

# OPTIMISED DESIGN, ANALYSIS OF AFFORDABLE HEIGHT-ADJUSTABLE TABLE

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**Abstract:** This paper discusses the design and analysis of "Height-adjustable" that is made by using an economical height adjustable table that is available in the market standards. Keeping the view of ergonomics of the table and building the table by reducing the cost of the existing table, are the significant improvements in the project while controlling all necessary conditions about a comfortable table. The goal was to reduce the cost of the existing height-adjustable table to make it available for students and employer working from home in this global pandemic. The selection of the material and mechanism used to adjust the height plays a significant role in the end pricing of the table and ergonomics - all designs of components and analysis are made using Autodesk Fusion 360 software for the most optimised configuration. In this design, the table is made using an aluminium frame and a linear actuator that are readily available in the market. The completed table is compared to tables available at the price to make sure our design is successful.

**Key Words:** height-adjustable table, linear electric actuator, fusion 360, Cost reduction, optimization.

## 1.0 Introduction:

The height-adjustable tables are one of the furniture that can adjust its height using different mechanical techniques. These adjustable types of furniture are magnificent in every comfort until prices come into matter. The height-adjustable tables are the comforts that cannot be easily affordable by low to middle earning classes. Currently, the best multi usable height-adjustable table is pricing at around twenty-five thousand to forty thousand Indian rupees (Rs.25,000 – Rs.40,000)[1]. Even there are adjustable table starting at fifteen thousand rupees (Rs.15000) but cannot be used for multi-purpose. So due to this high pricing, the affordability of these tables are limited. To say more about tables, they offer much ergonomics to people who use them. If a person has to work in the same position or have to prepare for something exam or project, sitting at the same place with the same poster hurts any person's physical posture and leads to many health problems[2]. In addition to this lousy working environment reduces the productivity of the work. These vertical size adjustable tables are one of the solutions to that problems. But not before finding a solution for the pricing of the table, as they cannot be affordable. There are many potential answers for this problem using local products for mechanism; smart utilisation of the resources available is a few options that reduce the price. So we have opted for using a readily available mechanical system, which is the first step to cut the cost and usage of high strength and less weight metal like aluminium. Also, along with less weight metal, the necessary use of plastics or wood can reduce weight, which plays a vital role in the adjustable system. This process allows us to have a comprehensive option in choosing a mechanism at the low end. Along with these, keeping up the ergonomic is one hell of a task as ergonomics play almost as important a role as pricing in the market. Moreover, defining the main purpose of the table to remain the basic size and structure essential for the strength of the table. With this, all efforts in a successful way enable a larger amount of people to get assessable to this beauty of invention and live a healthy life.

## 2.0 Case study:

Long periods of sitting in the organisation have become increasing public health and occupational health concern with a diverse range of devastating effects on the health of the working population. Particularly for those who meet or exceed national activity norms, prolonged sitting is a risk factor for inadequate health and early fatality. According to a study published by Baker IDI and Diabetes Institute, overweight workers and call centre employees who sit for long periods of time will boost their health by breaking up their sitting time with regular activity breaks. According to studies, switching between sitting and standing causes less pain and decreases the amount of exhaustion many people encounter at the end of the day. People in India take a glance first at the cost-benefit ratio and ought seeks to find the best quality at a lower cost. As a result, creating an aspect that meets comfort, expense, and encourages effective workplace experience is a critical challenge.[3]

**2.1 Constraints:** Cost reduction, less weight, ergonomic, optimization.

**2.2 Mechanism selection:** Mechanism selection is done considering cost, strength factors, load requirements, availability and variability in height. The specifications of the selected electric linear actuator are [4]:

-Actuator- electric linear actuator

-Self-locking force- 6000 N

-Stroke length- 500mm

-Weight- 2.6 kg

-Lifting system- lead screw with an electric motor system

-Electric rating: 12volts 3 amperes

**2.3 Material Selections:** Materials are selected bases on high strength to weight ratio, which help us to reduces the weight in the actuator and remains strong for bearing required loads with base parts need heavy and strong metal to withstand table weight.

- Aluminium 6061 alloy for top frame[5], Numerous researchers conducted investigations with numerous forms of reinforcement processes to enhance various properties. The strength and stiffness to weight ratio of such composites are extremely high. The fabricated composite can be used in applications that need low weight and high strength. The majority of scientists concluded that as the percentage of reinforcement throughout the base metal improves, the mechanical properties of composites, such as hardness, compressive strength, and tensile strength, improve.

