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Fuzzy and Ahp Approach for Designing a University Hall Bed Based on Anthropometric Analysis

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ARTICLE INFO

Article History:

Received: 28 February 2022
Revised: 08 March 2022
Accepted: 09 March 2022
Published online: 31 July 2022

Keywords:

Ergonomics
Fuzzy Approach
AHP Method
Anthropometry
Regression Analysis

ABSTRACT

Ergonomics is that branch of science which make the authors to think about anthropometric measurements during design of bed in different work areas. Students of Bangladesh are provided bed of different design without considering anthropometric data in different university hall. In this study, 125 students from a private university (Bangladesh Army University of Science and Technology) hall in Bangladesh participated to collect data of anthropometric measurements based on four alternatives related to bed dimensions of students. The result obtained from chi-square analysis showed that ache in backside of the body, tiredness; blood flow through the body; sleep and comfort are the outcome of anthropometric measurements of students. Analytic ordering process and fuzzy logic methods were used to rank between different designs parameters. Finally, linear regression analysis suggested the bed dimensions considering the stature of the students which help the furniture industry to design a bed for students' comfort.

1. INTRODUCTION

The words 'ergonomics' and 'human factors' are related to each other in much application. Ergonomics thinks about the physical prospects of surroundings like workstations and management panels, while 'human factors' is related to people work system widely. The two terms are generally used with the fitness of research or industry that are discussed. Ergonomics is a combined discipline that assembles expertise such as anatomy and physiology, engineering psychology and statistics to apply in the design of work station for human comfort. The relationship among worker, machinery and environment is studied in ergonomics and adjusted between the loads of works and skills of worker (Farnandez, 1959). Ergonomics includes anthropometric data to enhance the protection and reliability of equipment and to remove of adverse stresses. The relation between anthropometric data and workstation measurement plays a critical role on the efficiency on worker effectiveness (Halder et al., 2018). Sleeping on bed which is designed without ergonomic consideration affects human health adversely and is responsible for many health issues such as back problem, blood circulation problem, fatigue etc. (Islam et al., 2013). Balasubramanian et al.

(2013) suggested an RBG risk scale for composite assessment for multiple variables that collectively lead to ergonomic impairments such as posture, environmental cases, biomechanical forces etc. This comprehensive works can be used as a measuring scale to apply ergonomic strategies. Mehta et al. (2011) presents a study based on healthcare workers who are engaged to two types of patients handling task such as transportation and repositioning tasks suffering from musculoskeletal disorders. The results of this study suggest introducing ergonomic application in the design of hospital bed to reduce physical demands.

Chakraborty et al. (2014) provide guideline to furniture manufacturer with ergonomic considerations. AHP and fuzzy logic techniques are used for making resolution in the design of hospital bed based on relevant anthropometry data. Peteri (2017) presents an article related to the design of office chair with ergonomic considerations. Chandra et al. (2011a, 2011b) done a survey for hand measurements of male workers who works in manufacturing industry with anthropometric database which is helpful for the construction of manually operated device and selection of appropriate manual device for industrial worker. Anthropometric data and formal attributes are the key elements of a product with ergonomic quality. The knowledge of different ergonomic parameters is very crucial for resolution making regarding different types goods and their selection for appropriate facility location (Kaljun and Dolsak, 2012).

It is very necessary for design industry to collect anthropometric data for targeting population so that musculoskeletal disorders (MSDs) can be reduced by increasing comfort, safety and satisfaction level. MSDs are characterized as disorders or discomfort in the body's muscles, tendons, skeletal system, connective tissue, veins, and infrastructure that supports the arms, neck, and lower back. These MSDs, which are congenital and immune disorders, may lead to long term to pain and hinder the daily activities of students. Anthropometric scales need to be applied during furniture design (Meherparvar et al., 2015). Student mostly use furniture which are poorly designed, such furniture can result different health issue (Mokdad and Ansari, 2009)

In Bangladeshi universities, the bed is vital furniture where students spend their most prominent time. However, it is seen that the country does not take into account of ergonomics rules in the design of this hall furniture. Moreover, the manufacturer of furniture industry is not fully conscious about the bad impact of improper design of bed without ergonomic factors. By considering all the bad impacts of present situation in the university hall, sufficient research activities on ergonomic design are conducted to collect data about anthropometry and gain accurate knowledge. Students are affected by various health related problems due to use of inappropriate bed. However, the merge of ergonomics in designing bed can drastically reduce health related problem as well as improve students' comfort. Recently, researchers give attention on the use of anthropometric dimensions in different types of furniture such as correct seats for truck drivers (Mahamud et al., 2014; Halder and Sarker, 2016), seats for bus passengers (Hoque et al., 2016), educational furniture for university students (Hoque et al., 2014) and hospital bed for patients (Chakraborty, 2014).

