ERGONOMICS OF URBAN PUBLIC PASSANGERS TRANSPORTATION

Miguel A. Márquez
Jesús M. Garcia
Universidad Nacional Experimental del Táchira (UNET)
Laboratorio de Prototipos, Investigación y Desarrollo Tecnológico
San Cristóbal. Táchira. Venezuela

ABSTRACT

The present work contains an analysis, from the ergonomic point of view, of the urban public transport of San Cristóbal city, in which diverse aspects and variables related to the comfort and security of the users of this means of transport have been considered. The design of the drivers work station is also considered. Among the main aspects evaluated are the access and exit of the transport unit, the ease to arrive at the seats, dimensional access to the seats, and distribution of the seats. Each one of these aspects was related to anthropometric dimensions of the Venezuelan population, verifying its adaptation to the population of users. In addition, the dimensional data of the diverse units were compared with the values and parameters specified in the Venezuelan standard Covenin 51-92. Finally some suggestions appear on the actions to be taken in design terms that surely will contribute to improve the security and the comfort of the users. Special considerations are done taking into account elderly and children populations.

1 Introduction

The design of transport means has progressed considerably in the last two decades, mainly in the area of the comfort and security of the passengers. In European countries, USA and many others countries there are standards and regulations in order to prevent accidents and to assure the minimum conditions of comfort and safety of users.

Users differ in terms of age, stature, weight and mobility, therefore these factors must be considered in order to satisfy the users` requirements. The aspects to evaluate will be determined by the corporal dimensions of the population of users and by their mobility. The extreme cases are represented by those people of greater body size, individuals with physical limitations and specially the senior and young segments of population that by nature are most prone to accidents.

The basic aspects being considered are:

- Access and exit stairs of the transport units.
- Easy of displacement within the unit.
- Access to the seats.
- Space available in the seat for the user.
- Form of the seats and rakes of seat, and the back rest.
- Distribution of the seats.

2 Antecedents

The Engineer Pedro Rafael Velasquez, of the National Foundation of Urban Public Transportation (FONTUR), in his communication "Accessibility, Transport and Integration", exposes the importance of taking care of the people with disability or reduced mobility in terms of the right that they have to move freely and to maintain an appropriate standard of life, maintaining the principle of equality of opportunities [1].

As part of this approach it is necessary to define what is understood by accessibility, disability and reduced mobility; as well as to clearly establish the responsibility of offering these services to the community members.

The term "accessibility" is used to define certain characteristics in the quality of urbanisms, constructions and transport that allow any person to make a suitable use of these. On the other hand, the term "disability" supposes a physical, intellectual or sensorial deficiency, as well as it contemplates a mental disease or ailment that requires medical attention. Such deficiencies, ailments or diseases can be of permanent or transitory character, with objective characteristics that any professional of the medicine can verify.

A person with "reduced mobility" is affected by diverse factors that prevent their mobility and communication with the surroundings: for instance, people with reduced mobility include pregnant women, as well as injured, convalescent, and over weighted passengers, and infants among others.

In order to establish the scope of the present work it is necessary to define the units of public transport. According to Venezuelan standard Covenin 51-92, the transport units are classified in units of urban transport, extra-urban transport, peripheral transport, bus and minibus [2]. With the object of the present work, the interest will be concentrated in the units of urban transport, specifically minibus.

In addition, the standard Covenin 51-92 establishes some dimensional parameters and characteristic of the transport units trying to guarantee the comfort and security of the passengers. It is not in the scope of this work to discuss each one of these dimensions and characteristics, but attention will be paid to those representing certain interest from the ergonomic point of view.

3 Passenger Ergonomics

It is possible to carry a great number of passengers in public transport units, but in attention to the users comfort and safety, it is necessary to limit the number of passengers in such way that provide the minimum comfort that the users deserve.

The population of users varies in terms of age, size, weight and mobility, making necessary to consider this factors during the design phase. Extreme cases are represented by the population of bigger size, individuals with physical limitations or disabilities, and specially population segments of elderly and children, who are naturally more susceptible to accidents.

