Seat Design of Drivers Cabin for New EMU Rakes of Mumbai

Kundu Amar, Sharma Nishant and Ray G.G.
IDC, IIT Bombay, Mumbai

ABSTRACT

The Mumbai Suburban Railway is the first rail system in India which began services in Mumbai in 1867 transports today about 6.3 million passengers daily and has the highest passenger density in the world. The drivers (Motormen) are driving more than 8 hours in a day. They are suffering from musculoskeletal and psychophysical stresses due to their unsuitable workstation.

Considering the age old existing workstation design a new ergonomics based design approach is undertaken to redesign the workstation with advanced instrumentation. At present the operation is mostly in standing posture and drivers have difficulty in external visibility along with associated musculo-skeletal and psychophysical stresses with special reference to shorter drivers as per the UIC code while they are driving in sitting posture. The lack of ergonomics considerations in workstation design, layout, chair design, leg room while sitting, visual cone in horizontal and vertical plane, communication, personal space and so on as against operating the train, passenger behavior, trespassing etc. depicts a list of risk factors in driving train.

This paper highlights on the modification made in the chair design for the motormen based on the new concept workstation provided to us.

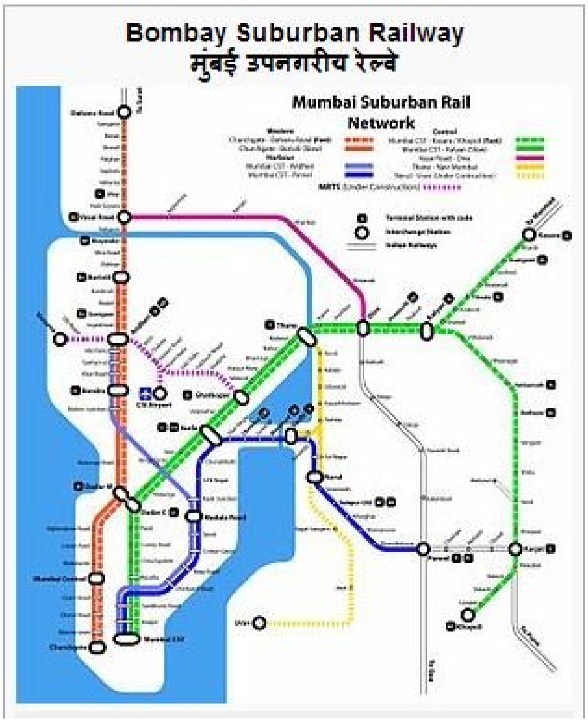
A user centered approach based on drivers' behavior and understanding the issues were made on board by personal interview method and observation method. 62 different anthropometric measurements of 50 motormen age range 30 to 60 years were collected by using 3D whole body scanner. Based on 3D anthropometric data a 3D model of the chair and the workstation were made by using Solidworks CAD software. The CAD drawing was then converted to a full scale prototype for simulation study.

A new concept horizontal and vertically adjustable chair with adjustable footrest was designed and fabricated o fit in to the given workstation to accommodate 5th to 95th percentile motorman. Visual limits in horizontal and vertical planes were also taken into account while optimizing the static and dynamic dimensions of chair. Care was taken to provide proper backrest, hand rest and footrest. Driver comfort was also taken into consideration while designing the chair.

Key words: Seat design, drivers cabin, EMU rakes

INTRODUCTION

Railways in India is an important public sector in terms of high revenue earning due to its highly integrated networking throughout the country. While the long distance trains connects different parts of the country, the suburban trains takes the major load of high volume of commuter transfer who are usually called as "Daily Passengers" usually travelling a distance between 200 to 150 km to reach the main city. To reach the main city suburban train service is one of our prime concerns for transferring the daily commuters timely and safely. Mumbai suburban railway is the first rail system in India which began services in Mumbai in 1867. Spread over 465 km, fig 1, Mumbai suburban railway operates 2342 train service and carries more than 7.24 million passenger daily and has highest passenger density in the world.



