DESIGN, DEPLOYMENT AND ANALYSIS OF AN AUTOMATED SENSOR CONTROLLED UMBRELLA

A Final Year Project Report

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of the Requirements for the Degree of
Bachelors of Mechanical Engineering

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ABSTRACT

This project is of a unique nature as it aims to address a major concurrent problem of ever decreasing space for commercialization and a need for outdoor solution as an alternative. While providing a primary design solution for smart automated umbrella for the services sector. The approach for this was to first conduct an extensive literature review where various existing products were studied and the market requirements were gauged. This helped in refining our problem statement and methodologies by contrasting with the ones implemented before. Numerous actuation mechanisms were considered and efficacy of various modes of deployment were considered. The umbrella assembly were modelled in SolidWorks as well as complete stress and kinematic analysis to configure the failure conditions of the design. Along with Arduino Mega for the complete mapping of the control systems and program to control the mechanism. The material of the device is also selected as a part of the analysis procedure.

The electrical system for the system is also designed and tested. These various subsystems after design and optimization are integrated into finalizing the design ready for prototyping. This product ultimately provides an excellent solution for deployable canopy systems and eliminates the need for restaurants and cafes to be an indoor establishment, positively impacting the environment.

ACKNOWLEDGMENTS

First and foremost, we would like to thank Almighty Allah for blessing us with the wisdom, the ability and the strength to pursue and deliver this project. We would also like to express our gratitude to our supervisor Dr. Sana Waheed for her continued support and guidance in completing this project. We would like to thank her for believing in us and helping us with her wisdom and expertise constantly that helped us develop as professionals. We would also like to acknowledge and give thanks for the constant support of our co-supervisor, Dr. Aamir Mubashar.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

TMP	Sliders Top Most Position
BMP	Sliders Bottom Most Position
GR	Gear Ratio

NOMENCLATURE

η	Efficiency
T_{IA}	Actual Torque on Input Shaft
T_{IS}	Torque on Input Shaft
T_{OS}	Torque on Output Shaft

CHAPTER 1: INTRODUCTION

1.1 Problem Identification

As far as mankind can remember, cement and mortar had been used for all services sector including restaurants and café. With outdoor sitting being a recent phenomenon. However unknowingly the rabid urbanization by mankind has had a major toll on the climate with the sea levels rising and the weather being increasingly unpredictable. Mankind across the board is encouraging environmentally friendly practices including decreasing the carbon footprint in new and existing business ventures. With that outdoor sitting has been increasing rapidly and even becoming trendy for restaurants and cafés calling for an innovative and adaptable solution to make outdoor sitting not just viable but a priority.

1.2 Motivation

However outdoor sitting in its current state is still frowned upon and not entirely accommodating. For starters the current solutions of deployable shades employed in restaurants are laborious and require extensive workforce to deploy and are obviously marred with human delay at the advent of any natural phenomenon or consumer choice. Secondly, its appearance is not aesthetically pleasing and only serves the purpose of a shade or a blockade. Additionally, the market available solutions are not scalable or adaptable to the changing weather. Lastly but most importantly, deployable umbrellas have been treated as a luxury and the market available solutions are highly expensive further discouraging its widespread use.

1.3 Solution

We aim to design an Automated Deployable Umbrella that is sensitive to rainfall, sunlight and temperature and is aesthetically pleasing to look at. The aim of this product is to resolve the aforementioned problems with the market as well as the environment. The shift from cemented establishments and decreased reliance on brick kilns replaced with a ready to deploy product the carbon foot print due to new and existing ventures in services sector will be reduced manifold. The fact that our product would be integrated with sensors and will deploy automatically will forgo any demand for the labor and will eliminate the human reaction error and the business will save on the labor costs. Additionally, the increasing cost of construction and spiking prices of building rents the business will save a lot from a one-time investment through our product. Along with the fact that our solution is ready to go and would not delay any entrepreneur to wait for construction etc. We also aim that the product we make will provide premium aesthetics and ambiance which previously was a tradeoff between indoor and outdoor sitting in line with the already available products used in beaches and other membership-based establishments. Moreover, the design solution that we propose is scalable based on the establishments needs so a custom order could also be placed for a business's specific needs. Lastly, as we will show in the literature review, we intend our product to not just be competitive with market prices but much lower to create a competitive advantage and encourage the use in local businesses of Pakistan that considered it to be a premium by careful selection of our materials and other requisites

1.4 Problem Statement

The aim of this project is to design an automated umbrella that deploys at the account of sunlight, temperature and rainfall and that can be produced cost effectively for the local market use in the recreational services sector. This problem statement can be divided into three main categories described below.