3.1 Sampling of the public transport units

The sampling of the transport units allows measuring the pertinent dimensions, from the ergonomic point of view, such as:

- Inner height (A)
- Inner Width (B)
- Width of the aisle (C)
- Width of the individual seats (D)
- Height of back rest of the seats (E)
- Height of the seat cushion from the unit floor (F)
- Gap between seats (G)
- Inner length of the unit (H)
- Width of the twin seats (I)
- Depth of the seat cushion (K)
- Separation between the seat back rest and the contiguous chair (L)
- Inclination of back rest (M)
- Height from the road to the first step of the access or exit stairs (N)
- Height of the steps of the access or exit stairs (O)
- Track of the steps of the access or exit stairs (P)
- Width of the access or exit door (Q)
- Number of passengers.
- Kind of unit (Light buses type A and type B)

Figure 1 shows the considered main variables during this study of the units of public transport.

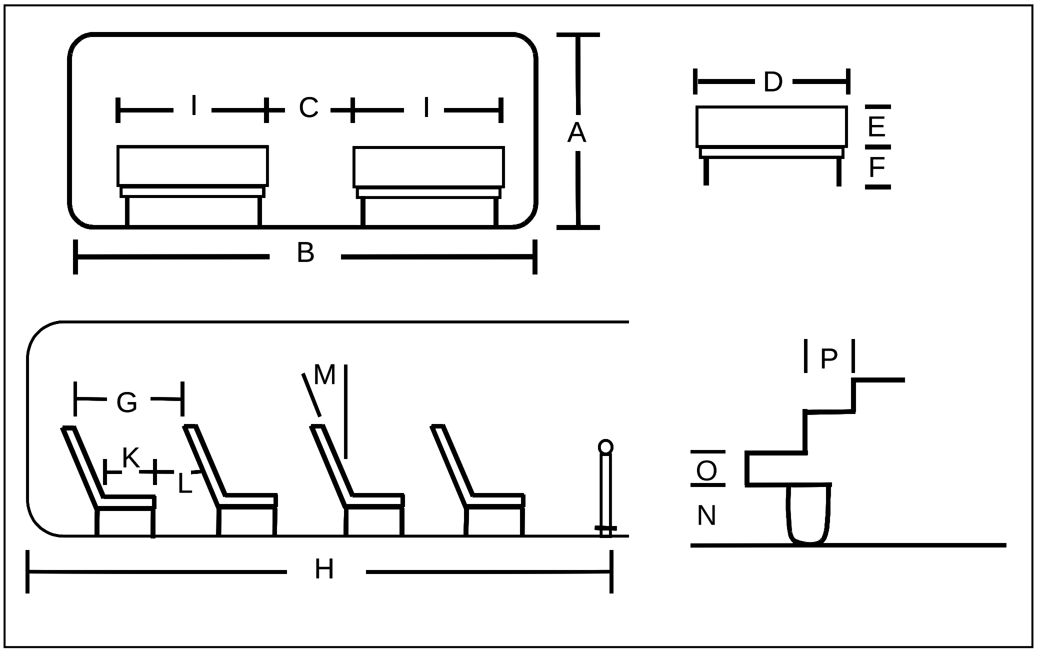

Figure 1.Dimensional variables of the transport units considered in this study

The means of ergonomic documentation of the public transport units used was photography, in order to observe and to document with clarity those important aspects in relation to the users comfort and safety.

3.2 Anthropometric analysis

In the modern world it is impossible to design in terms of average dimensions. It is for that reason that anthropometry plays a capital role in the world of design. In terms of public transport, it is necessary to define the spaces of circulation, access and exit doors, as well as the dimensions of the seats considering the more corpulent people. On the other hand, the dimensions of the smaller people are used to define the height of the seats, height of the superior handles, height of the steps of the access and exit stairs, and finally the height of the last step of these stairs in relation to the road level. It must be added that public transport is also used by elderly population and people with physical disability, which forces to make certain considerations to facilitate the access, the security and the comfort of these segments of the population during the use of the public transport.

A detailed observation of the statistical data obtained, shows a great dispersion of the data values of the considered variables. The main reason, to which this dispersion of the data can be attributed, is the lack of control by the corresponding authorities as far as construction and distribution of the seats, space distribution and circulation of the users inside the units of public transport; giving freedom of action to the proprietors. There is not control on satisfying the minimum requirements of design according to security standards and the comfort of the users established in Standard Covenin 51-92.

Dimensions of transport units were compared with the anthropometric data available of the population of users and the established values in the corresponding standard.