Background	
Locale	Mumbai Metropolitan Region, Maharashtra, India
Transit type	Suburban Rail
Number of lines	6
Number of stations	Western: 36 Central: 62 Harbour: 38
Daily ridership	7.585 million[1]
Annual ridership	2.64 billion
Headquarters	Churchgate (WR) Chhatrapati Shivaji Terminus (CR)
Website	Western Railway Central Railway
Operation	
Began operation	16 April 1853
Operator(s)	Central Railways Western Railways (Western Line only)
Train length	9/12/15 coaches
Technical	
System length	427.5 kilometres (265.6 mi)
Track gauge	1676 mm (5 ft 6 in) Broad Gauge
Electrification	1500V DC/25,000V AC Overhead catenary
Average speed	50 km/h (31 mph)
Top speed	100 km/h (62 mph)

Fig 1: Route of Bombay Suburban Railway (Source: Wikipedia- Mumbai Suburban Railway)

While transfer of daily passengers is of prime concern, their lives are in the hands of the motormen who drive the suburban trains or Electric Multiple Units (EMU) coaches. With high load of mental load in terms of trespassing, daily passengers' issues, management issues it is really a miracle that how these trains are running on time and safely. The high level of Physical, biomechanical, psychological and environmental load the motormen (drivers) are exposed to while operating the age old motorman's cabin is one of the major factor in stress accumulation. With the advancement technology, and demand in better quality of service, it is now imperative to relook at the motorman's cabin and redesign it considering different issues like motorman's operational ergonomics, work posture, remote communication, visual limitations, and fatigue accumulation and so on.

The Mumbai Railway Vikas Corporation Ltd (MRVCL) a public sector undertaking of Govt. of India, under the Ministry of Railways, is responsible to execute the New Generation Mumbai Urban Transport Trains as sanctioned by Ministry of Railways. Out of multi-faceted approaches, one of the major approaches is redesigning the Motorman's cabin with integration of state of the art technology and ergonomics.

PROBLEM IDENTIFICATION

To understand the issues while driving the EMU rakes, 12 of experienced (more than 5 yr) motormen were observed while driving the train to and fro from one end to the other end of their travel route. Each route comprised of about 2 to 2.5 hour journey. Video photographs were recorded and a questionnaire was introduced to obtain the issues of dissatisfaction/ discomfort felt by them. Motormen were also allowed to give their suggestions for improvising the driving system. The study was conducted in Mumbai and all the motormen were responsible in driving the Mumbai Suburban EMU trains. Paragraphs below highlight the issues emphasized by the motormen.

Sitting Posture and Master control holding posture

- The right hand of the motorman is always engaged with the master control or Dead Man's Handle (DMH), the left arm with the brake control and other operations, the right leg with the hooter and the left leg is used to support him on the floor while standing or in sitting posture.
- Long gap between the seat and workstation, fig 2, forces the motorman to bend forward and sustain it for long time. This results in muscle fatigue in both hands, especially in the right for sustained operation of the DMH.
- Motorman cannot keep both the legs properly in the space since the master controller unit occupies a portion of the leg room space.
- The arm rest of the chair is placed below the hip level of the motor man. Similarly, due to the low height work surface and restricted leg room, the motor man is compelled to sit forward and seldom uses the backrest.

Fig 2: Unergonomicsitting posture due to insufficient workspace

A tall and bulky motorman (95^{th} - percentile) in terms of body depth has difficulty in placing his legs within the specified leg room as shown in fig 3. This forces him to take awkward sitting postures which are difficult and non-ergonomic.

Fig 3: Motormen are unable to keep their legs in the leg space provided

Whereas a motorman towards the 5^{th} percentile in body height has his legs dangling from the chair since there is no mechanism to adjust the height of the chair. Even if there is a mechanism to lower the chairs height, his eye will drop down below the required visual cone.
The left hand of the motorman is mostly free during the journey but the right hand is continuously loaded for operating DMH or the master control. There is no proper hand support provided to keep the left hand which in other way will be hanging. Naturally the motormen use the emergency brake control as a hand rest, fig 4, which he is not supposed to do.

Fig 4: Using emergency break to balance him

Each motor man has his own way of holding the DMH, fig 5, usually to be operated by ight hand. He shifts his holding position frequently during the journey. He even shifts his hands. ustained muscular loading with high degree of wrist dorsiflexion are the main issues.