**Table 1: Aluminium 6061 properties[6]**

| Al6061(as cast) | Hardness (BHN) | Young's Modulus(GPa) | % Elongation |
|-----------------|----------------|----------------------|--------------|
|                 | 62.8           | 79.8                 | 8            |

- Cast Iron for the base, due to its high strength properties.[7]

#### 2.4 Parts of the table.

A top frame- made of Aluminium 6061 alloy for less weight and high strength, a base made up of mild steel of both strength and weight to make the base heavy, and stable, an electric actuator made up of aluminium alloy, Bolts 10mm, Tabletop (Plywood/Plastic/Fibre, Plywood selected while designing)

**2.5 Target Cost:** Cost is the biggest factor for this project as this is a try to reduce the cost of the item. So we have to make this decision after looking into the market competition and their pricing. There are few giant furniture like IKEA producing some classes of these products, but they are Highly-priced from a range of 25-45 thousand rupees. This makes it difficult to get it and most people don't use it for keeping heavy things, so their costly design is not fully used.

So our initial maximum price considering is 12-13 thousand rupees. There are a few manufacturers which have height-adjustable tables. But these tables are small in size or have manual lifting mechanisms. So we have decided our table should be large enough for basic activities, and So pricing. So we have decided our table should be priced below 13k.

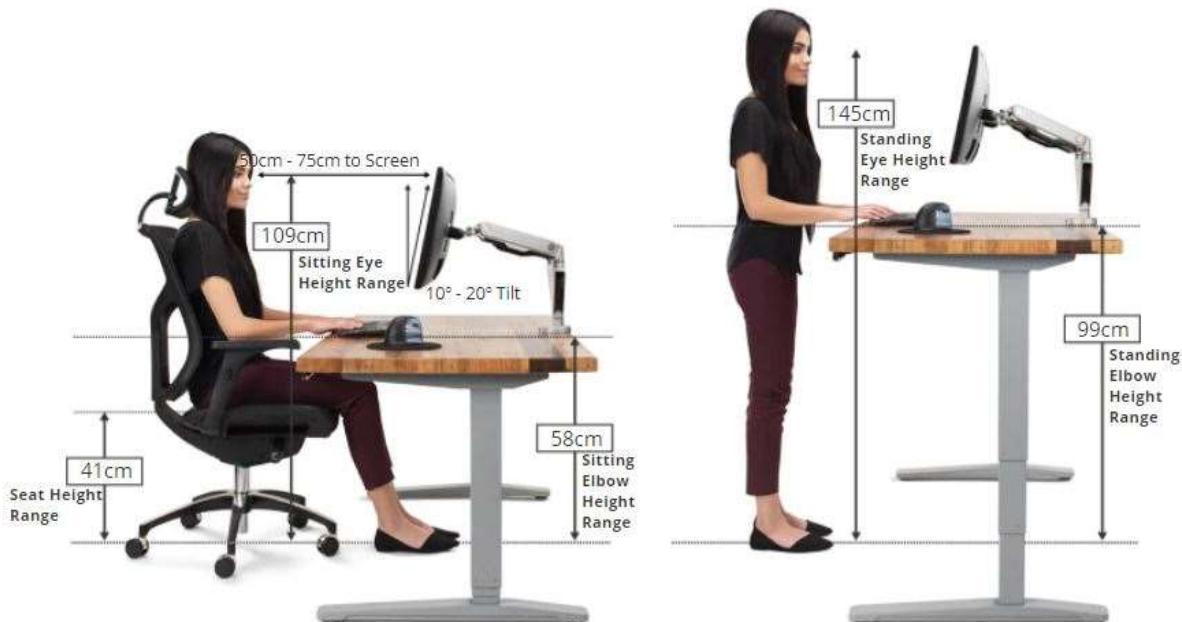
Load capacity is a factor that people look for. To do that we have to calculate weight in real-time before quoting the maximum weight.

**2.6 Target Design dimensions and load:** Dimensions of the table are decided after learning about minimum requirements for general work of employees and students above 12 years of age. The minimum and maximum height of the table is considered according to target customers which is also above 12 years. weigh is being calculated according to the general usage of a table in table life.

**2.6.1 dimensions of the table** are decided after learning about minimum requirements for general work of employees and .students above 12 years of age. The minimum and maximum height of the table is considered according to target customers which is also above 12 years. weigh is being calculated according to the general usage of a table in table life. We have one restriction of minimum height due to the non-adjustable height of the actuator.

