds to simulated environments as though he or she is actually in the field. Under these conditions, the simulated environment can be manipulated to further research in many aspects of pedestrian facility design with low-risk to participants in the study. The simulator is being designed so that it can be modified to also operate for wheelchair and bicycle user research as well. Based on response to various safety and health-related scenarios, the participant makes decisions regarding the effect of the virtual built environment on his safety, health and comfort. The findings can be reintroduced into field conditions allowing improvements in public health and safety. Design standards related to the walking environment, such as urban design, landscape, sidewalk engineering, intersections, tree planting, and others, can be evaluated safely in the PED-SIM. Other current needs for research in pedestrian environments can be examined so that the simulator can be designed with enough flexibility to support various research needs. This paper discusses the considerations in the design of the PED-SIM, which accommodate a variety of current pedestrian research needs related to improving both the safety of the pedestrian environments designed for transportation corridors, as well as defining the nature of walking facility design required by the health industry for preventive and curative use.

## INTRODUCTION

Pedestrians represent about 12.6 percent of people killed, 4.8 percent of persons incurring incapacitating injuries, and 3.3 percent of non-incapacitating injuries in traffic crashes *(1)*.

It appears that there is a need to research spatially significant factors affecting different types of pedestrian users. Increasing pedestrian fatalities and injuries are difficult to inhibit without significant research in the environmental factors, which are contributing to the safe accessibility of pedestrian facilities. Individual user groups such as those walking for health, commuting, or those walking for leisure, respond differently to the environment at different times of day and during different seasons.

There is a need to create a simulator that can provide diverse environments for study, whereby the simulator itself does not affect the participant's perception and cognitive response to the environments being simulated. The simulator's design must also take into account the safety issues and the cost effectiveness in simulating environments. Though there has been some research in the field of transportation and health to study the effect of landscape on curative and safety performance, there has not been enough investigation into how a simulator could be set up for conducting such a study.

To design a pedestrian simulator, researchers at the Texas Transportation Institute (TTI) are considering the following questions:

- Who are pedestrians?
- What is the nature of walking?
- What are the current research needs regarding pedestrians and walking?
- What aspects of walking offer the greatest impact on pedestrian spatial perception?
- What is the correct basis for simulation of a pedestrian world?
- What type of technology do researchers use to most accurately portray the simulated world?
- What type of physical motion should the people have freedom to make in order to perceive that they are a part of such an environment?
- What are the other factors that influence the design of a pedestrian simulator?

This paper addresses these questions as considerations in the development of the PED-SIM and also describes one way to create a Pedestrian Environment Simulator that is currently being undertaken by researchers at the Texas Transportation Institute.

## NATURE OF PEDESTRIANS

Pedestrian user groups can be categorized into different classes according to their usage as commuters, health walkers and spiritual walkers. Commuters are those who use the sidewalks for the purpose of their daily activities. Commuters include transit users, shoppers, school-age people, and others who are walking to get somewhere else. Health walkers form the community who use sidewalks for the purpose of health, which might be fitness, or for curative therapy. Health walkers walk preventively as well as curatively, where their origin and destination are the same, the purpose being the physical therapeutic benefit of walking. Spiritual walkers are people who walk to engage the environment at the human spiritual level, seeking peace or a meditative respite. Spiritual walkers may have a destination such as a temple or sacred natural place. Formally, they may embark on pilgrimages like those in northern Spain, Chartres, Mecca, across India, or in walk-a-thons, aware of the invisible aspects of the path that they are on. Indigenous literature indicates ample examples of spiritual walks attesting to rites of passage in nearly every continent. The spiritual walk is referenced here because it represents the pinnacle of the walking experience, and from this experience, the researcher can define an optimum technology.

Each of these three pedestrian user groups have different spatial needs as each group operates within different ranges of speeds, horizontal spatial demands, origin/destination scenarios, and view corridors. Untermann *(2)* indicates a generic bubble of horizontal spatial demands for the generic pedestrian that is consistent with Edward Hall's early anthropological study of personal space in public places. However, past designs for pedestrian facilities indicate a static design envelope for pedestrians. The dimensional differences between the sets of pedestrian planning standards are alarming given the rise in pedestrian fatalities. While updated design guidelines are moving forward from this static vision, the generic definition of the "pedestrian" continues.

To develop user characteristics that are quantifiable, and justifiably provide the basis for physical design standards, this research will take into account the three user groups and their sub-groups, as well as variations that may occur by virtue of age, culture, and climatic conditions in the field. The simulator that is designed must provide a way to explore the cognitive basis of all facility users so that an assessment of their walking requirements can be incorporated into network planning and pedestrian risk management of contemporary transportation facilities. In the

1980s, Seneviratne and Morral noted that the operational quality of pedestrian features is not necessarily governed by its capacity. Environmental features such as the number of attractions (restaurants, shops, etc.) can be more important *(3)*.