- **Automation:**

To design an umbrella which is fully automated. Most of the similar products available in the market involve manual effort for its deployment. Our aim is to reduce the human effort to zero and make the deployment and folding mechanism fully automated.

- **Cost Effective Solution:**

To produce a cost-effective solution to our problem. With this project, we are targeting the recreational sectors mainly restaurants. Also, we wanted to gain an advantage over our competitors. These are factors that were the driving force for us to produce a cost-effective product.

- **Local Manufacturing:**

To make a product for the local market using materials from the local market. The local manufacturing of the umbrella enables us to produce the product at a cheaper rate compared to such products in the international market.

1.5 Objectives

The objectives of this project are defined below.

- **Literature Review and Market Survey**

Study of the literature available regarding our problem and finding possible solutions like the design, automation, deployment, analysis, control system and suitable material. Also, to get an idea regarding the components to be used in the manufacturing of the product and the similar products in the market, conduct a market survey.

- **Design of Initial Concepts:**

Create initial concept designs, select the most suitable and ideal design and create a detailed model of that as a final design.

- **Incorporation of Control System:**

Incorporate a control system that ensures the automation of the umbrella possible depending upon the rain and sunlight which are detected by the sensors installed.

- **Perform Structural Analysis:**

Optimize the final design and perform all the required analysis on the product in a detailed manner to make sure it does not fail under any condition.

- **Fabrication of the Prototype:**

Fabricate the prototype and test it completely to make sure it works exactly as expected (dependent on the covid 19 situation).

CHAPTER 2: LITERATURE REVIEW

2.1 Existing Products and Applications

The first step in our literature review was to scout for existing products that were in the market and their prospective applications. Primarily the premium umbrellas were used in beaches and in resorts. But the most motivating application that aligned with our views of a deployable canopy system was attempted in Masjid-e-Nabwi in 2010.

Figure 1 Masjid-e-Nabwi courtyard

With a combination of 250 umbrellas an area spanning over 143,000 square meters was covered to protect the worshippers from rain and scorching heat of the sun. Each umbrella has a surface area of 25.5 x 25.5 meters and 15 meters height. (1) The cloth used in the umbrella was a special material of composite PTFE with qualities including but not limited to UV ray protection and carefully crafting the material ensured that the temperature was reduced significantly as well.

We took Masjid-e-Nabwi as the motivation because it fit our vision of replacing the traditional design solution of cement roofing the entire area of 143,000 square meters. Instead, they reduced the cost of such large-scale construction with a deployable canopy system.