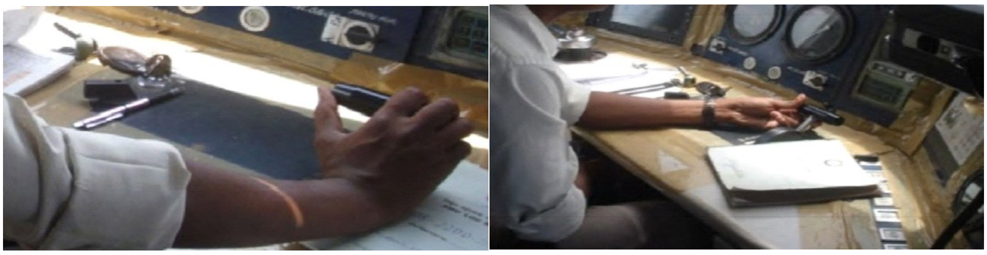


Fig 5: Non-ergonomic posture to operate the main control

Some motor men were found to be using the log book as a support for the Right wrist. The screws of the master controller were hurting the wrist of the motorman. Stretched and unsupported arm, shoulder weight is transferred to the twisted wrist. The fatigue in thumb and wrist is transferred to the entire hand, shoulders and in turn causes back pain.

- There is a need for support to the hand which holds the main control (DMH). The height of the table is very low and the arm rest is way below the elbow of the motor man.
- The design of handle and the reach should be such that it reduces the fatigue on people with varied body dimensions.
- The main objective of our study was to design a seat for existing workstation, which helps motorman to maintain ergonomic sitting posture.

GENERAL GUIDELINE

The MRVCL is following the UIC (French: Union Internationale des Chemins de fer or International Union of Railways) code for Motorman's Workstation Design as mentioned below.

Seat related:

1. Drivers cab must be designed to cater for operation by a lone driver
2. The driver's seat must be laid-out in such a way that the driver is seated and facing the track when driving.
3. The driver's seat is positioned on one side of the cab, so that he/she can keep the train under observation from side which he/she occupies, and communicate with station staff while at the same time still being able to operate the brakes.
4. The driver's cab must be designed so that the driver can also drive in the standing position.
5. An extra seat facing the track must be provided for a second person.

Visibility from driver's cabs:

6. Visibility of high signals: High signals located up to 2.50 meter to the right or left side of the track center, and positioned at a height of up to 6.30 meter above the running surface, must be visible over a distance of 10 meter or more between them and the front plane of the buffers.
7. Visibility of low signals: low signals located to the right or left of the track, level with the running surface,z and at a distance of up to 1.75 meter from the track center, must remain continually visible over a distance of 15 meter or more between them and the front plane of the buffers.
8. It was agreed that the minimum distance at which low signals are visible should be reduced.

METHODOLOGY

To begin with, the user study, activity analysis & problem identification were carried by using personal questionnaire and observation method. Whole body 3D Anthropometric data were collected by scanning the whole body of 50 motormen using a 3D scanner (Anthroscan 3D VITUS smart XXL; Human Solutions Company, Germany). Statistical methods were used to obtain 5^{th}, 50^{th} and 95^{th} percentile value of each anthropometric dimension. 2D Manikins were made by using these anthropometric data. A questionnaire on body discomfort was distributed to all the motormen. The questionnaire included a body map to help the participants identify the different body areas in question and their boundaries. The body areas in the questionnaire were neck, upper back, lower back, shoulder, elbow, wrist, hip, thigh, lower leg and foot. The discomfort level ranged from 0 for no discomfort to 5 for maximum discomfort. It was observed that some of the motormen could not rank the level of discomfort as per the given scale. They just wrote the segment name of type of discomfort.

ANALYSIS OF SEAT LOCATION, DIMENSIONS AND FOOT REST LOCATION

A list of problems and issues pertaining to Chair design has been mentioned earlier. Most of the Motormen were complaining for the existing chair design. Based on the CAD model on new generation workstation, as received from MRVCL, ergonomics analysis of existing workstation was carried out by using the manikin derived from the anthropometric data derived from the Indian motormen data as shown in fig 6. According to the UIC code, Motormen need to see the lower level of signal at a distance of 15 m from the front buffer and upper level of signal at a 10 m distance from buffer.