The units of urban transport, considered in the present work, can be classified in two types depending on their size. Units type "A" with capacity of 11 passengers and units type "B" with capacity of up to 30 passengers. All seats facing the front of the unit. The sample size includes 80 vehicles type "A" and 108 vehicles type "B". Tables 1 and 2 respectively display the summary of the results for the vehicles type "A" and "B".

Minimum and maximum values found of each one of the dimensional variables, as well as their averages and standard deviations values. In order to complement the analysis a sample of anthropometric dimensions of the Venezuelan population of users, men and women in ages between the 17 and 63 years of age was used [3], also a sample of anthropometric dimensions from the Latin population [4], was used in order to evaluate the extent of adaptation of the vehicles in relation to the population of adult users.

Table 1.- Dimension of the units of transport type "A" [cm.]

Variable	Average	Standard Deviation	Maximum	Minimum
A	180.58	9.96	191	132
B	201.53	19.22	224	148
C	48.99	9.66	74	30
D	34.47	3.08	43.5	28
E	58.56	9.57	75	41
F	40.72	3.41	48	30
G	66.51	7.98	87	50
H	431.88	87.65	594	243
I	73.5	9.56	106	27
K	37.07	3.14	42	27
L	27.09	5.01	40	15
M [Degrees]	14.54	6.10	38.9	7.4
N	38.84	6.02	57	27
O	24.01	5.76	42	11
P	31	5.69	41	20
Q	84.64	26.54	122	50

Table 2.- Dimensions of the transport units type "B" [cm.]

Variable	Average	Standard Deviation	Maximum	Minimum
A	184.70	8.23	196	170
B	208.94	21.13	260	180
C	47.38	6.52	66	32
D	71.20	22.62	131	32
E	64.07	8.86	87	43
F	40.90	3.01	48	32
G	68.46	8.95	88	47
H	474.22	75.29	700	327
I	77.31	9.21	90	35
K	38.69	4.56	76	32
L	26.37	5.94	57	16
M [Degrees]	14.08	4.35	29.27	2
N	41.36	5.62	55	25
O	22.15	4.37	35	12
P	29.51	6.78	58	18
Q	71.72	23.03	125	40

3.3 Units` access and exit doors

All the users must pass through the access and exit doors, therefore it is required that its dimensions satisfy the 95 percentile of the population. Table 3 shows the results of the comparison of this dimension with the anthropometric dimensions of hip width, shoulders and of elbows width, as well as the established value in Standard Covenin 51-92.

The minimum value registered obviously does not satisfy the requirements established in the standard, therefore users are forced to assume awkward postures and are exposed to risk when getting on to and exiting of the transport units.

Table 3.Dimensions of the access and exit doors.

Dimensions of the access and exit doors [cm]				**Standard Covenin 51-92**	**Hip Width**		**Shoulders width**		**Elbows Width**	
Type “A”		**Type “B”**								
X	**Xmin**	**X**	**Xmin**							
84.6	50.0	71.7	47.0	70.0	43.0 (*)	40.4 (**)	55.3 (*)	52.6 (**)	51.3 (*)	50.5 (**)

(*) Márquez 1996, (**) Panero 1991

Figure 2 shows an example of the awkward positions that the users must adopt when getting on the transport units type "B". It is easy to observe, that although the door satisfies the dimensions recommended by the standard, the main disadvantage appears because the access doors are not opened in their totality, only half of the door is open. This reduces the space available so that the user can access or exit the unit in a comfortable and secure way.

Figure 3 shows to the same disadvantage and situation of risk at the time of exiting the transport units. This risk factor increases when the passengers carry on object in their hands which prevents them from holding appropriately to avoid falling.

Figure 2.Position assumed by the users when accessing the transport units.

Figure 3.Position assumed by the users when descending from the transport units.

3.4 Access and exit stairs.

The inappropriate dimensions of the steps, specifically when this is very high, increase difficulty during the access to the transport unit, especially for the people of short stature, elderly and children. In addition, at the moment of descending from the transport unit, the risks of falling are even greater due to the instable posture in which the users find themselves.

Table 4 presents the comparison of the dimensions of steps height with the values recommended in the bibliography as far as maximum dimensions for steps height of stairs of public use and in working spaces [5]. Figure 4 shows examples in which steps height are too large, forcing the user to deliver an extra effort to raise themselves to the transport unit.

Table 5 presents the comparison of the dimension of the track obtained in the sampling of the units of public transport and the values recommended in the related bibliography. In relation to the track of the steps of access and exit stairs, dimensions should prevent the accidents that can be caused due to the very small room in the steps to place the feet at the time of descending,.