This research is conducted through survey activities with the purpose to collect anthropometric data from students and develop a structure to identify various health related issues like back problem, blood related health issu, discomfort, tiredness and sleeping problem caused by inappropriate hall bed and implication of anthropometric measurements in the design of university hall bed.

2. LITERATURE REVIEW

Hossain & Ahmed (2010) conduct a survey of 88 male students to measure 36 longitudinal and stationary ergonomic parameters for the design of residential hall furniture with anthropometric measurement of human body, body structure and dimension. The mismatch situation between body and bed has been considered during the design of bed. Laios & Giannatsis (2010) presents a case study regarding redesign of bicycle for children and teenagers with 7-14 age limit based on anthropometric data. Virtual technique for modeling have been employed to redesigned new bicycles with ergonomic considerations and the principle component analysis method is used to reduce the dimension of large data set into smaller one to find meaningful data. For satisfied performance, new redesign bicycle are produced fully in several commercial shops of Greece as increasing proper fitting prevents injury. Widanarko et al. (2011) have done a survey of 3003 men and women with 20–64 age to describe the outbreak of physical disorder in New Zealand. The rate of prevalence was high, about 54% for low back, about 43% for neck, and shoulder (42%). The report of prevalence of musculoskeletal symptoms for females is comparatively high in the different parts of body where the high symptoms for males are in elbows, low back and knees. Dianat et al. (2012) have conducted a survey on 978 Iranian high school students who are 498 girls and 480 boys and identified the potential discrepancy between dimensions of classroom furniture and users with anthropometric characteristics. The five dimensions of classroom are compared with nine anthropometric measurements of students using match criterion equations. The appropriate dimensions are proposed for the students. Mohammed et al., (2014) proposed a design of the bed to develop a multifunctional bed with comfortable sleeping of bedridden persons and nursing disabled persons. Halder et al., (2018) studied the integrated approach of ergonomics and MCDM taking a sample of 102 truck drivers. The health status of truck drivers is compared with normal people and shows that drivers suffer much than normal people. Seat breadth is suggested as a design criterion to design truck drivers' seat.

Ansari et al. (2018) obtained anthropometric parameters from a random selection of 207 students. The statistical software (SPSS) was used to analyse data and the CATIA software was used to design chair. Thariq et al (2010) focused on mounted desktop chair for university students because comfortable chair helps students to concentrate and learn effectively. The goal of this study is to design a chair that supports students to develop of healthy and comfortable posture.

Since the main focus of authors is to calculate the different ergonomic criteria to design university hall bed for students, several similar types of literature have also been found in those fields. Kumar and Deepak (2015) present a multipurpose design of bed for college students by considering the outcome of anthropometric analysis. The additional feature which attached with bed are reading table, book shelf, cloth hanger, and shoe rack. CAD and simulation software are used to develop model. Bhuiya and Hossain (2015) develop a methodology and use artificial neural network to design university hall furniture based on anthropometric. Taifa and Desai (2016) conducted a survey to know health status of students and suggested for anthropometric application in the design of bed. Additionally, a seminar or workshop conducted to teach students about the negative impacts of using poor design hall furniture. Igbokwe et al., (2019) performed survey over four hundred students of different ages and level and used anthropometric tools to record anthropometric measurements. The data were analysed with the help of different statistical tools and compared with the dimension of existing furniture. Based on the results of irrelevancy, a model classroom was suggested considering the height, depth and breadth of seat, height and angle of backrest height and armrest height.

3. METHODOLOGY

A. ANTHROPOMETRIC MEASUREMENTS WITH SAMPLING EXPERIMENTS

This research was conducted based on a sample of 125 students from Abbas Uddin Ahmed Hall in Bangladesh Army University of Science and Technology, Saidpur were taken as samples. The participants were viewed from right position to record anthropometric, at that time they were standing and sitting in an upright posture perpendicular to the ground, with their legs bent at an angle of 90 degree, and their feet straight on the ground. The measurement process was conducted with the participants with the condition of bare foot and light clothing (shorts and t-shirts). During this analysis, the following anthropometric measurements were considered and collected, which are shown in Figures (1-4).