Clearly, because much public walking for health purposes is accommodated within the transportation corridors, the standard features of roadways, transit facilities, and the like need to be addressed in terms of how they impact the pedestrian. The University of Massachusetts Medical School recently showed mindful exercises elicit immediate, positive psychological states such as enthusiasm, alertness, and greater self-esteem *(4)*. Research indicates that brisk walking may offer the same health and fitness benefits as running or jogging, but without stress to the joints and risks of injury. Physicians recommend brisk walking as an efficient and safe form of exercise.

A mechanical platform describing walking behavior from a biophysical perspective is being generated at Cornell. The Passive Dynamic Walking group's research at Cornell University is centered on understanding how humans walk from a Newtonian mechanics point of view *(5)*. They have designed a machine that resembles a set of human legs in two dimensions. This machine, called passive dynamic walker, picks up on the ideas and inventions of Tad McGeer and focuses on the aspects of coordination that can be largely explained by mechanics *(6)*.

The concept of the spiritual walk has been opened in the West just in recent years as the medical community addresses ayurvedic and holistic health practices from the East. Harvard researchers are defining psycho-physiological responses to meditation that affect reduced stress levels and improve overall health. Walking as a form of active meditation in labyrinth use was studied at Texas A&M University and led to review of considerable existing research in sacred landscapes and pilgrimage sites. At a recent GUPHA meeting held at Texas A&M University, researchers from Finland concluded that urban design and community planning based on real data may provide the key to future health care programs that address the human spirit holistically.

## PEDESTRIAN RESEARCH NEEDS

Current transportation industry interests in pedestrian research have increased significantly since very early works by Fruin on pedestrian capacity and Untermann's community accessibility *(7,2)*. Most of the new sidewalk design developments have emerged from conformance with the American with Disabilities Act (ADA), and very little has specifically reviewed the needs of various user characteristics of walking people.

Recent work by the Department of Transportation Statistics identifies user characteristics of pedestrians and pedestrian risk management as two high priority areas for research efforts. Traditional transportation industry has placed most of its pedestrian initiatives within the same administrative structure as bicycle research. This has resulted in misdirected research based on the premise that the pedestrian functions like a bicycle rider who in turn functions like a car driver. Psychologically and cognitively, this has led to misinformation regarding pedestrian needs. The Highway Capacity Manual (HCM) provides a methodology for computing Level of Service (LOS) under a variety of situations, primarily for automobile drivers, but it also offers methods for computing LOS for pedestrian facilities *(8)*.

In a recent survey, Bigelow evaluated the 11 factors pertaining to pedestrian facilities: walking safety, crossing safety, security, continuity, amenities within facility, convenience, handicapped access, attractiveness, comfort, pavement quality, and pavement width *(9)*. Evaluating these in the simulator may provide a more interesting framework for pedestrian design research.

Although sidewalk design is often undertaken in transportation planning as an issue of capacity and level of service, other considerations such as pedestrian safety and user characteristics have been identified as a data gap in research. From the perspective of elements in the medical community, walking performs both preventive, as well as curative care for patients suffering from Parkinson's disease, debilitating injuries, Alzheimer's, and heart disease. Current health industry interests in research related to pedestrians occurs in areas of walking as a factor in preventive care, alternative medicine therapies, walking for maintenance of existing health and transitional therapies that use body movement and physical therapy to assist patients in returning to normal activity after suffering from stroke or other ailments.

There are also pedestrian issues related to public health and transportation. In this instance, safety becomes the research bridge between the two industries, as aging populations often incorporate walking as part of a health maintenance program, while at the same time providing accessibility options which are no longer accommodated by the private vehicle.

The industry needs the use of the simulator to determine performance measures that define the success or failure of facility design. Urban design, architectural and landscape treatments have a direct impact on the roadside environment often defining the pedestrian realm. Studying the impact of landscape architectural features on pedestrian performance is warranted to assure that in the interest of community greening or aesthetics, thresholds of safety are being respected.

## ENVIRONMENTAL SIMULATIONS

Environmental simulations provide a means of optimizing or improving the level of fit between future environmental conditions and the needs of individuals and groups who will occupy a particular setting. Kenneth Craik carried out research into the question of realism in simulation in 1983 in the inception of the Berkeley Simulation Laboratory regarding the differences between simulation technology *(10)*. Bosselmann summarizes the factors that Kenneth Craik considered in 1983 for the Berkeley Simulation Laboratory regarding how an individual perceives an environment. Among these factors are the characteristics of the observer, including attitudes toward the environment. Because of the range of pedestrian users, this research will be attempting to consider subject characteristics as the primary factor influencing design of the PED-SIM at TTI.

There has been research in the field of landscape architecture regarding the economic and safety impact of greening initiatives on driver behavior. But as of yet, there has not been a controlled evaluation of what aspect of the landscape is having the apparent impact. The Texas Transportation Institute's Driving Environment Simulator is positioned to evaluate the roadside landscape and urban design treatment of the pedestrian environment on driver behavior. Using compatible technology, TTI will be in a position to evaluate the impact of landscape technologies on pedestrian behavior in the future. Currently the effects of changes in the pedestrian environment is hindered by the absence of pedestrian environment simulation research which can capture the pedestrian's visual and cognitive perception at low-risk.

