

Front-Loading of Occupant Ingress-Egress Targets in Vehicle Architecture

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ABSTRACT

Achieving comfortable Ingress-Egress (I/E) is a major ergonomic challenge for Occupant packaging engineers during vehicle design. Vehicles should be designed so that the targeted drivers are able to comfortably get in and out of it. Simulating occupant ingress/egress motion for vehicle involves many constraints and capturing actual behavior of human motion is cumbersome. In recent years, there are number of studies to investigate occupant ingress/egress motion and to understand perceived discomfort, influence of specific design parameters, age impact etc. These studies majorly used techniques like real time motion capturing in a vehicle mockup, comparison of joint torques developed during the ingress/egress motions etc., to identify the occupants discomfort aspects. This paper aims to capture the ingress/egress influencing parameters and incorporating the parameters in vehicle architecture layout during concept phase itself considering various anthropometric measurements. The critical areas affecting occupant ingress-egress were identified and the related vehicle dimensional targets as per SAEJ1100 were front-loaded in vehicle architecture layouts. This helps to monitor the ingress-egress targets & ensure minimal design changes during vehicle development phase.

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INTRODUCTION

The ease of getting in and out of a car is one of the ergonomic issues that catch the attention of many car manufacturers. It represents the first physical contact of the customer with the car. Therefore, it is important to ensure a pleasant sensation while accessing the car [1]. Many useful researches have been conducted around the world to study I/E related issues on humans. It is one of the interest research area since it has many degrees of freedom and complex motions involved. I/E scenarios of occupant studied using Digital Human models (DHM) in a virtual CAD environment to represent the I/E motion and study the design impacts. But I/E study in virtual environment is difficult due to its combined requirements motion variations, population variations and age specific body restrictions such as Range of Motion and joint strength for I/E. *Don B Chaffin* talks about the general problem of lacking of inbuilt posture and motion prediction models for various populations in DHM which prevents us from doing dynamic human performance prediction specific to particular population in virtual environment [2].

The studies also focusing primarily on the actual user trial conducted on physical mock up to understand the occupant comfort aspects during I/E. Various subjective questionnaires about the discomfort and ease of getting in and out of a vehicle are also used. This method will provide us subjective feedback data of users' perceived discomfort in a rating scale [3]. But this process is limited to subjective rating and the rating can be varied based on the sample selection and physical mock up capabilities. Next improvement in this evaluation is creating the database from user trials and incorporating the motions onto DHM to assess I/E of vehicle in CAD environment [4].

Few researches are improved the above scenario in measuring load/torque exerted on human joints during I/E body motions. These studies are helpful in understanding musculoskeletal related issues in human. The joint loads developed during car I/E motions, and in particular the motor torques (torques acting along the degrees of mobility of the joints), might be an important parameter to explain the difficulties perceived by drivers while getting in and out of cars [5]. *T Robert et al.*, studied and estimated the joint torques developed during I/E motions and analysed the influence of the car geometry and subject anthropometry on the torques developed.

It is evident that many methods have been developed and still evolving to meet I/E requirements and using one method alone won't be sufficient to identify I/E characteristics. Front loading Occupant packaging targets in vehicle architecture definition is a major task since it is the key factor that differentiates the success of vehicle in market. This requires the influencing parameters affecting I/E to be front-loaded in the vehicle architecture that can be monitored during the vehicle development. Few studies focused on the influence of specific car design parameters on I/E motion and discomfort. There are few most critical vehicle design parameters influencing such as the roof height, sill height and width identified [1]. Keeping this in mind, a methodology had been worked out in this article to identify and link the vehicle design dimensions in vehicle architecture to meet I/E requirements of the target occupants.

METHODOLOGY

Understanding how drivers and passengers move and interact with respect to a vehicle is very important for vehicle packaging. I/E is a typical example of such motion and interaction. Being able to assess a vehicle's I/E performance early in a design process is therefore crucial to successful vehicle development [4]. In order to front-load I/E requirements of occupants on vehicle architecture, the following methodology has been worked out. This also aims to identify and incorporate the specific I/E requirements with respect to Indian ethnic attire like *saree* and *dhoti* influence the motion characteristics of users.