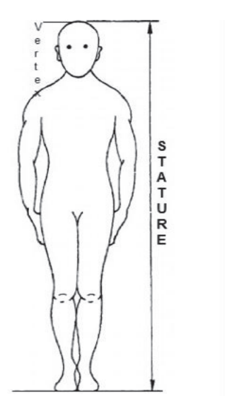

Figure 1: Stature

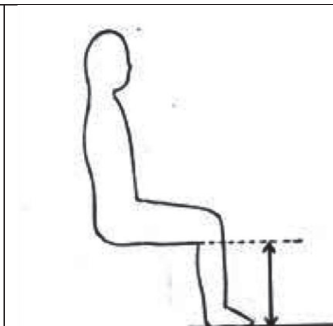

Figure 2: Popliteal Height

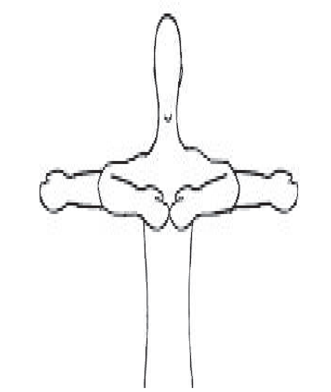

Figure 3: Elbow Span

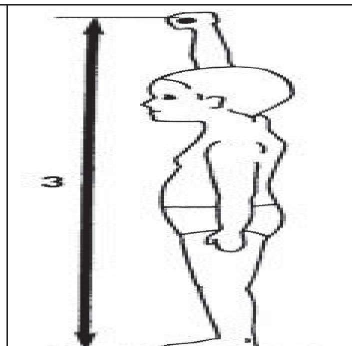

Figure 4: Vertical grip

Anthropometric data were taken from participants ranges from 20 to 25 years old to remove the impact of age on stature. In order to record data from the 135 participants including students and experts on different health issues associated with student anthropometry as well as bed measurements, a survey was performed through a set of pre-selected questionnaires. These statistics have been used for numerous research works.

4. DATA ANALYSIS TECHNIQUE

The chi-square test was conducted to mark the relation between physical demand of students and anthropometric assessment in developing the perfect hall bed. In addition, AHP was adopted to determine the most important seat dimension associated with anthropometric element accountable for causing serious health issues. At first correlation equations for participants' anthropometric estimation depending on their stature were formulated, then Linear regression analysis was conducted. The Chi-square test and AHP procedure are described below:

In Chi-square test, null hypothesis (H_0) where variables are not related to each other and alternative hypothesis (H_1) where variables are related, were considered to identify whether the null hypothesis was result worthy (at $X_{cri}^2 < X_{cal}^2$) or rejected (at $X_{df}^2 > X_{cal}^2$). The value of X_{cri}^2 was determined depending on the value of degree of freedom. The value of degree of freedom was determined based on the Equation (1).

Degrees of freedom = (row−1) × (column−1) ……… (1)

In addition, the value of X_{cal}^2 and expected frequency were determined according to Equation (2) and equation (3).

$$X_{cal}^2 = \sum(observed - expected)^2 / expected \quad \text{........ (2)}$$

Expected frequency = (total row values)*(total column values) / (overall values) ....(3)

For AHP analysis, a pair-wise assessment matrix was designed according to 1-9 pREFERENCES scale of Saaty (Saaty, 1980; Saaty, 1990). Similarly, the relative importance of elements at every stage was calculated. The pair-wise evaluation of variable i with variable j form a square matrix $An \times n$ considering n factors as follows:

$$A_{n\times n} = \begin{matrix} Attribute \\ 1 \\ 2 \\ 3 \\ \cdots \\ \cdots \\ n \end{matrix} \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & \cdots & a_{3n} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & \cdots & a_{nn} \end{bmatrix}$$

Where, a_{ij} illustrates the correlative significance of attribute i in relation to variables j. In the matrix, aij = 1 when i = j and aji = 1/aij. Then, the equation (4) and equation (5) was used accordingly to developing normalized resolution matrix and the weighted normalized resolution matrix.

$$C_{ij} = \frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \quad \text{i= 1, 2, 3,…n; j=1, 2, 3,…….n;} \quad \text{..............(4)}$$

$$w_i = \sum_{j=1}^{n} \frac{C_{ij}}{n} \quad \text{i= 1, 2, 3,……,n;} \quad \text{...............(5)}$$

$$W = \begin{bmatrix} w1 \\ w2 \\ w3 \\ \vdots \\ w_n \end{bmatrix} \quad \text{.......................(6)}$$

The maximum Eigen factor (γ_{max}) was calculated using equation (7)

$$\lambda_{max} = \frac{row\ matrix}{H} \quad \text{..................(7)}$$

Where H = $nth\ root\ value / \sum nth\ root\ value$ and row matrix = $\sum_{j=1}^{n} a_{ij} e_{j1}$

Finally, consistency index and consistency ratio was calculated by the following equation

$CI = \frac{(\lambda_{max} - n)}{(n-1)}$ and CR = CI/RI

Where RI is randomly generated consistency index chosen from standard table

5. RESULTS AND DISCUSSION

A. Chi-Square Test Analysis

A statistical hypothesis test, manifested for a set of variables from a single population to assess the important relation between two nominal variables, is the Chi-square independence test. One of the drawbacks of this tool is that, in order to be valid, the predicted value of each cell must equal to five or greater than five. The Chi-square (2) test was conducted in this study to identify the relations between students' physical demands and ergonomic aspects. The expected frequency was presented in parentheses with the actual observed frequency as shown in Table 1.