The ideal minimum height of the table for working conditions is +/- 76 (due to restriction of actuator height)

The avg height of an 18-year-old person is 163 cm [8], and the height required for the should be 163 cm human being is 63 cm while having a chair of height at 41 cm. So minimum height should be 63 cm, but due to the actuator minimum height, we have to push this height and it cannot be less than <76 cm.



**Figure 1: sitting to standing table height as per website [thehumansolution.com/ergonomic-office-desk-ergonomic-chair-and-keyboard-height-calculator/](http://thehumansolution.com/ergonomic-office-desk-ergonomic-chair-and-keyboard-height-calculator/)**

The maximum height of the table is decided by the stroke of the actuator, which 50 cm. so max height could be  $>76+50\text{cm}$ .

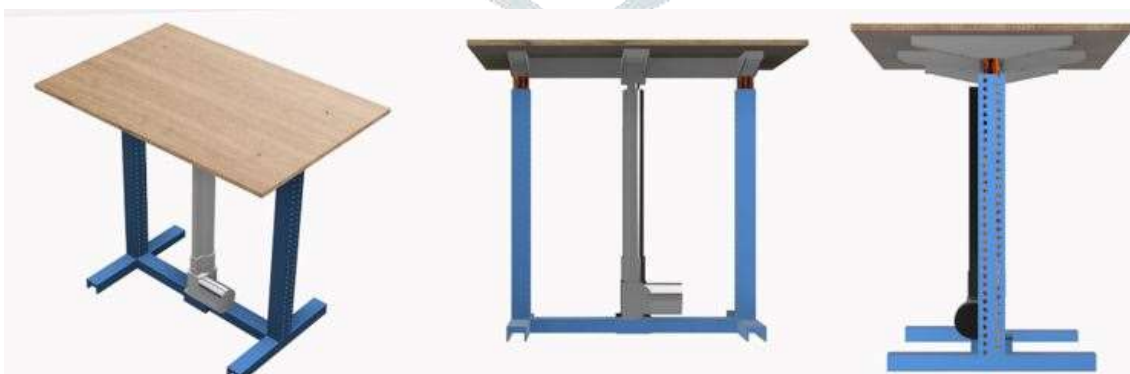
Breath is also calculated similarly that customer using a keyboard in front of the laptop, customers should feel comfortable while using it and the laptop shouldn't fall off the table. To this, we have decided that width should be  $<50\text{ cm}$

**2.6.2 Load:** The minimum load requirement is also calculated on the general usage of students and employees. So conditions are table having a laptop, cooling pad or laptop stand, one keyboard, a mouse pad, a dairy and a mouse. So a maximum of 10-15 kg will be placed on the table. To make it safer at max load, we have extended the Max load target to 20 kilograms. The models we have designed are tested at 3 times more weight to make sure that our model doesn't poise to danger at any unexpected load on the table.

### 3.0 Proposed designs:

#### 3.1 Design 1: 3 legs in a single line

This design of the table has 3 legs arranged in a straight line in the middle of the table. The middle leg is the actuator, and the rest of the two legs on either side. These legs are provided with a locking system, when legs are lifted higher they are ended being resting on the pins that are inserted in provided pin slots. We have to insert these pins manually according to the lifting height.



**Figure 2: Rendered Image of the 3-legged table with fusion 360**

### 3.1.1 Expected cost for manufacturing design:

**Table 2: 3 legged table Specifications and cost of the table**

| NAME OF THE PART | MATERIAL USED        | WEIGHT OF THE PART (in kg) | COST PER kg | TOTAL COST (in INR) | DIMENSIONS (if any) in cm |
|------------------|----------------------|----------------------------|-------------|---------------------|---------------------------|
| FRAME            | Aluminium 6061 alloy | 4.289                      | 260         | 1,435.2             |                           |
| BASE             | Aluminium 6061 alloy | 7.401                      | 260         | 2314.3              |                           |
| SUPPORT LEGS     | Teak wood            | 6.14*(0.106*)              | 1600*       | 169.6               | 4.6*3.5*77                |
| Tabletop         | PLY wood             | 2.76(7***)                 | 75**        | 525                 | 90*60*1.5                 |
| Actuator         | -                    | 2.5                        | -           | 6,199               |                           |
|                  | Total                | 23.09                      | -           | 10643.1             |                           |

\* per cubic feet

\*\* Variable cost

\*\*\* In Square feet

#Miscellaneous cost: the that's are added expect materials used in the design. This cost here includes the estimated cost of the control system for the actuator and its parts. The expected waste of materials (=20 % has been added to the total cost of the material)