Historically, there have been simulators for team training, flight training, battlefield, and car and train driving simulators. Human factors and planning research groups, psychology groups, and Artificial Intelligence research groups use these simulators for analyzing the situation models, mental models and cognitive task analysis. Because of an existing perception that pedestrians are being killed because they do not realize the cognitive and perceptual processes at work in drivers, the PED-SIM needs to develop as a simulation model that can be used for administrative decision making, as well as for pedestrian training. The TTI Driving Environment Simulator can provide the interface to facilitate research around the perceptual relationships between pedestrian and driver, using safety and response time as performance measures of existing standards.

By modulating the architectural environment of the simulated pedestrian realm based on case studies of field circumstances, researchers can examine thresholds of optimal environments on pedestrian and driver behavior at the same time. PED-SIM simulator can be structured to address the primary attributes that affect pedestrian perception and use of sidewalks as referenced above. It would be possible to measure the simulator to establish a standard measure for each of Bigelow's attributes *(9)* in order to rate the quality of various pathways and examine what constitutes an appropriate revision to the standard. This research aims to identify measures of each attribute as it affects people safety, health or comfort, or whatever the purpose of the walk.

Ecological analyses show that the human environment is a multi-dimensional and complex one *(11)*. But research has shown strong evidence that architectural attributes of the environment play bigger roles than the others *(10)*. In the case of suburban pedestrian facilities, pedestrians are mostly affected less by congestion and more by safety, the walking environment, and aesthetics *(12)*. So the first and foremost task of this simulator is to make the participant perceive the architectural attributes of the environment.

Many different kinds of simulations may be required to identify the variety of negative outcomes associated with poor environmental design and urban planning *(13)*. The simulator design is to include an interface with vehicular traffic so that the pedestrian environment can be evaluated in terms of proximity to vehicular behavior, as well as interacting (at intersections or crosswalks) with vehicular movements.

## FIELD DOCUMENTATION AND VIDEOGRAPHY

A critical consideration in the design of the simulator is to guarantee that the result of subject cognition under the simulated environment will match with real life conditions. In this regard, a series of video imaging of field conditions is underway. The fieldwork will be used to design the simulated environments. The test results from the simulator will be taken back to the field for corroboration.

In addition to locations in south Texas, locations to be documented include those identified as pinnacles of walking environments *(14),* or as places of high pedestrian deaths (environments within the road corridor where repeated pedestrian vehicular conflicts are occurring).

Video imaging results in visual portrayal of landscape changes, which can be used to assess the effects on individuals present in the simulated world. The video imaging is a very useful tool, which can be used to mimic the changes made to the environment. This is accomplished with computer aided tools that are not detectable, easily portray changes in the landscape, and provide a way to surrogate the environmental conditions. Most of the simulators currently used employ some form of video imaging to provide visual effects of the environmental condition under which the research is conducted.

A perpetual trap for researchers using video is the sophistication of the production styles used in the commercial television. The varying shots, the inserts, and the special effects are there to attract viewers and prevent them from switching to rival channels. Such methods can be counterproductive in interaction research where the purpose is to produce a details-comprehensive record rather than to encourage viewers to fill gaps from their imagination. This mistake is particularly likely to happen when recording is delegated to technical staff who do not fully understand the principles underlying the research, or how the tapes will be analyzed. A second consideration pertains to which persons, from which angles need to be included in the picture to produce a satisfactory sample of the interaction for this purpose. In general, it is difficult to make tapes which can satisfy more than one aim, and multipurpose recording should be avoided whenever possible *(13)*.

High positive correlation has been found between the video recording method and the controlled real life presentation. A similar relation is present between the facial expressions and a person's mental framework. The video technology can be used to present, in a controlled setting, a stimulus that can adequately represent the complexity of the original situation in order to elicit and measure the subsequent reactions *(15)*.

Maxwell, et al.*(16)* reports that there are 3 types of measurements possible with video records. They are behavioral measurement, behavioral judgement, and judgmental rating. This research is concerned with the judgmental rating, where the researcher is concerned with measuring the impression created by the subject. Frequently, judgmental ratings will be obtained in studies of person perception where the effects of various experimental manipulations on the impression are being accessed. Though there are inherent disadvantages related to video simulations, such as the inability to slow down the speed of events, limited measurements to easily codable categories, and the effects on raters of such variables as time of day, extraneous cues, and others. However, they can be overcome by researchers pilot testing the video and carefully eliminating or controlling common sources of bias.