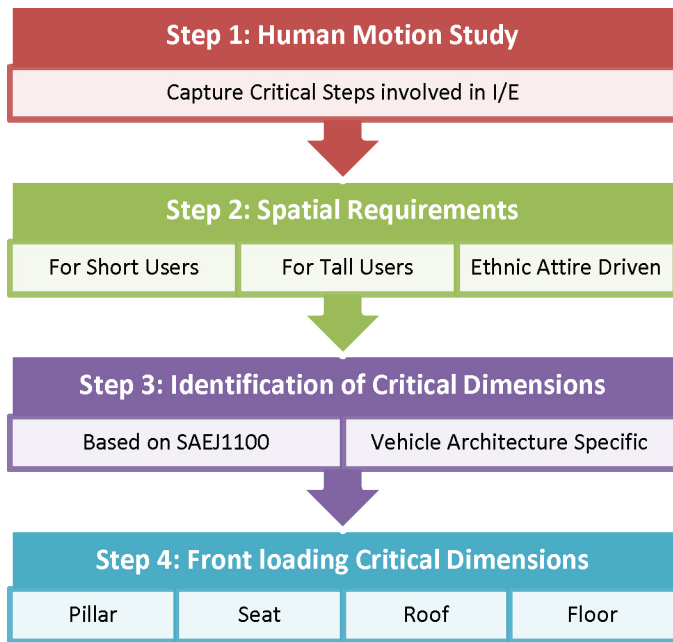


Figure 1. Methodology to front-load I/E requirements on Vehicle Architecture

STEP 1: HUMAN MOTION STUDY

Studying human motion behavior is the first step to understand I/E process. Though many such attempts have been already done, it is important to create database capturing occupant experience during I/E process from demographic variations, cultural variations and age specific motion variations into design.

M. LU *et al*, investigated the elderly people's motion strategies when entering and exiting the rear seat of minivans with sliding doors. This study found in either the ingress motion or the egress motion, nine critical key frames that can be defined based on the timing when the subject's body posture starts to be affected by the car components. For example, when the head passes through the door frame, the body posture may be changed in order to react to the different roof height or door width. Each individual thus takes a specific posture according to the relationship between his body size and the vehicle geometry [5].

In order to explore the I/E scenario specific for Indian population, a three row seating multipurpose right hand drive vehicle mockup has been made and relevant interior and exterior dimensions were maintained as per design to capture the critical frames where the body posture is impacted by the vehicle architecture. Total 33 subjects including tall and short stature from the target population made to complete I/E task in seating buck. Video frames are analyzed to identify critical vehicle areas impacting occupants during I/E.

STEP 2: SPATIAL REQUIREMENTS

Spatial requirements for users during I/E depends on the occupants body motion scenario and Vehicle architecture. Length, width, height and clearance requirements of occupants in vehicle architecture are identified from the human motion study.

The prediction of human movement strategies is a complex topic, but two observations are important here. First, strategy for ingress and egress is associated with both design variables and subject characteristics in an interactive way. For example, shorter-stature people may be more likely than taller people to choose a headfirst strategy for a given vehicle door opening. However, decreasing the available space will cause more of the taller people to use a hip-first strategy, until for a very small door opening nearly all people will use the hip first strategy. Hence, while taller and shorter people may have preferences that are usefully associated with their body size, the preferred strategy is dependent on the environment [6]. Thus the spatial requirements of short and tall occupants are differently influenced by the vehicle architecture.

Short Driver I/E Scenario

During ingress for driver seat, it is observed that most of the users using their left foot to reach the floor first and followed by their hip entering the driver seat as shown in the [Figure 2](#).



Figure 2. Short User Ingress motion for 1st Row

Right foot reaching ground first and cautiously taken their head out during the egress as shown in [Figure 3](#).



Figure 3. Short User Egress motion for 1st Row

Passenger I/E Scenario for Short User @ 2nd Row

During ingress for passenger seat, it is observed that most of the users using their right foot to reach the floor and followed by their hip entering to 2nd row passenger seat as shown in the Figure 4. The egress scenario found similar to the ingress scenario like foot reaching ground first followed by the hip exiting the seat as shown in Figure 5.



Figure 4. Short User Ingress motion for 2nd Row



Figure 5. Short User Egress motion for 2nd Row

In case of ingress into the 3rd row passenger seat, the second row passenger seat to be tumbled as found in most of the 3 row multipurpose vehicle. It is found that, users using their right foot to reach the floor cautiously moving their head and followed by their hip entering 3rd row passenger seat and passing their legs between the tumbled seat and the C-Pillar.

Figure 6. Short User Ingress motion for 3rd Row through second row door

This is the toughest task compared to any of the row seat position for the users since they have to make more than two steps inside vehicle with limited roof. Users found cautious about the head and shoulder clearance during I/E into the 3rd row. Figure 6 and Figure 7 shows the ingress and egress scenario of short users for the 3rd row seat position.

Figure 7. Short User Egress motion for 3rd Row through second row door

Tall Driver I/E Scenario

Tall driver I/E requirements are identified from the motion analysis done for tall users. It is found that, the users taking upper body between seat bolster and BIW top first and entering their hip to the seat. Subsequently, the user swinging their knee and foot from outside to inside vehicle. High clearance is of prime importance since the user have to cross the steering wheel in order to attain the driver seating posture. Figure 8 and Figure 9 shows the Ingress and Egress Motion of the tall drivers respectively.



Figure 8. Tall User Ingress motion for 1st Row