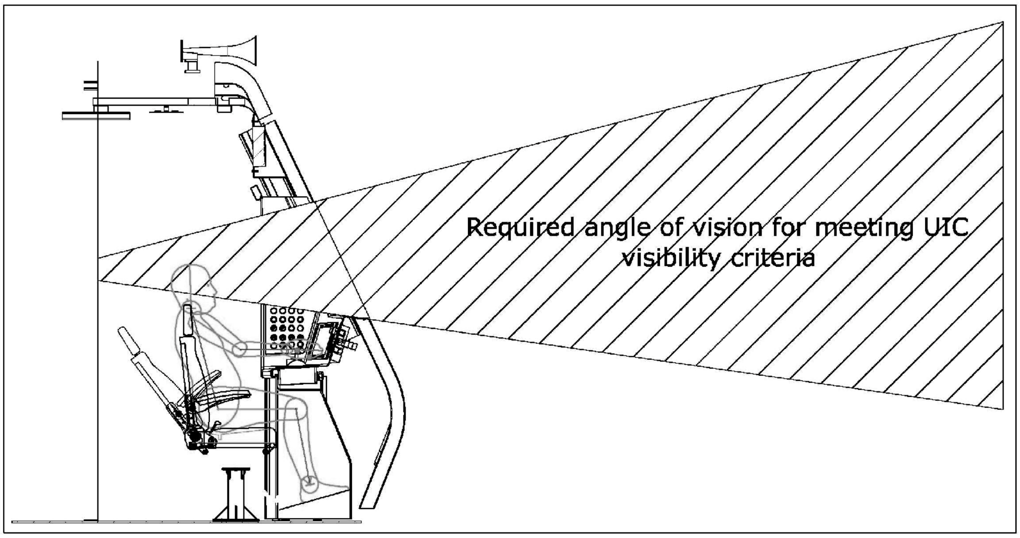


Fig 6: Existing Workstation & Required visual cone

To fulfill the UIC recommendation, the motormen's eye must be within this visual cone which should be achieved by the proposed modified chair. As per general ergonomics practice, one must take into account the eye level of both the tall (95^{th} %ile) and short (5^{th} %ile) Indian motorman. While fixing the eye position for the 95^{th} %ile, (fig 7a) a 25 mm clearance between the thigh and the bottom surface of worktable was obtained. The backrest angle was provided to 105^0 which is usually considered for the general alert type working chair. The knee angle was fixed to 105^0 which was the available maximum under the given design condition. A shoe clearance of 30 mm was provided as mentioned in UIC specification. In the existing workstation no proper armrest was provided. From our analysis the seat height (including compressed seat cushion) for the 95^{th} %ile was derived as 475 mm, armrest height (fixed) observed as 300 mm from SRP. The footrest height observed was 85mm and footrest angle was 120 upward.

In relation to 5^{th} percentile motorman, (fig 7b) the seat height became to 525mm, armrest height was 300 mm & footrest height worked out was 195mm. Forward & backward (X-axis) travel of the seat as achieved was 190 mm for easy ingress and egress (swivel motion). With 190 mm forward-backward (X-axis) travel of the chair a space between the chair and the back wall was just sufficient for one person to move behind the chair in need. But this space (25 cm) was not sufficient if a 95^{th} percentile motorman want to move behind the chair while the chair has been pushed backward to the extreme by another 95^{th} percentile driver as evident from fig 7c. The larger abdomen size of the motorman due to sedentary job may be the reason for this.

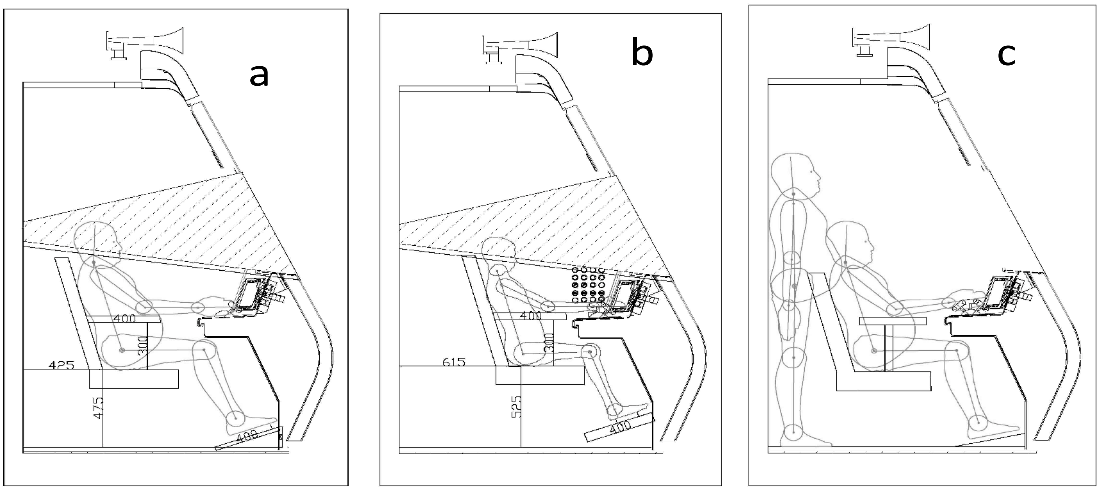


Fig 7: Ergonomic Sitting posture of (a) 95^{th} %ile, (b) 5^{th} percentile motormen. (c) 95^{th} %ile motorman is sitting in his workstation & 95^{th} %tile motorman trying to pass behind the driver's seat