## MOTION

Phillip Denne Guilden, et al. *(17)* reports that no one drives or flies in accordance with visual cues as primary response. Careful studies have shown that a person engaged in vehicle guidance control responds to tactile disturbance and only later to visual disturbance. This is thought to be due to the experiences of early life, which teach balancing skills as fast reaction to external forces on the body. It is anticipated that the motion and tactile experience of the body may have a cumulative impact on the subject's response before the visual impact occurs. These reactions are entirely subconscious and they act on the human brain to update the model of body motion and to predict its future position–there is no delay in an interposed consciously accessing reasoning process.

In pedestrian simulation, the issue becomes more complex as the pedestrian has a 1:1 aesthetic relationship with the surrounding landscape.

Simulated visual perception research focusing on landscape settings has been limited by the technological and cost restrictions of a simulator that can create an environment to help researchers assess the landscape effects on individuals. Simulating driving environments for the vehicular user is further developed partially because the perception mechanisms at work are not as detailed at higher speeds of movement.

The Texas Transportation Institute has a Driving Environment Simulator (DES) in place (Figure 1). While the design of the DES was made with the vehicular traffic research needs in mind, some adaptations to the existing infrastructure can facilitate simulation of some pedestrian environments. Recently, graphic technology has become less expensive and can provide researchers and practitioners with cost-effective simulations and projects in practice have been able to employ some crude, but effective 3-D simulation of landscapes in public information and outreach situations.

In the first iteration of the PED-SIM simulator, the research subjects will be allowed to move at normal speed on a treadmill-like device so that the physiological effect of motion will impact the reaction of the subjects to the environment. In this way, the subject's perception of being a part of the environment will also be enhanced, as their physical movement would match the movement of the image. It will be interesting to see how much the person's cognition power can help in matching the speed with which the film is shot and the person walks.

## SIMULATOR DESIGN FACTORS

The design of the simulator is based on considerations of the nature of multiple pedestrian activity to assure that the researchers, practitioners, and the public can benefit from a tool such as PED-SIM. The most challenging aspect of a modeling project, particularly where visualization is concerned, is that of managing expectation and controlling the scope and requirement creep. Managing expectations refers to the fact that the researcher has to keep in mind the inherent disadvantages in the visual models and try to keep within the limits of validity. The cognitive and perceptive responses are the limits of expectations that this research is based on. As stated earlier, there has to be a single goal behind each visual model. It will be futile if this study targets more than one pedestrian group in visual models.

Cost and realism of the image are major considerations in the physical development of the simulator. Investigations have shown that while frame-by-frame animation of videography is technically possible and yields a highly realistic visual outcome, it is cost prohibitive. Additionally, research in environmental perception indicates that using less sophisticated graphics, such as wire frame models, ultimately yields reasonable subject reaction. The DES technology at TTI has been advanced to the point where cost-effective expansion into the landscape and architectural realm of the pedestrian worlds seems to be the most likely line of pursuit in the development of the PED-SIM's graphic technology.

Arranging the simulator so that the researcher can observe the subject while the experiment is underway affects the results. Though direct observation has its own sources of artifacts and bias, it is frequently obtrusive *(18)*. The obtrusiveness refers to the fact that subjects are aware that they are being assessed. The problem with obtrusive assessment is that it can be reactive; that is, it can influence the performance of the subjects. As a result, the simulator should have an observation booth, which allows researchers to observe without impacting subjects' awareness that they are being assessed.

The next important source of subject evaluation will be from the facial expressions made by subjects in the simulator. The simulator should provide the facility to capture the observer's behavior in the simulator for the purpose of behavioral research to understand safety issues and health issues, the details of which are beyond the scope of this paper.

The need to capture the psycho-physiographic reaction of the person in the simulator is important, as it is related to safety behavior from the simulation on the participant. PED-SIM will incorporate the use of psycho-physiographic measuring devices to perform the same. This would complete a three-part evaluation of subject reactions: observation by researchers of pedestrian movement, recording of facial expression for future evaluation and psychophysiological monitoring of skin conductance, heart beat, etc.

The consideration regarding the type of people to be used as participants of the simulations is also a very important factor in the design of the simulator. The simulator must be easy to use for all people participating in research and with no age or sex barrier.

Because of health research concerns, the simulator must be able to respond to subjects who may require physical assistance from another person, wheelchairs and other ambulatory devices. Consequently, the simulator must provide flexibility in equipment size and resistance.

**Validation**

The PED-SIM is a general man-model simulator. The validation mechanism (Figure 3) of the PED-SIM and the Stimulus–Response Segment (Figure 4.) are the most important aspects, which provide guarantee that the observed readings are accurate.

Once the first components of the PED-SIM are in place, the simulator will be tested to assure that the data generated in the simulator is valid. The case-study process for this undertaking is described below. The most important difference, which researchers at TTI think will make the PED-SIM most accurate, is the Validation Phase illustrated in Figure 3. Firstly, the participant is made to walk through a predetermined neighborhood environment. During this walk through, researchers will record his perception of the environment. After a week, the same environment is reproduced in the simulator, the process is repeated, and observations are compared to make sure that the simulated environment is as close as possible to the natural environment.