Table 1: Predicted and actual value after experiment

Problems	Criteria				
	Bed stand Height (N1)	Bed breadth (N2)	Bed height (N3)	Bed length (N4)	Total
Back pain (M1)	20(29.62)	76(73.6)	56(52.67)	86(82.11)	238
Fatigue (M2)	61(39.07)	97(97.10)	69(69.49)	87(108.33)	314
Blood circulation (M3)	19(24.76)	61(61.54)	34(44.04)	85(68.66)	199
Comfort (M4)	34(36.71)	92(91.22)	70(65.29)	99(101.78)	295
Sleep (M5)	33(36.83)	89(91.53)	68(65.51)	106(102.12)	296
Total	167	415	297	463	1342

The noticeable value 86 in second rows and fifth column of table 1 represent that 86 individuals among the total participants believe that length of bed is responsibly accountable for back problem. The value indicated in bracket with the observed value 86, was the expected value which was 82.11. Similarly, 76 individuals (Observed value) think that the bed breadth was responsible for back pain (Expected value was 73.6) and so on. The calculated value of χ_{cal}^2 was about 41.01 while the critical values for 12 degree of freedom were 21.026 and 26.217 respectively, at 95% and 99% confidence level. The status of $\chi_{cal}^2 > \chi_{cri}^2$ implies that, for both cases, the null hypothesis Ho is rejected. Where, the null hypothesis (Ho) and alternative hypothesis (H1) are assumed as, Ho: students' musculoskeletal disorders are not associated with anthropometric factors, H1: students' musculoskeletal disorders are associated with anthropometric factors. In abstract, from the Chi-square test, it is seen that students' musculoskeletal malfunction are associated with anthropometric factors. That's why, the anthropometric measurements must be considered for appropriate design of seat dimensions.

6. DETERMINATION OF WEIGHTS AND ALTERNATIVES BY AHP

The analytic hierarchy process (AHP) is a resolution making method and used for solving complex resolution making problem to take correct resolution. It is a systematic approach for selecting alternatives from many and developed by Thomas L. Saaty (Saaty, 1990). The complex problem is presented in the form of step by step system which consists of main goal, criteria, sub criteria, and associated alternatives related to problem. In the figure 5, the relative stratified structure for the students' bed design considered in this research is illustrated.

From the hierarchy structure, there were three stages, the highest stage of the process depicts the goal of the problem which was the design of student's bed and the second stage consists of 5 health related criteria for target goal. In the last stage, four substitutes (anthropometric estimation) related to bed size are considered. The assessment of five criteria was considered based Saaty priority scale and a pair-wise comparison matrix was constructed (shown in table 2). The value of normalized weight and λ_{max} were calculated from pair-wise comparison matrix. Finally, the value of CI and CR were determined from equations (8) and (9) respectively, given above to measure consistency. From the value of CR, it is seen that the assessment of pair-wise comparison matrix is consistent. The result showed that back pain was the most critical indicators with priority values of 48.1 percent respect to target whereas fatigue and blood circulation achieved second and third position with relative weight of 27.64% and (12.5%), respectively. After that, assessment on different substitutes was observed to find out which alternative is most responsible for human discomfort. The results of assessment of different substitutes are shown in table 3 to table 6.