Other relevant dimensions related to the proposed chair design are given in Table 1.

Table 1: Different relevant dimensions of the proposed chair

Parameters	Existing Dimensions	Dimensional consideration	Recommended Dimensions
Cushion Width	490 mm	95th percentile hip breadth (480mm) + Clearance	540 mm
Seat Total Width	580 mm	95th percentile Elbow to Elbow (608mm)	610 mm
Backrest Breadth	475 mm	100th percentile chest breadth (403mm) + Clearance	450 mm
Backrest Height	475 mm	100th percentile lower lumbar ht (193mm) to 0th percentile sitting acromion ht (524mm)	190 mm to 525 mm
Cushion Ht	512 or 612mm	According to ergonomic analysis 475mm – 525mm	475mm – 525mm
To and Fro Adjustable		According to ergonomic analysis (190 mm)	190 mm
Seat cushion Depth	440 mm	1st percentile buttock popliteal length (423 mm)	420 mm
Seat Reclining	30 degree	15 degree	15 degree
Armrest Length	333 mm	5th percentile forearm length (213mm)	210 mm
Armrest Breadth	45 mm	50th percentile forearm breadth (95 mm)	95 mm
Armrest Height		5th percentile Elbow Rest height (300 mm)	300 mm
Footrest Height	130 mm	According to analysis (85 mm – 190 mm)	85 mm – 190 mm
Footrest Depth		100th percentile foot length + Shoe clearance + Clearance (284 +50+50) mm	400 mm
Footrest Breadth	560 mm	According to workstation design (560 mm)	560 mm
Footrest Angle	30 degree	According to ergonomic analysis (12 degree)	12 degree

DESIGN AND DEVELOPMENT

From the study and subsequent discussions with drivers it was concluded that the seat required minimum three movements in terms of 1) Forward/Backward movement (X-Axis, +/- 95mm from the center of seat mount on floor), 2) Vertical movement (Z-axis, 475 to 525 mm from floor) and 3) Swivel motions for easy ingress and egress.

DESIGN OF SEAT: SEAT BASED HEIGHT ADJUSTMENT

Motormen's seat height adjustment is an essential component for such driving operations to fit the maximum motorman population with variable anthropometric dimensions. This adjustability should be achieved by the motormen with minimum human efforts and minimum operations. A vertical travel of 50 mm (475 – 525 mm) was to be achieved keeping in mind the other adjustments. In the Proposed concept, a screw Jack mechanism, fig 8, was used as mentioned earlier.

	Challenge faced	Solution found
1.	Torque multiplication	3X gearbox
2.	Parallel movement	Guide rods in Channels
3.	Maintaining Alignment during X axis traverse	Rods moving in a slot
4.	Assisting lifting of weight	Torsion Springs
5.	Easy access to the chair	Swivel motion with a lock
6.	Locking the seat height at specific location	Screw Jack

Fig 8: Mechanically adjustable seat using screw jack mechanism (A- CAD Model, B – Prototype Model)

FOOTREST DESIGN

To make the seat height compatible with the motormen, a foot rest with height adjustability was conceived along with the chair design. Height Adjustment is an essential feature for the footrest to fit a large number of users with variable anthropometric dimension. Care was taken such that the operation of the foot rest should be performed with minimum human efforts and minimum operations. A vertical travel of 100 mm was to be achieved keeping in mind the other adjustments. In this concept, a scissor mechanism was used for the height adjustability of the footrest. A torsion spring helped the upwards movement of footrest and by foot pressure it could go down. For sliding of scissor mechanism throughout the base, regular robust sliding mechanism already available in the market was used. A concept model of the footrest is shown in fig 9.