The next important element in the design of the PED-SIM is its S-R Segment where researchers run preliminary simulation to acclimatize the participant of the research with the simulation environment. This enables the participants to adapt to the simulator settings. There are no observations taken during this period of the simulation. This gives subjects time for adjustment to the simulator settings before the actual simulation starts and ensures observations are as close as possible to real world observations as possible.

The Validation phase and S-R segment of PED-SIM are depicted as shown in the Figure 1 and Figure 2 respectively.

At this writing, the PED-SIM (Figure 2) is in the validation phase. Videographic and computer generated images are being tested. Treadmills, treadmill variants and various ground surface conditions are being tested. Field surveys of individuals representing different pedestrian user groups are being formulated based on interviews underway in several locations.

## CONCLUSION

The paper has discussed the parameters of the pedestrian user groups, the background of environmental simulation, as it is relevant to pedestrian environment simulation, and the methodology being undertaken to develop the PED-SIM at TTI. The conclusions in the design of the PED-SIM at this writing are as follows:

- Current research demand for pedestrian data is high. The simulator will provide a low-risk method for researchers around the country to conduct a wide range of transportation and health related pedestrian research.
- There is enough evidence that people who commute adjust themselves to provide space for other co-walkers. The simulator may be capable of capturing the adjustment behavior of the people in order to study the effect of width on the pedestrians to walk safely and to do a congestion analysis on sidewalks.
- There is enough evidence that people walking for health do require surfaces and configurations that differ from the continuous strip of scored concrete used for standard sidewalks. The simulator may be capable of evaluating different ground surface conditions.
- To utilize the data generated in decision-making regarding the configuration of transportation corridors for pedestrian accommodation, the results of critical simulated experiments must be recreated safely and field-tested.
- There are enough demands for safety research in this area that the simulator needs to be able to adjust to intersection and mid-block conditions. The pedestrian environments may be tied into the Driving Environment Simulator.
- The simulator needs to evaluate existing and proposed pedestrian environments at a level realistic enough to be friendly to public decision-making and technically accurate to be useable by layman, the transport-people, as well as transportation and health researchers.
- The simulator needs to operate in a cost-effective and efficient manner.

## REFERENCES

1. Traffic Safety Facts 1997. Report DOT-HS-808-806. NTHSA, U.S Department of Transportation, Washington D.C., 1998.
2. Untermann, Richard K. Accommodating the pedestrian: Adapting towns and neighborhoods for walking and bicycling. New York: Van Nostrand Reinhold. 1984.
3. Seneviratne, P.N , and J.F. Morall. Level of Service on Pedestrian facilities. Transportation quarterly, Vol.39, No.1, 1985, pp.109-123.
4. Hildreth, Suzane. "The new Body/Mind workout". In Natural Health (Jan/Feb) 1994, pp. 54-56.
5. Garcia, Mariano, Chatterjee, Anindya, Ruina, Andy, Coleman, Michael. The simplest walking model: stability, complexity & scaling. ASME Journal of Biomechanical Engineering, 1998.
6. McGeer, T. Passive dynamic walking. International Journal of Robotics Research*,* Vol. 9, No., 2, 1990, pp. 62-82.
7. Fruin, John J. Pedestrian planning and design. Mobile, Ala.: Elevator World, 1987.
8. Special Report 209: Highway Capacity Manual, 3rd ed. TRB, National Research Council, Washington D.C., 1994.
9. Bigelow, J. "Determination of a Suburban Pedestrian Facility Level of Rating Scale. Undergraduate thesis. University of Virginia, Charlottesville, 1999.
10. Bosselemann, P. and Craik, K.H. Perceptual simulations of Environments. Bechel, Marans, R. & Michelson, W. (eds.), Methods in environmental and behavioral research. New York: Van Nostrand Rinehold, 1978.
11. Stokols, Daniel. Strategies of Environmental Simulations Theoretical, Methodological, and Policy Issues. Marans, R.W. and D. Stokols, (eds.), Environmental Simulations: research and policy issues, 1993.
12. Miller, John S., J. A. Bigelow, and N. J. Garber " Calibrating Pedestrian Level-of-Service metrics with 3-D Visualization.
13. Summerfield, Angela B. Recording Social Interaction. Dowrick, P.W. and J. S. Biggs, (eds.), Using Videos Psychological and Social Applications, Chapter 1, pp.3-12.
14. Jacobs, Allan B. Great Streets. MIT press, 1993.
15. Casswell, Sally. Applications of Recording Human Performance. Dowrick, P. W. and J. S. Biggs (eds.), Using Videos Psychological and Social Applications, Chapter 2, pp.13-21.
16. Maxwell, Gabrielle M., K. Pringle, and K. Judith. The Analysis of Video Records. Dowrick, P. W. and J.S. Biggs (eds.), Using Videos Psychological and Social Applications, Chapter 4, pp. 33-45.