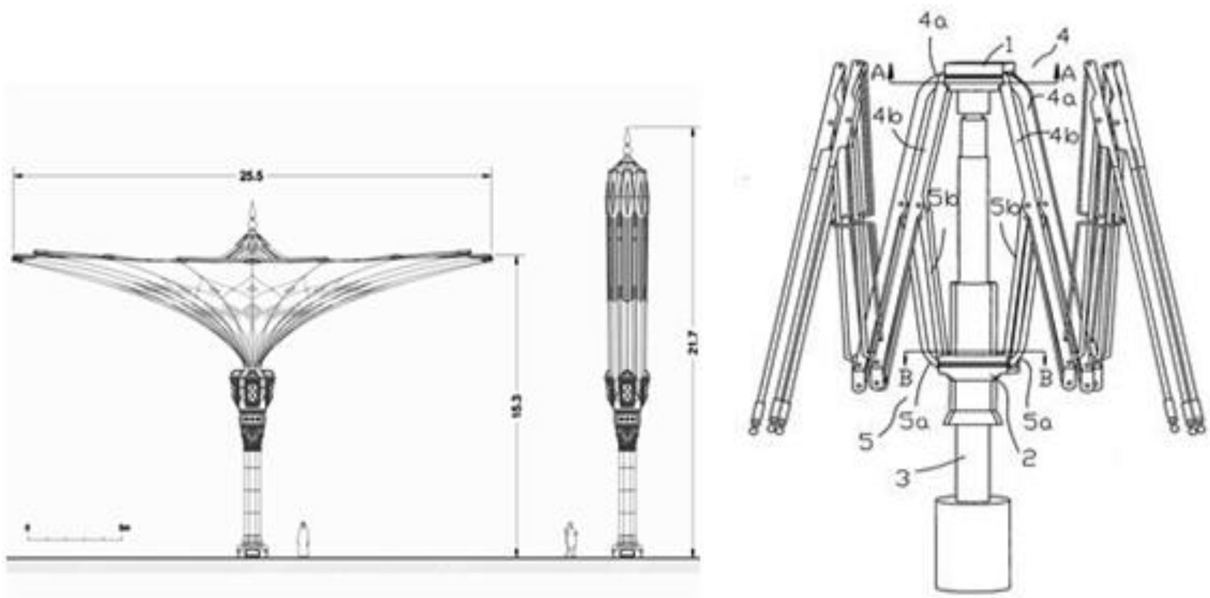

Figure 2 Masjid-e-Nabwi Projections

Masjid-e-Nabwi was a large-scale one-time project but our aim is to pursue a moderate to small scale projects for which various products in the market exist.

Currently these products are not locally manufactured and mainly used in western countries namely USA and Canada. The main company that makes such products in America is "ShadeScapes" that produces world class umbrellas used in beaches, recreational parks, and open offices. These umbrellas, although premium, are not automated and are relatively expensive and premium products since they are manufactured in very limited countries.

Figure 3 Shadescapes Cantilever Umbrella

Spectre Offset Umbrella:

One of the premium products of ShadeScape is the Spectra Offset Umbrella which is a planar umbrella with various deployment options: a straight 90 degrees angle pole or a Forward leaning 80 degrees angle pole. (2) These products come in different variations of Solo, Duo where two diamond canopies are combined side by side. These can be further coupled to make a Quattro arrangement with four connected poles in the center and two square or diamond canopies can also be combined back-to-back. (3)

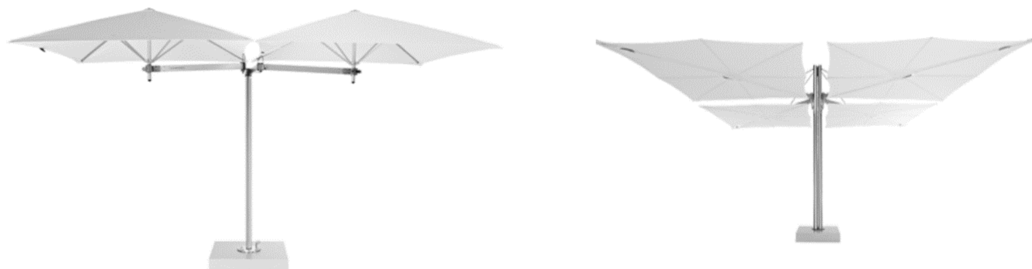

Figure 4 Spectre Offset Umbrella

The various specifications and dimensions of a standard umbrella have been shared on their official website and come in various sizes depending on the application and the seating requirement.

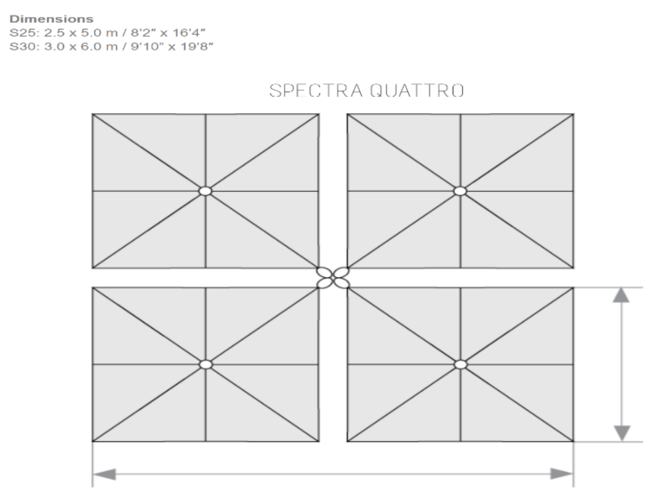

Figure 5 Design Specifications

These premium umbrellas have various features some which are limited just to the premium versions like LED lights whose brightness could be controlled. Other properties include ultraviolet rays protection against sunlight. But these umbrellas are not perfect as they need Protection Cover for their covering in case of heavy wind and rain. Another drawback is that they are not fully automated as the manual movement of the slider upwards to deploy it is required. Also, a single such umbrella costs a heavy amount of around $3,000 - $4,000. (4)

2.2 Choosing Prerequisites

2.2.1 Material Selection

In order to validate the said design and manufacture we had to decide upon certain perquisites, primary of which were the selection of materials for the sheet of the umbrella as well as the material for the chassis and the mechanism.