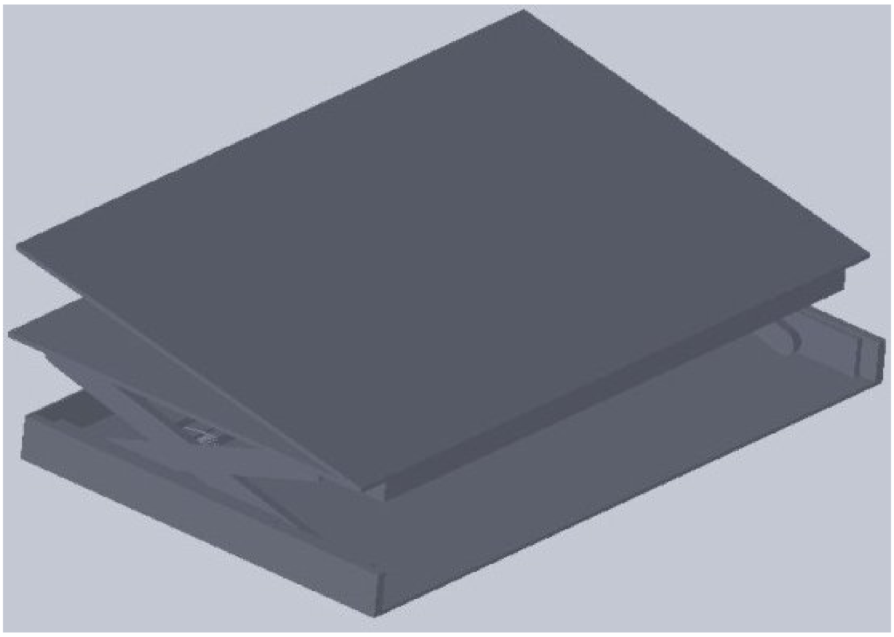


Fig 9: Adjustable Footrest

CONCLUSION

A new concept horizontal and vertically adjustable chair with adjustable footrest was designed and fabricated to fit into the given workstation to accommodate the 5^{th} to 95^{th} percentile motorman. Visual limits in horizontal and vertical planes were also taken into account while optimizing the static and dynamic dimensions of chair. Care was taken to provide proper backrest, hand rest and footrest. Driver comfort was also taken into consideration while designing the chair. The entire concept with executable engineering drawings has been submitted to MRVCL for execution.

ACKNOWLEDGMENT

The authors take pleasure to say thanks to all the motormen for their support during the study and to MRVCL for sponsoring the project.

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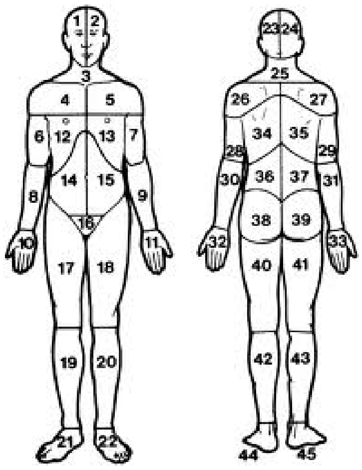
ANNEXURE: 1

Questionnaire for Anthropometric Study

1. Sl. No:
2. Age:
3. Gender:
4. Place of Origin: (State Wise):
5. Place of Work: (State Wise):
6. Education: (Secondary, Graduate, Masters):
7. Type of vehicle operate per day: (EMU, Car, Scooter/Two wheeler)
8. How long you take to reach from your residence to the Rly station for joining to your job?
9. By what mode you travel from Residence to Rly Stn & vise versa?
10. On average how many hours at a stretch you work?
11. Average Total Working Hour per day.
12. Do you have any off day schedule?
13. Do you get proper rest?
14. Do you feel any discomfort in your different body part after the end of your present EMU coach operation? If yes, what are those places? Can you mark them in terms of severity having highest pain as 5 point, no pain as 1 point?

    Head, eye, neck, shoulder (Rh, Lt), upper arm (Rh, Lt), forearm (rh. Lt), hand (Rh, Lt), Chest, Mid back, Hip, Thigh (Rh, Lt), Knee (Rh, Lt), Calf (Rh, Lt), ankle (Rh, Lt), Toe (Rh. Lt)



15. What was the most mentally stressful event you ever had so far?
16. Do you have any problem of Acidity or issue of constipation?
17. Do you suffer from any ailment? If yes, where?

    Thanks you for your support towards developing a better designed Motorman Cabin.