17. Phillip Denne Guilden Ltd UK. The Mother of Invention. International Conference on Simulation, 1998, pp. 1-7.
18. Crook, Steve. The use of Simulation and Virtual Reality in the Design of Airport Terminals. In International Conference on Simulation, 1998, pp. 8-11.

LIST OF FIGURES

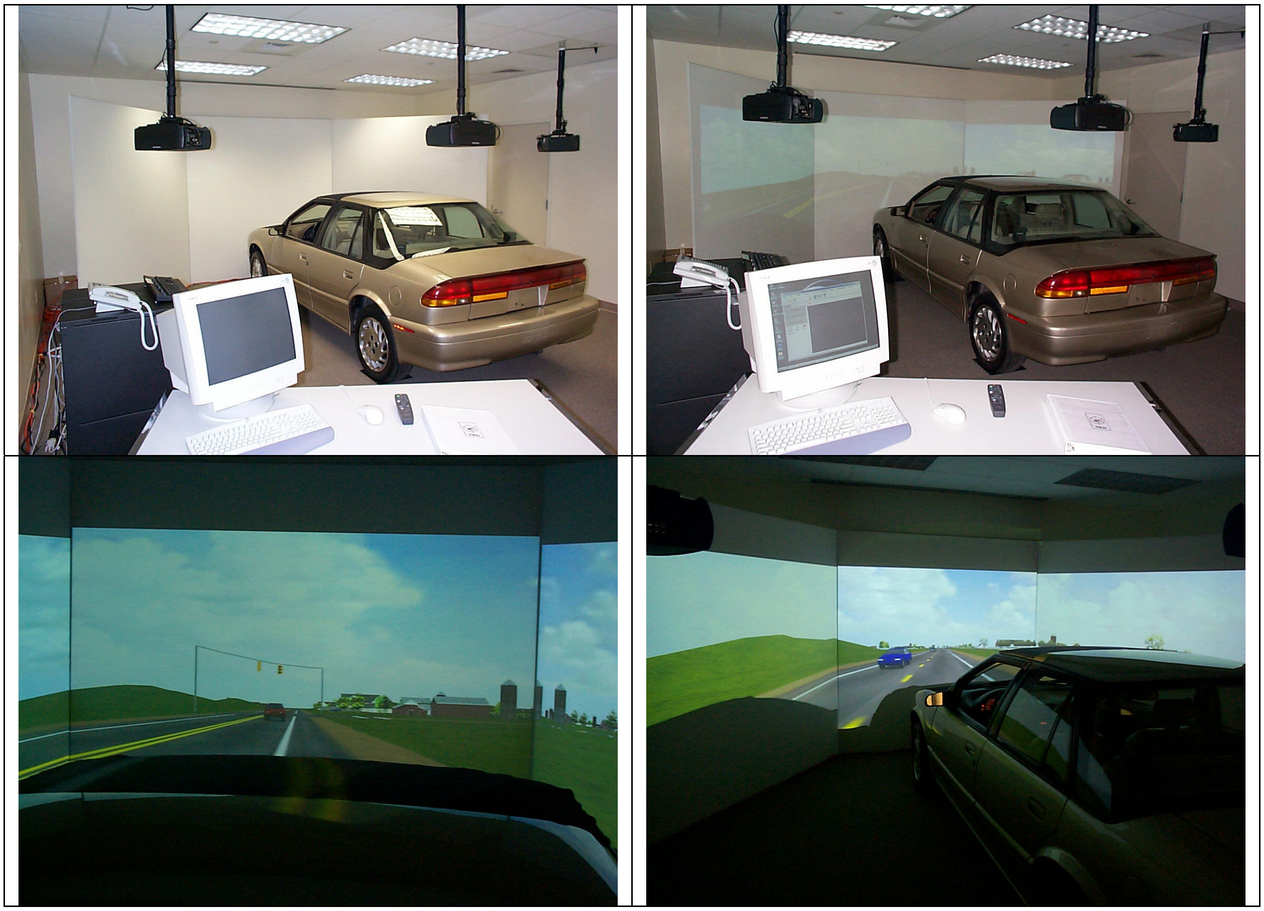

FIGURE 1 DES at the Texas Transportation Institute, Texas A&M University.

FIGURE 2 Typical Sidewalk and Crossing images used in PED-SIM.