Table 4.- Dimensions of step height and comparison with recommended dimensions.

Dimensions of step height [cm]				**Standard Covenin 51-92**	**Knee Height**		**Height recommended based on the knee height (***) [D*0.4]**	
Type "A"		**Type "B"**						
X	**Xmax**	**X**	**Xmax**					
24.7	34.0	22.1	33.5	---	46.2 (*)	49.0 (**)	18.5 (*)	19.6 (**)

(*) Márquez 1996, (**) Panero 1991, (***) Grandjean 1991

Table 5.Dimensions of the track and comparison with recommended dimensions.

Dimensions of the track [cm]				**Standard Covenin 51-92**	**Recommended minimum dimension [cm]**
Tipo "A"		**Tipo "B"**			
X	**Xmin**	**X**	**Xmin**		
31.0	20.0	29.5	18.0	---	25.0

Once again it is observed that the average values of the track of the steps satisfy the recommended values. Nevertheless, the detected minimum values create a high risk of accident at the moment of descending from the units. Figure 5 shows a clear example in which the tracks of the stairs are not homogenous, which represents a high risk of accident.

Figure 4.Step heights too large.

Figure 5.Not-homogenous step tracks representing accident risk.

Figures 6 and 7, show examples of step tracks of access and exit stair that are not appropriate representing accident risk.

Figure 6.Very small step track of the stairs, scene of insecurity during the access.

Finally it is necessary to consider the height of the last step of the access and exit stairs from the road, which generally is a dimension greater than the height of the other steps. This represents a greater falling risk when exiting of the units of transport, as well as great discomfort at the moment for accessing. Figure 8 shows this case.

Table 6 presents the comparison of the distance from the road to the last step with the values recommended in the references.

Table 6. Height from the road to the last step of the access and exit stairs.

Dimensions of the road to the last step [cm]				**Dimensions recommended for stairs of public use**	**knee Height**		**Recommended step height as a function of the knee height (***)**	
Type “A”		**Type “B”**						
X	**Xmax**	**X**	**Xmax**					
38.2	57.0	41.4	53.1	17.0	46.2 (*)	49.0 (**)	18.5 (*)	19.6 (**)

(*) Márquez 1996, (**) Panero 1991, (***) Grandjean 1991

Figure 7.Very small size of step track represents a greater risk of accident when descending.

Figure 8.The last step represents a great risk of accident when descending.

3.5 Dimensions of the circulation corridors.

In order to define appropriate dimensions of the corridors of circulation, it is necessary to consider the bigger size people, being in this case the dimension corresponding to wide of the hip the critical dimension of design. Table 7 presents the values obtained and recommended for this dimension.

The averages of the dimension of the corridors width do not reflect any apparent problem, but the detected minimum values show that the displacement of the users within the unit is uncomfortable, forcing in most cases to lateral displacements. It is possible to observe that the passengers who travel seated are forced to invade the corridor of the unit, which reduces even more the available space for displacement inside the unit. See Figure 9.

Table 7.Dimensions of the circulation corridors and comparison with the hip width.

Dimensions of the circulation corridors [cm]				**Standard Covenin 51-92**	**Hip Width**		**Hip Depth**	
Type "A"		**Type "B"**						
X	**Xmin**	**X**	**Xmin**					
48.9	31.0	47.5	32.0	----	43.0 (*)	40.4 (**)	29.2 (*)	33.0 (**)

(*) Márquez 1996, (**) Panero 1991

Figure 9.Discomfort to move within the transport unit type "B".

3.6 Seats dimensions

In order to evaluate the seats it is necessary to consider, in some cases, the segments of taller and bigger sized population, for example when evaluating the space available for the legs on seated position; and for others, the sector of smaller population, for example for the height of the seats. Table 8 presents the data corresponding to the height of the seats and their comparison with the values recommended according to ergonomic criteria.

Once again the average dimensions are not very elevated in comparison with the values recommended in relation to the back-knee height of the population of users, however, a great dispersion of the data and maximum values, which are very far from satisfying the conditions of comfort of the users, are observed.

Table 8. Height of the seats and comparison with recommended dimensions.