Expected cost for control components= 1,300 Rs

Approximate Total cost of the table = 11943.1 Rs

### 3.2 Design 2. Single leg in the middle:

This table designing with the most optimized conditions. It is shaving only one leg in the middle and it also the mechanical leg for the table. The actuator in the middle takes all the weight and forces acting on the table. The table base is designing to have the heavyweight metals and spread over a large area. The frame is designed to be the lightest to reduce the weight and pressure on the table



**Figure 3: Rendered Image of 1 legged table with fusion 360**



## 3.2.1 Expected manufacturing cost per design:

Table 3: 1 legged table Specifications and cost of the table

| NAME OF THE PART | MATERIAL USED        | WEIGHT OF THE PART(in KG) | COST PER KG(* in sq feet) | TOTAL COST (in INR)# | dimensions (if any) in cm |
|------------------|----------------------|---------------------------|---------------------------|----------------------|---------------------------|
| FRAME            | Aluminium 6061 alloy | 2.6                       | 260                       | 860                  |                           |
| BASE BLOCK       | Cast Iron            | 5.132                     | 50                        | 307.6                | 10*10*7                   |
| TABLETOP         | PLY wood             | 2.76(7*)                  | 75**                      | 525                  | 90*60                     |
| ACTUATOR         | -                    | 2.5                       | -                         | 6,199                |                           |
| MILD STEEL PIPES | Mild steel           | 6.67                      | 60                        | 480                  | 2.3*1.3*(0.5))            |
|                  | total                | 19.662                    |                           | 8371.6               |                           |

\* In Square feet

\*\* Variable cost

#Miscellaneous cost: the that's are added expect materials used in the design. This cost here includes the estimated cost of the control system for the actuator and its parts. The expected waste of materials (=20 % has been added to the total cost of the material)

Expected cost for control components= 1,300 Rs

Approximate Total cost of the table = 9671.6 Rs

## 4.0 Comparison of dimensions and analysis of table :

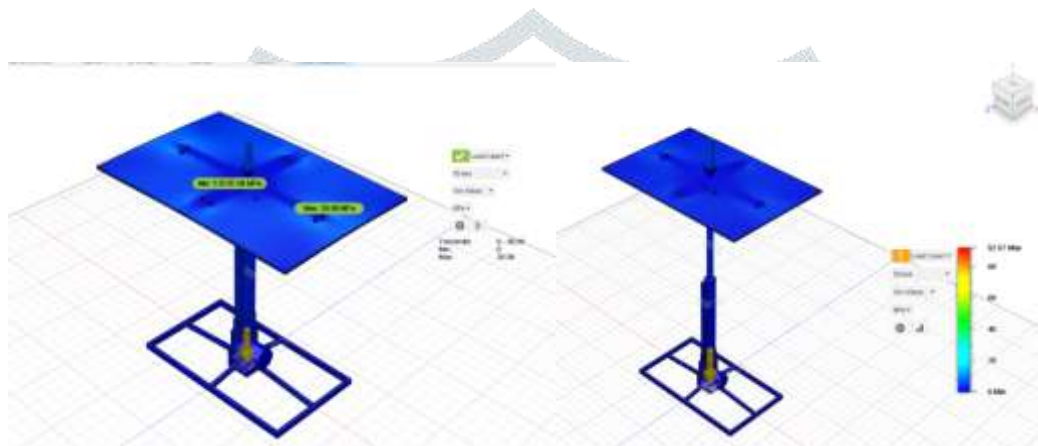
Table 4: minimum height

| Table Type     | Dimension of tabletop (cm*cm*cm) | Height cm |
|----------------|----------------------------------|-----------|
| 1-Legged Table | 90*60*1.5                        | 83.6      |
| 3-Legged Table | 90*60*1.5                        | 80.01     |