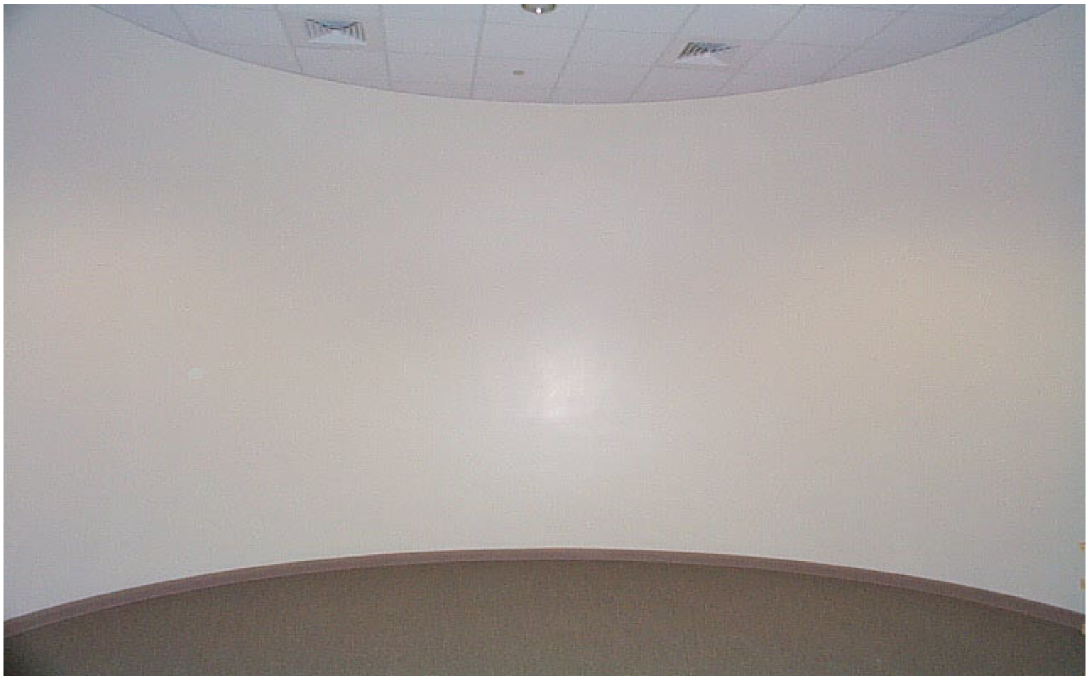

FIGURE 3 PED-SIM Curved Projection Walls.