For the umbrella sheet we researched the most common material choices by the industry and did detailed research in order to better weigh their pros and cons and to make an informed choice. We managed to narrow down our materials to 4 candidates. These materials obviously varied a lot in pricing and hence their properties so we put each of our material to a decision matrix test to find the most adequate and feasible.

Table 1 Umbrella Sheet Material Properties

Material Name	Price (X)	Properties
Nylon	Starting 2.5$/ meter	Blocks UV, WR, Shrinks with humidity, Corrosion Resistance (CR)
Polyester sheets	Starts 2$ / meter	CR, Light, washable, Faster dried, Static shock
Plastic (PVC, POE, EVA) (Cheapest) quality and price	Starts 1 $/ meter	Cost effective, resist distortion, opaque, UV, Elastic
PTFE (on fiber glass or on fabric)	Starts 3.5$ /meter	Blocks UV, CR, No friction,

With standard width of 1-1. 5 m, Max Quality Price = Atleast 3*X

The initial comparison done between these materials included their market prices at the time and the material properties that each material possesses. To ensure that the product provides ample protection against natural phenomenon like UV rays from sunlight and friction coefficient to dispose of rain droplets these properties become extremely important in decision making but at the same time they also come at some cost. Additionally, the material properties that contribute to the stability and longevity of the material were also taken into account including fatigue cycles and weight (density) of the material became quite relevant in terms of our choice. Some of the data that we gathered along those lines is as follows:

Table 2 Umbrella Sheet Material Comparison (5), (6), (7)

Material Name	Density	Yield Strength	Fatigue	Friction coefficient
Nylon	1.15g/cm3	103MPa	107 cycles, 19 MPa	0.3-0.4
Polyester	2.7 g/cm3	276 MPa	96.5 MPa	0.057-0.063
PVC	1.38 g/cm3	3.45-68.9 MPa	-	0.2-0.3
PTFE	2.2 g/cm3	19.7-21.7 MPa	-	0.08-0.320

2.2.2 Actuation Mechanism

In any assembly, actuation plays a pivotal part in determining how the mechanism would be driven and controlled. Any actuation type requires a control signal and some type of power to drive it. Mainly there exist three types of actuation mechanisms

1. Pneumatic Actuators
2. Hydraulic Actuators
3. Electric Actuators

Each of these actuation types contain advantages and drawbacks of their own and the choice of actuation is highly dependent on the situation and the variables like payload delivery, speed and the environment to name a few. We went in depth into the workings of these various types and compared their advantages and disadvantages.

1. **Pneumatic Actuators:** A pneumatic actuator is an actuation device that derives energy of actuation by converting kinetic energy stored in the compressed air or any other gas and converts the subsequent energy into useful mechanical drive to power the actuation. The mechanism primarily comprises of a piston which forces the diaphragm and consequently the air in the upper part of the cylinder which creates the necessary force due to the pressure for deployment.

   A schematic diagram of a pneumatic actuator is shown as follows.

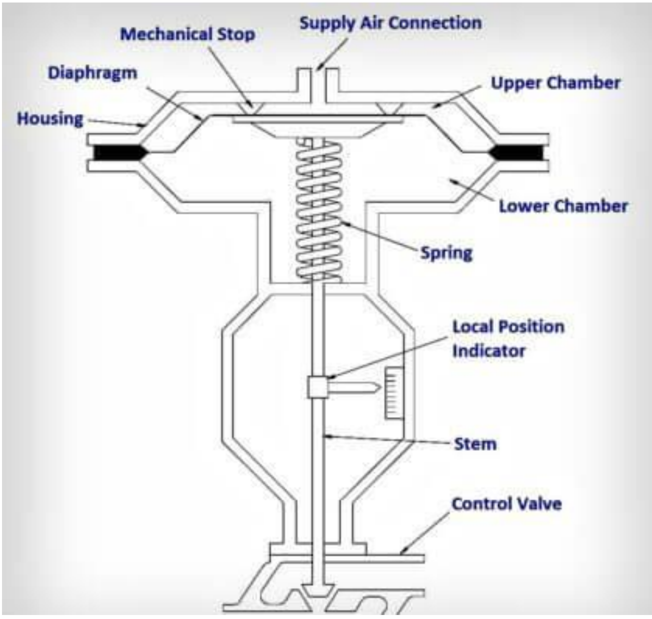

Figure 6 Pneumatic Actuator

The working principle and nature of pneumatic actuation has various benefits as well as various drawbacks.