Height of the seats [cm]				**Standard Covenin 51-92**	**Maximum dimension recommended [cm] (*) (**)**
Type "A"		**Type "B"**			
X	**Xmax**	**X**	**Xmax**		
40.7	48.0	40.9	48.1	---	39.3

(*) Márquez 1996, (**) Panero 1991

In terms of the available space to accommodate the legs in the seated position, it was compared with the anthropometric dimension corresponding to the length from the gluteus to the front of the knee when seated, considering the higher segment of population. Table 9 presents this data and the comparisons. Once again it is possible to observe that average values do not fulfil the minimum requirements of comfort to accommodate the legs in the available space, as shown in Figures 10 and 11. Further more, minimum dimensions found during this work are so small that do not allow an adult user to fit in the seat.

When this dimension is very small the main problem that appears is the contact between the knee and the rigid surface of back rest of front seat, which causes pain and annoyance to the passenger. Finally, in the case of abrupt braking or vibrations product of the irregularities of the road, the knee is subject to continuous blows. Some times the space available for the legs is so small; that the passenger cannot place his legs in there causing greater discomfort, as much for the seated passenger as for those passing through the corridor, as it is shown in Figure 11.

Table 9. Space available to accommodate the legs

Space available to accommodate the legs [cm]				**Standard Covenin 51-92**	**Glut - knee length**	
Type "A"		**Type "B"**				
X	**Xmin**	**X**	**Xmin**			
64.2	48.0	65.1	52.1	70.0	69.3 (*)	65.3 (**)

(*) Márquez 1996, (**) Panero 1991

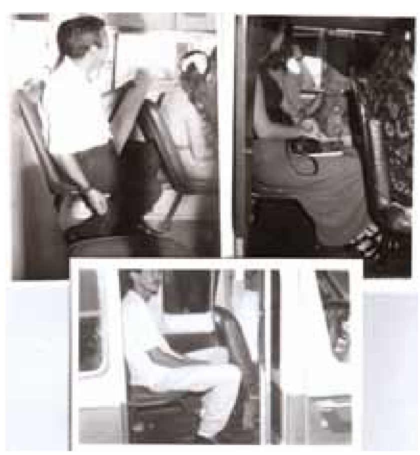

Figure 10. Insufficient space to accommodate the legs.

Figure 11. Passenger cannot place his legs in the room provided.

Another dimension of the seat that is of extreme importance as far as the comfort requirements is the width of the seats. It was possible to observe that usually the seats are designed to lodge two people and some times three, therefore the analysis will be done based on the space available for each passenger. Table 10 presents the summary of these data and their comparison with the corresponding corporal dimensions.

It is possible to observe that the average values of this dimension in the seats are far from satisfying the necessities of comfort related to necessary space for the users. One of the consequences is the fact that the passengers must travel tight to others invading the individual space, causing physical and psychological annoyance. In addition, the passenger who seats near the corridor interrupts the circulation and constantly struck by the passengers in transit.

Table 10. Seats width and comparison with related corporal dimensions.

Seats width [cm]				**Standard Covenin 51-92**	**Hip width**		**Shoulders width**	
Tipo "A"		**Tipo "B"**						
X	**Xmin**	**X**	**Xmin**					
37.2	31.4	38.1	31.0	----	43.0 (*)	40.4 (**)	55.3 (*)	52.6 (**)

(*) Márquez 1996, (**) Panero 1991

The last set of variables to be considered in the present evaluation is the back rest and seat cushion angles. For the horizontal surface of the seat a backwards inclination angle is recommended, which inhibits the sliding of the individual due to the effects of the braking. As far as the back rest of the seat backward inclination is recommended, this contributes to the comfort of the user. The values recommended for these angles appear in Tables 11 and 12.

Found angles, in the horizontal surface and back rest of the seats, are inferior to the recommended values, bringing annoyance and lack of security for the passengers, since the angles do not prevent the sliding forward in the case of abrupt braking. Also, the inclination of back rests forces the passenger to travel in a very unnatural position, causing fatigue and annoyances.

Table 11. Inclination of the horizontal surface of the seats.

Inclination of seat cushion [degrees]				**Standard Covenin 51-92**	**Recommended value in degrees (*)**
Tipo "A"		**Tipo "B"**			
X	**Xmin**	**X**	**Xmin**		
2	-5	4	-4	----	14 - 24

(*) Grandjean 1991

Table 12.>- Inclination of back rest of the seats.