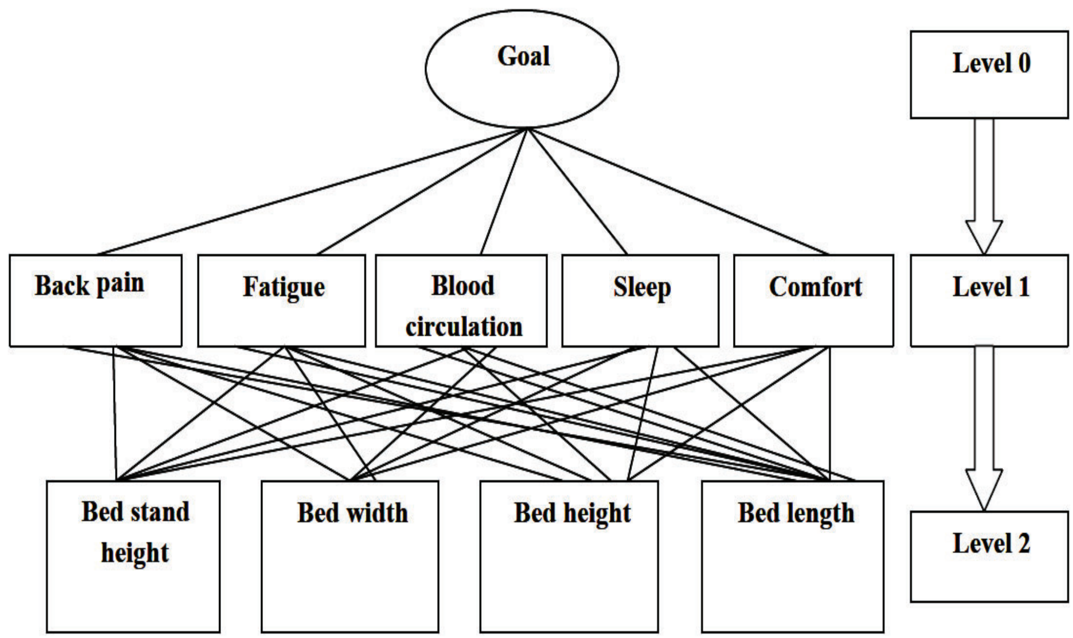

Figure 5: Concerned hierarchies for bed design

Table 2: Assessment matrix with dimensions (λ_{max}= 5.196, CI = 0.049, RI = 1.12, CR = 0.043 <0.10)

Attributes	M2	M2	M3	M4	M5	Normalized Weight	Rank
M1	1	3	4	6	8	0.481	1
M2	1/3	1	4	4	6	0.2764	2
M3	1/4	¼	1	2	4	0.125	3
M4	1/6	¼	½	1	2	0.073	4
M5	1/8	1/6	¼	½	1	0.044	5

Table 3: Assessment for attribute M1 (λ_{max}= 4.14, CI = 0.046, RI = 0.90, CR= 0.05 < 0.10)

Parameters	N1	N2	N3	N4	Normalized weight	Rank
N1	1	¼	1/3	1/6	0.064	4
N2	4	1	2	¼	0.213	2
N3	3	½	1	1/5	0.136	3
N4	6	4	5	1	0.585	1

Table 4: Assessment for attribute M3 (λ_{max} =4.16, CI = 0.053, RI = 0.90, CR = 0.059 < 0.10)

Parameters	N1	N2	N3	N4	Normalized weight	Rank
N1	1	1/3	¼	1/7	0.062	4
N2	3	1	2	1/5	0.177	2
N3	4	½	1	1/9	0.139	3
N4	5	5	7	1	0.622	1

Table 5: Assessment for attribute M4 (λ_{max} =4.157, CI=0.052, RI = 0.90, CR = 0.058 <0.10)

Parameters	N1	N2	N3	N4	Normalized weight	Rank
N1	1	1/3	1/3	1/5	0.0765	4
N2	3	1	2	1/3	0.216	2
N3	3	½	1	1/6	0.14	3
N4	5	3	6	1	0.568	1

Table 6: Assessment for attribute M2 (λ_{max}=4.0025, CI=0.00083, RI = 0.90, CR = 0.00092 <0.10)

Parameters	N1	N2	N3	N4	Normalized weight	Rank
N1	1	½	1	1/7	0.09	2
N2	2	1	2	1/3	0.19	4
N3	1	½	1	1/8	0.087	3
N4	7	3	8	1	0.633	1

Table 7: Assessment for attribute M5 (λ_{max} =4.0025, CI =0.00083, RI = 0.90, CR = 0.00092 <0.10)

Parameters	N1	N2	N3	N4	Normalized weight	Rank
N1	1	½	1	1/8	0.079	3
N2	2	1	2	1/5	0.151	2
N3	1	½	1	1/9	0.076	4
N4	8	5	9	1	0.691	1

Table 8: AHP approach for final assessment

Parameters	Attributes and their weight						
	M1 (0.481)	M2 (0.2764)	M3 (0.125)	M4 (0.173)	M5 (0.044)	Priority weight	Rank
N1	0.064	0.09	0.062	0.079	0.0765	0.0725	4
N2	0.213	0.19	0.177	0.151	0.216	0.1976	2
N3	0.136	0.087	0.139	0.076	0.14	0.1185	3
N4	0.585	0.633	0.622	0.691	0.568	0.609	1

At the final stage, the priority weights of every alternative were calculated with the consideration of pair-wise measurements of substitutes with respect to each resolution criteria as shown in table 8. Hence, in order to identify the final alternative ranking, the local weights of each alternative from priority matrix were multiplied by the normalized weight of the resolution criteria with respect to the goal. The priority matrix showed that bed length contributed to the highest priority weight such as 60.9 percent which can be assumed as vital element in the reduction of health issues like back pain, fatigue, increasing the level of comfortableness, maintaining proper blood circulation, and proper sleep trend. Based on the score of the all-design parameter, the bed length was ranked as 1. Therefore, bed length should be the most significant design parameter for designer during design of bed.