Advantages:

- If air is used as the gas, then it is virtually in infinite supply, readily available and at no cost. We can also vary the load provision by utilizing different gases namely natural gas to achieve greater pressure and energy requirements.
- Pneumatic actuators can be implemented in adverse environmental conditions like high temperature and under radiation exposure.
- The maintenance and cleaning of the actuation mechanism is relatively easy as the mechanism is not very dust prone since the passage of gas keeps the instruments clean from contaminants.
- Pneumatic actuation is relatively safer since lack of electricity usage keeps the mechanism free from sparks and hence the gases will not ignite or catch on fire.
- As compared to other actuation mechanisms pneumatic actuation is very light weight and can be used in a wide variety of applications without limitations of bulkiness or weight.

Disadvantages

- Air compression is more expensive than the cost of electricity.
- Pneumatic actuation may be prone to energy losses due to the leakage of gases in the mechanism.
- Pneumatic actuator is highly responsive especially at the extreme points of the start and finish. Thus, increasing the accuracy of the mechanism and the deployment motion.
- The power requirements are actually much larger because in order to maintain the mechanism in the deployed position the compressor must run continually. (8)

2. **Hydraulic Actuators**: Hydraulic actuator is a fluid-based mechanism which converts hydraulic power into equivalent mechanical power via motor. The motion produced can be rotatory as well as linear. The working mechanism consists of a spring-based piston driven by hydraulic pressure which results in a force on the piston opposite to the force caused by the spring. Deployment occurs through valve opening which occurs when the hydraulic force exceeds the compressive force of the spring. (9)

A schematic diagram of a hydraulic actuator is shown as follows.

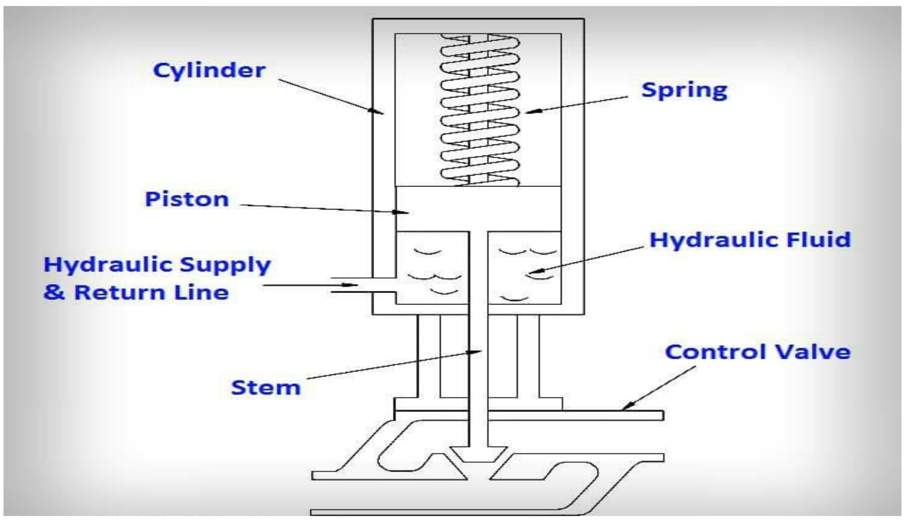

Figure 7 Hydraulic Actuator

Advantages:

- Hydraulic actuators can be used in applications with significantly higher load requirements than other actuation mechanisms.
- As opposed to pneumatic actuation the hydraulic actuators are built to hold force and the mechanism in place therefore addition or continual fluid supply is not a requirement.
- The power losses in hydraulic actuation can be minimized significantly by locating pumps and motors at a considerable distance away. Also benefiting in space management and design.
- Hydraulic actuators are much more durable and stable in their design and construction in comparison with actuation alternatives.