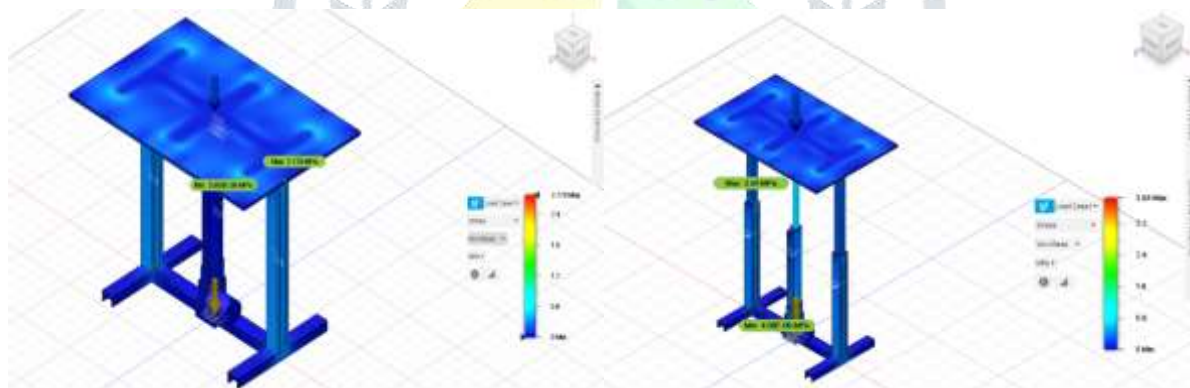
3 legged table is 3 cm shorter than the single-legged table

**Table 5: Comparison of analysis of table**

|                          | LOAD | STRESS (MPA) |          | FACTOR OF SAFETY |
|--------------------------|------|--------------|----------|------------------|
|                          | KG   | MAXIMUM      | MINIMUM  |                  |
| DESIGN-1: 3 LEGGED TABLE |      |              |          |                  |
| LIFTING POSITION         | 60   | 3.84         | 4.06E-06 | 15               |
| RESTING POSITION         | 60   | 2.78         | 3.89E-06 | 15               |
| DESIGN-2: 1 LEGGED TABLE |      |              |          |                  |
| LIFTING POSITION         | 60   | 92.07        | 5.14E-05 | 2.99             |
| RESTING POSITION         | 60   | 36.06        | 5.87E-06 | 5.82             |



**Figure 4: Stress in sitting & standing position for 1 legged**



**Figure 5: Stress in sitting & standing position for 3 legged**

**5.0 General discussion and recommendations:**

The study is mainly focusing on reducing the price of the Height-adjustable table by using a locally available height-adjustable mechanism, to reduce the gap between the financial burden. We tried to reduce the cost well while retaining most of the ergonomics for being a decent height adjustable table. While reducing the cost we have tried to remove unwanted features and retain the main features to basic level usage, as we are focused on customers like work-from-home employees, university students that have to work for long hours, even this table can be used by high school children doing basic works on the table, instead of heavy usages. This provides much more comforts with these recommendations

- Fixed at one place (if a customer is living in their own property) to extend the weight capacities and limitations.
- Using an adjustable chair, so a customer can raise your comforts is table minimum height is not sufficient
- Loads on the table can be placed in the middle, which reduced the partially applied load and increases actuator efficiency
- If a customer wants to change the tabletop size he can easily change them.
- Increasing efficiencies in measurement performance and, selecting the required product quality reduces scrap.

## 6.0 Limitations;

- The prices of the components may vary from place to place, so cost may differ slightly
- When the table is lifted to the maximum height, the load on the table should be strictly below the cautious load limit
- A heavy load(load greater than recommended load) should not be placed on one side of the table unless the table is fixed to the ground.
- The price of the materials can differ depending on the region, where user shop either in-store or online.

## 7.0 Result:

From the above results either of analysis and dimension of the table we got clear results. We have analysed the designed tables at 3 times larger load than the intended load to make our design can withstand some additional unexpected weights. The analysis result of the 3-legged design has a factor of safety of 15 in both rating and lifted position which is about 5 times greater than the minimum required number. This defines the table design as over-engineered as per our requirement. This means design 1 has overachieved than we have expected and also approximate the price of the table is more than design 2. This table does not meet our required category. Whereas design 2 with one leg, showed us prompting results at the same 3 times load. Achieving 5.82 Factor of safety when in resting position and 2.99 when lifted, which is the minimum requirement has been met but has me cautious when using the table was lifted. Moreover, design 2 satisfies the budget condition as well as the load condition. Design 2 is not expected to create any problem at the intended 15-20 kilogram, but need to be careful about load when exceeded beyond that. Moreover, design 2 (single-legged table) is optimized for the general and our intended usage. So design 2 is a better design compared to design 1 for the given conditions.

## 8.0 Conclusion:

To summarise, design 2 has generated the most anticipated results under our target conditions, with some caution at higher loads than expected. When comparing the costs of the two projects, design 2 was less expensive than design 1, and design 2 also met most of the expectations. To save money and increase comfort, the three legs have a partial automatic design with a pin locking mechanism that can be changed to meet the needs of the user, client, or professional. Further designs using various materials could have a positive effect on this study in the future.

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