Inclination of back rest [degrees]				**Standard Covenin 51-92**	**Recommended value in degrees (*)**
Tipo "A"		**Tipo "B"**			
X	**Xmin**	**X**	**Xmin**		
104.3	90	103.9	92	----	110 - 130

(*) Grandjean 1991

4 Drivers ergonomics

Drivers of public transport suffer a great deal of injuries and labour absenteeism; higher than others occupations. It is believe that this is in most part due to the difficulty of designing a work station appropriated to a most drivers and to satisfy all demands imposed by the task performed by the drivers.

Epidemiologic studies allow identifying three categories of disease among drivers: cardio-vascular, gastro-intestinal, and muscle-skeletal. Being the muscle-skeletal disease the worst including neck and back pain [6].

Awkward postures, muscular effort, arm vibration, whole body vibration and sitting for long periods of time in restricted postures, are contributing elements placing a mayor stress in the spine and causing back pain [7]

Drivers usually give a mayor priority to leg comfort rather than the reaching of controls when adjusting the drivers' seat [8]

Direct observation of drivers task allows to say that the steering wheel should be more in the vertical plane, this brings two advantages: Movement range is reduced therefore fatigue is reduced, and small population segment will be able to operate the steering wheel in a more efficient biomechanical way. Besides, large steering wheels force drivers to incline the torso forward loosing the contact with the seat back rest.

The pedals selection is critical and most transport units have orientation angles between 40º and 50º, forcing a full extension of the ankle to operate the accelerator.

Regarding the control panel, there are hundreds of recommendations for selecting proper controls, but universal design principles are applicable to all of them. As a fact, recommendations about manual controls are done based on direct observation of human interaction in the military industry where pilots are young, men, and highly trained, which it is not the usual case of public transport drivers. Therefore, it is recommended to continue specific research work on this field [9].

5 Conclusions

- The design of public transport units design is not different from the ergonomic point of view used for the conception of other work stations. Therefore attention must be given to the trilogy: Worker – Equipment – Working environment.
- A design pattern does not exist, from the ergonomic point of view, of the units of public transport; which must consider in first instance the safety and comfort of the users.
- A complete lack of satisfaction of the minimum requirements of the population of users in terms of its corporal dimensions is observed. This indicates the necessity for redesign of the units of public transport, in which the anthropometric dimensions of the population of users must be considered.
- A lack of consideration towards the segment of population of children, senior and people with physical disabilities of diverse nature is observed in the design of public transport units.
- In most of the cases, those dimensions considered in Standard Covenin **51-92**, are not respected, which suggests a lack of control on the part of the corresponding government agencies.

6 Recommendations

As result of the present work, it is possible to make certain recommendations in order improve the public transport service of San Cristóbal city, and possibly take it like a pilot project, which can be used in other cities of the country. It is recommended:

- The Mayor Office of San Cristóbal city must lead a campaign to obtain solutions to the identified problems of design, and efficiently control the conditions of public transport units; in such way that service is safe and comfortable for the population of users in consideration.
- Motivate the chassis manufacturing companies for urban public transport vehicles in the country to consider designing lower chassis in order to facilitate the ergonomic design of the transport units. Currently, the units' body are made on chassis designed for trucks.
- Extend the present research work in order to evaluate all the segments of the public transport including buses used in the urban transport and units of interurban transport.

7 Acknowledge

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Biographical Sketch

Name: Miguel Márquez

Title: Ph.D.

Position: Associated lecture of the Mechanical Engineering Department at the Universidad Nacional Experimental del Táchira (UNET), Venezuela.

Current

Activities: Lecture of the *Introduction to Ergonomics* and graduate level courses in Mechanical and Industrial Engineering Departments, at the Universidad Nacional Experimental del Táchira (UNET), Venezuela.

Lecture of CAD/CAM undergraduate level course in the Mechanical Engineering Department at the Universidad Nacional Experimental del Táchira (UNET), Venezuela.

Coordinator of the Prototyping Workshop at the Universidad Nacional Experimental del Táchira (UNET), Venezuela.

Coordinator of the Advisory Committee of Postgraduate Studies of Mechanical Engineering at the Universidad Nacional Experimental del Táchira (UNET), Venezuela.

Vice-President of Special Events of the International Society for Productivity Enhancement (ISPE)

Member of the International Organizing Committee of the 22nd International Conference on CAD/CAM, Robotics and Factories of the Future, India, 2006. ISPE Event.