7. FUZZY APPROACH FOR PRIORITIZING ALTERNATIVES

Linguistic values are used in this approach to calculate the scores and weights for these variables. In trapezoidal or triangular fuzzy numbers, these linguistic ratings were described. Linguistic assessment could be a more practical approach instead of numerical values as human preferences cannot be calculated with exact numerical values. In other words, by linguistic variables, the ratings and weights of the parameters in the problem are evaluated. The resolution matrix was transformed into a fuzzy resolution matrix and a weighted-normalized fuzzy resolution matrix was also constructed once the fuzzy scores of the resolution makers were pooled. The fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS) were described in this study. In this procedure, a vertex method is then applied to measure the gap between two fuzzy scores. The gap of each alternative from FPIS and FNIS can be measured, respectively, using the vertex process. Finally, to determine the ranking of each alternative, a closeness coefficient is established.

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The higher value of the correlation coefficient means that an alternative is respectively closer to FPIS and farther away from FNIS. Here, to capture the vagueness of these linguistic evaluations, linear trapezoidal membership functions were taken sufficient. In positive trapezoidal fuzzy numbers, these linguistic variables can be represented. The linguistic weighting variables shown in Figure 6 are used by ten resolution-makers (called T1 to T10) to measure the value of the criterion. Table 9 indicates the relevance of the parameters identified by these resolution-makers. 10s resolution-makers, furthermore, use the linguistic rating variables shown in Figure 7 to assess candidate ratings or four alternatives concerned with regard to each criterion.
After that, to build the fuzzy-resolution matrix and calculate the fuzzy weight of each criterion, all the linguistic assessments are turned into trapezoidal fuzzy numbers, as in Table 10. Then a normalized fuzzy resolution matrix was drawn as of Table 11 from 11by dividing each factor with 10 as the total ranking under this process is 10. As in Table 12, a weighted normalized fuzzy resolution matrix was created in the following step. Each item of Table 11 is multiplied with each entity of Table 12, which indicates its respective weights, for the crating of this matrix. Each element is taken from Table 12 in the next step to classify FPIS (A*) by profoundly observing the highest element in each row of that specific criteria, then similarly observing the minimum element in each row of that specific criteria for obtaining FNIS (A-).FPISs (A*) are (0.94, 0.94, 0.94, 0.94) (0.90, 0.90, 0.90, 0.90) (0.97, 0.97, 0.97, 0.97) (0.97,0.97, 0.97, 0.97) (0.94, 0.94, 0.94, 0.94)whereas FNISs (A−) are conversely identified as (0.21, 0.21, 0.21, 0.21) (0, 0, 0, 0) (0.03, 0.03, 0.03, 0.03) (0.24, 0.24,0.24, 0.24) (0.12, 0.12, 0.12, 0.12).To measure the gap between two fuzzy scores, a vertex method is applied. The gap of each alternative from the FPIS and FNIS can be measured using the vertex method, as shown in Tables 13 and 14, respectively. Lastly, to decide the ranking hierarchy of all alternatives, a closeness coefficient of each alternative is defined. The higher value of the proximity coefficient means that the alternative is similar to the FPIS and closer to the FNIS at the same time. The addition of distance under positive ideal solutions and negative ideal solutions (dI∗and dI−.) respectively is shown here in Table 15. As lower distance coefficient results in higher priority, alternative N4 is at the highest priority level instead of N1 is the least for hospital bed design from Table 15. It is interesting to see that the priority rankings are the same in both fuzzy and AHP methods, which voluntarily reflect reliable outcomes.