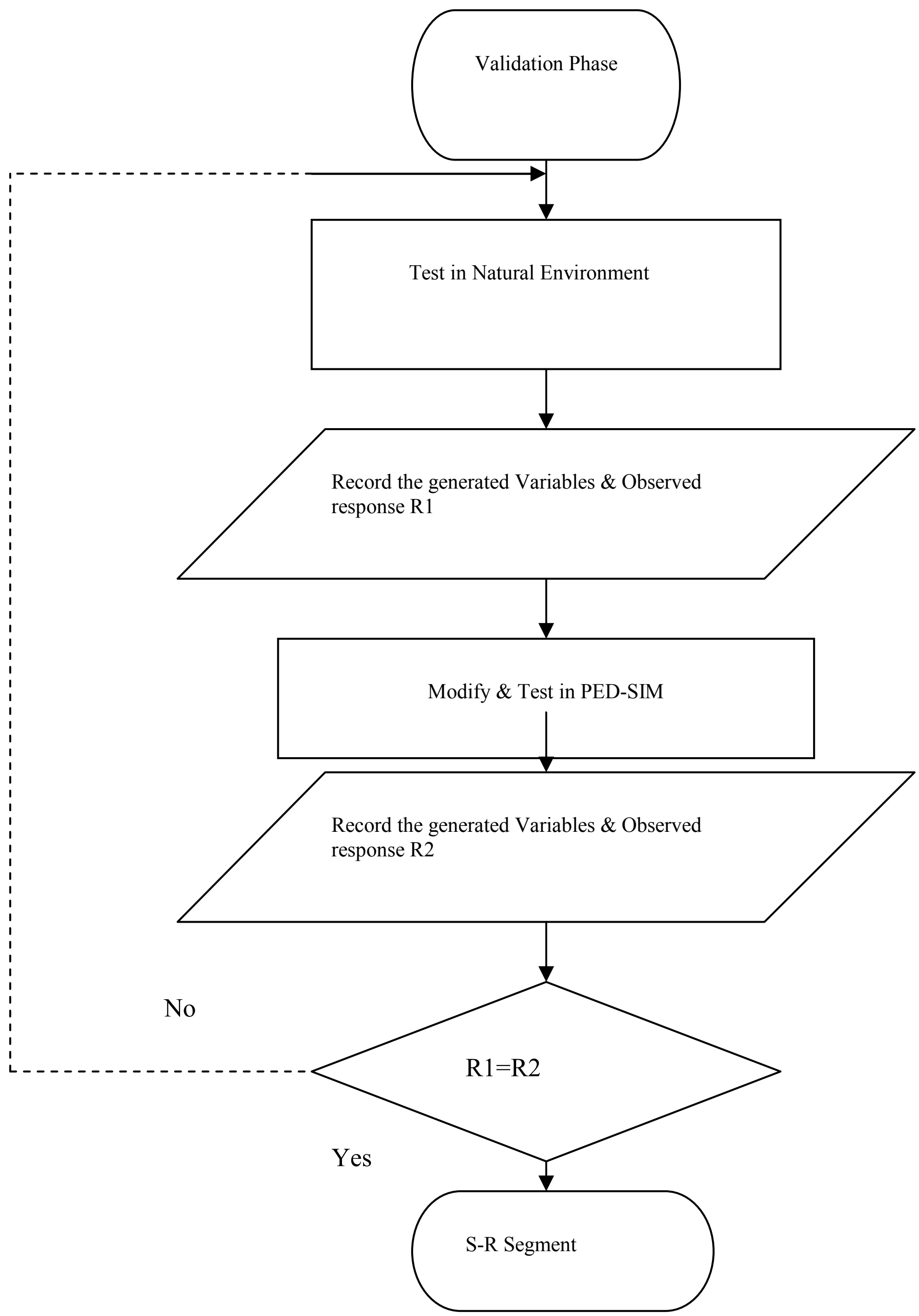


FIGURE 4 Validation Phase of PED-SIM

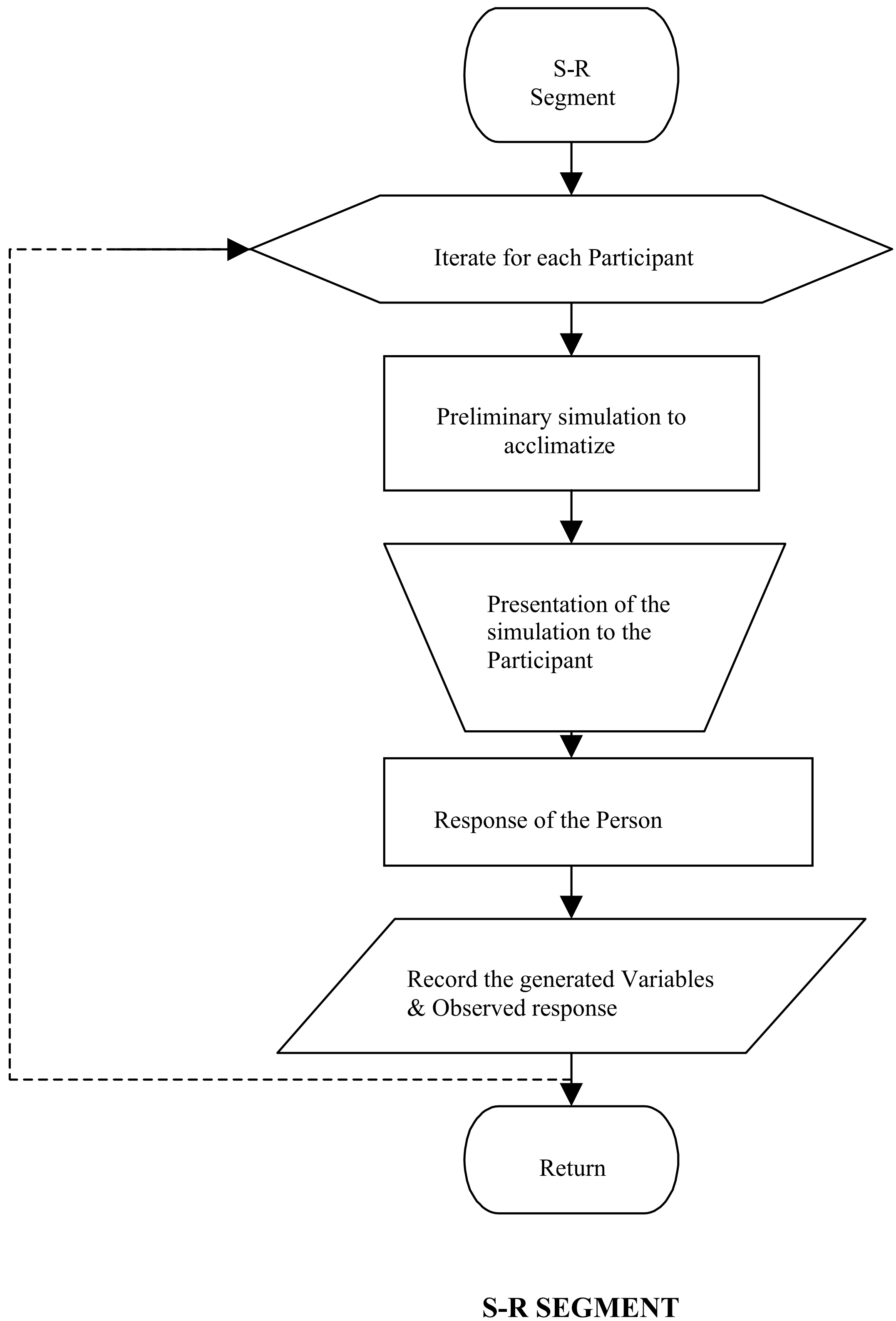


FIGURE 5 Stimulus Response phase of PED-SIM.