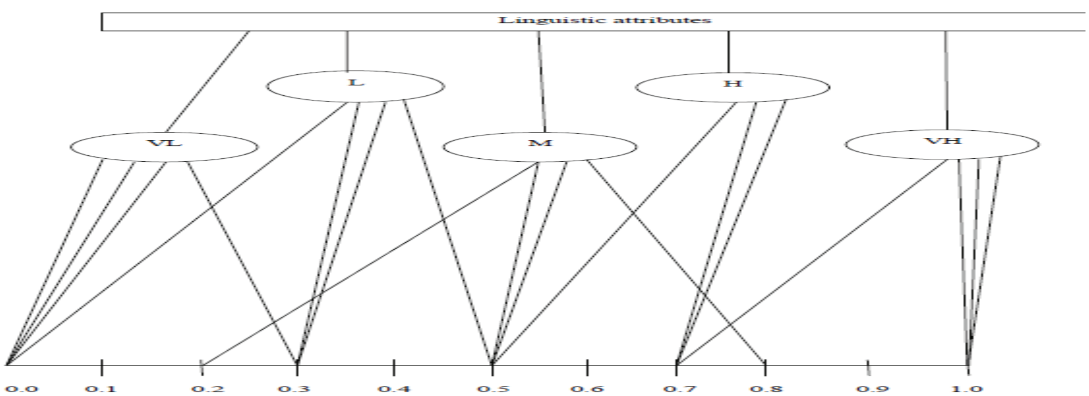

Figure 6: Weights of the linguistic attributes for criteria

Table 9: Ten Resolution Makers Weight Assignment to Each Criteria

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
M1	VH	H	VH	H	H	M	VH	VH	VH	H
M2	H	M	H	H	VH	H	VH	VH	H	H
M3	H	M	H	M	M	H	M	VH	H	M
M4	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH
M5	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH

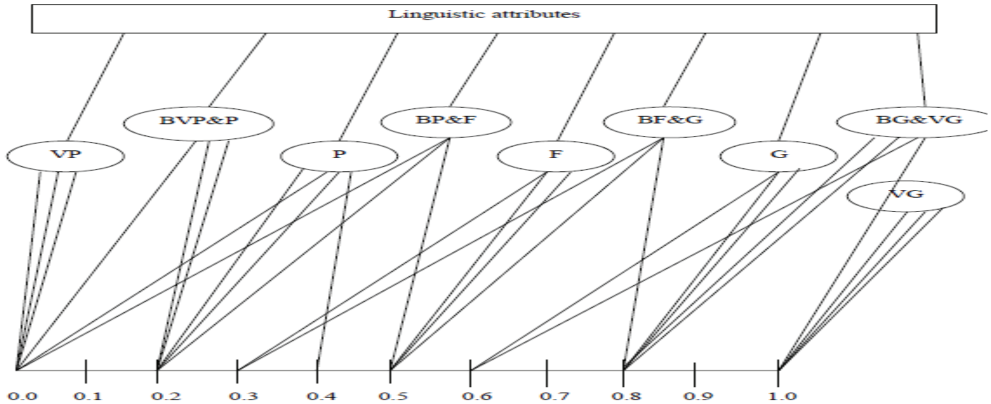

Figure 7: Weights of the linguistic attributes for alternatives

Table 10: Fuzzy resolution matrix under fuzzy approach

Criteria	N1	N2	N3	N4	Weights
M1	(2.1,4.1,4.7,6.7)	(4.9,6.9,7.5,9.1)	(6,8,8,9.4)	(6.2,8.2,8.2,9.4)	(0.57,0.83,0.83,0.95)
M2	(0,1.2,1,3.2)	(3.3,5.3,5.3,7.3)	(3.6,5.6,5.6,7.6)	(7,9,9,10)	(0.53,0.77,0.77,0.98)
M3	(0.3,2.3,2.9,4.9)	(5.4,7.4,7.7,9.1)	(3,5,5.6,7.6)	(6.5,8.5,8.5,9.7)	(0.37,0.63,0.63,0.90)
M4	(2.4,4,4.6,6.6)	(5.6,7.7,7.7,9.1)	(3.8,5.2,5.5,7.3)	(6.5,8.5,8.5,9.7)	(0.7,1,1,1)
M5	(1.2,3,3,5)	(5.2,7.2,.7.5,9.1)	(5.5,7.5,7.8,9.4)	(6.6,8.6,8.6,9.4)	(0.7,1,1,1)

Table 11: Normalized fuzzy resolution matrix

Criteria	N1	N2	N3	N4
M1	(0.21,0.41,0.47,0.67)	(0.49,0.69,0.75,0.91)	(0.6,0.8,0.8,0.94)	(0.62,0.82,0.82,0.94)
M2	(0,0.12,0.1,0.32)	(0.33,0.53,0.53,0.73)	(0.36,0.56,0.56,0.76)	(0.7,0.9,0.9,1)
M3	(0.03,0.23,0.23,0.49)	(0.54,0.74,0.77,0.91)	(0.3,0.5,0.56,0.76)	(0.65,0.85,0.85,0.97)
M4	(0.24,0.4,0.46,0.66)	(0.56,0.77,0.77,0.91)	(0.38,0.52,0.585,0.73)	(0.65,0.85,0.85,0.97)
M5	(0.12,0.3,0.3,0.5)	(0.52,0.72,0.75,0.91)	(0.55,0.75,0.78,0.94)	(0.66,0.86,0.86,0.94)

Table 12: Weighted normalized fuzzy resolution matrix

Criteria	N1	N2	N3	N4
M1	(0.12,0.34,0.39,0.64)	(0.28,0.57,0.62,0.86)	(0.34,0.66,0.66,0.8)	(0.35,0.68,0.68,0.8)
M2	(0,0.09,0.08,0.3)	(0.17,0.41,0.41,0.71)	(0.19,0.43,0.43,0.74)	(0.37,0.69,0.69,0.9)
M3	(0.01,0.14,0.14,0.44)	(0.25,0.47,0.48,0.82)	(0.11,0.31,0.35,0.68)	(0.24,0.53,0.53,0.8)
M4	(0.17,0.4,0.46,0.66)	(0.39,0.77,0.77,0.91)	(0.27,0.52,0.55,0.73)	(0.45,0.85,0.85,0.9)
M5	(0.08,0.3,0.3,0.)	(0.36,0.72,0.75,0.91)	(0.38,0.75,0.78,0.94)	(0.46,0.86,0.86,0.9)

Table 13: Distance between Ai (1,2,3,4) and A* under fuzzy approach

Distance	M1	M2	M3	M4	M5
d(N4, N*)	0.35	0.31	0.48	0.27	0.25
d(N2, N*)	0.41	0.51	0.52	0.32	0.33
d(N3, N*)	0.36	0.49	0.64	0.47	0.31
d(N1, N*)	0.60	0.79	0.80	0.57	0.66

Table 14: Distance between Ai (1,2,3,4) and A– under fuzzy approach

Distance	M1	M2	M3	M4	M5
$d(N4, N^-)$	0.48	0.71	0.56	0.57	0.69
$d(N2, N^-)$	0.42	0.47	0.51	0.51	0.60
$d(N3, N^-)$)	0.47	0.49	0.39	0.32	0.63
$d(N1, N^-)$	0.25	0.17	0.22	0.25	0.23

Table15: Computation of d_I^* ,$d_I^-$and closeness coefficient (CCi)

Alternatives	d_I^*	dI−	$d_I^*+d_I^-$	CCi =dI−/d∗I+d−I	Rank
Bed length(N4)	1.66	3.01	4.67	0.64	1
Bed breadth (N2)	2.09	2.51	4.60	0.54	2
Bed height (N3)	2.27	2.30	4.57	0.50	3
Bed stand height (N1)	3.42	1.12	4.54	0.25	4

8. LINEAR REGRESSION ANALYSIS

The purpose of used regression analysis in this research work to estimate the impact between different anthropometric variables. One of the anthropometric parameters, the stature height, is considered as independent variable whereas others three parameters such as elbow span (bed width), popliteal height (bed height) and vertical grip length (bed stand height) are assumed as dependent variable. The objective of this analysis was to facilitate the resolution making process through reducing complexity. Here, only one design parameter is selected as independent variable and put on the developed equation instead of all parameter. By this approach, one can easily find out the others design criteria. The formulated equations are presented in table 16.

Table 16 Correlation among all design variables

Dependent variables (Y)	Prediction equation
Elbow span (bed breadth)	Y = −0.539 × Stature height or bed length−1.893
Popliteal height (bed height)	Y = 7.546 + 0.223 × stature height or bed length
Vertical grip reach (bed stands height)	Y =1.404 × stature height or bed length −25. 54

9. CONCLUSIONS

Ergonomics has attracted the attention of artificer for developing more comfortable and efficient furniture over the last two decades, regardless of university bed and others. A structure for ergonomic considerations for the design of comfortable bed design was built in this research. This research was conducted using anthropometric data from 125 male students and 10 expert opinions on different health related issues. In this work, the most successful design parameter responsible for the student' physical problem was defined by well-known approaches, namely Fuzzy and AHP approach. It was interesting to see that the priority rankings were the same in both fuzzy methods and AHP, which voluntarily represented reliable outcomes. Finally, to estimate the design parameter dependent on the student's stature, the linear regression model was applied. This study will provide a better solution for Bangladeshi students to design a hall bed. Only 125 male students were included in this report, but future anthropometric data of more male students as well as female students can be considered for design suitable hall bed.

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