Disadvantages

- The hydraulic mechanism is prone to fluid leakage which leads to decreased efficiency and increased requirements for cleanliness and upkeep. The potential for damage to and by the electrical appliances also increases.
- The maintenance requirement for hydraulic actuators is significantly higher as there are many components to monitor including motor, pump, fluid reservoirs and valves.
- The overall bulkiness and the weight of the mechanism is quite high. (10)

3. **Electric Actuators:** An electric actuator is an electric powered mechanism often driven by a motor which converts rotary motion of the motor into linear actuation. The working principle of the electric motor consists of a helical screw which is primarily responsible for converting motors rotary motion into linear motion as

the power screw rotates it moves upwards and deploys the actuator. The mechanism also consists of a gearing system and a driveshaft which transmits motion from motor to the main screw.

A schematic diagram of an electronic actuator is shown as follows.

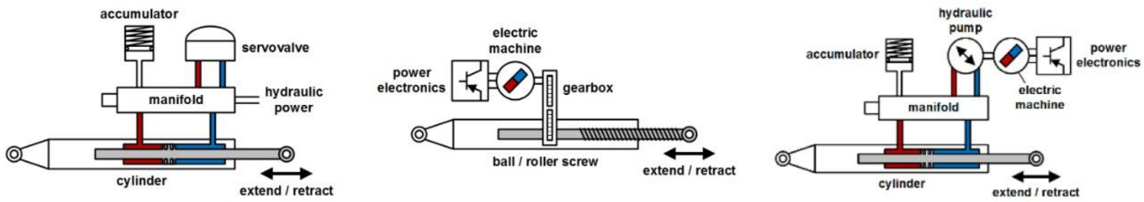

Figure 8 Electronic Actuator

Advantages:

- Since the electric actuators are driven by motors their design and load requirements are quite scalable by varying the motor and transmission ratios.
- Electric actuators are normally equipped with a feedback loop which allows immediate diagnosis of any problem arising in the mechanism along with freedom to vary and reprogram the control motion, speed and stroke lengths of the actuator.
- Electric actuators are highly precise and can be used in applications that are sensitive to small input changes.
- Electric actuators are quieter in working than their counterparts.

Disadvantages:

- Electric actuators are the most expensive actuation mechanism due to the complex design and its prime mover, namely the power screws being extremely expensive and the constant electric requirement adds to the overall cost of using electric actuation.

- The electric actuators are not as durable and stable in extreme environments and are greatly dependent on the environmental conditions. (11)

2.2.3 Link structures

The umbrella structure consists of a main mast or pole and a link structure on which the umbrella sheet rests. The latter consists of a series of mechanical linkages.

Mechanical Linkages: Mechanical linkages consist of a series of links arranged in an assembly in a specific manner to manage and distribute forces and/or to achieve a specified motion path. The links are rigid structures that open and close according to geometrical orientation producing linear, rotary and sliding motions to name a few.

These linkages can be arranged in a way to make either an open-chain mechanism or a closed chain mechanism.

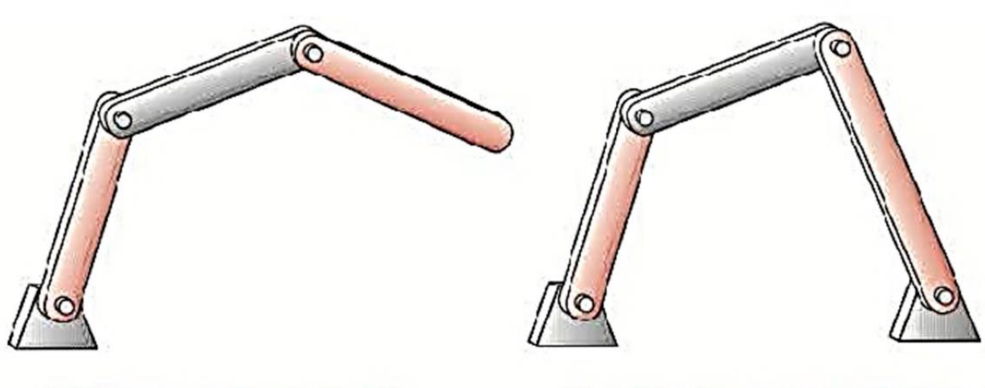

Figure 9 Open and Closed Mechanism Chain

The linkage types which are mainly used in making working mechanisms for complex motions are four-bar and five bar linkages deriving their names from the number of links involved in the respective mechanisms. Note that most of the time, one of the links is a ground link.

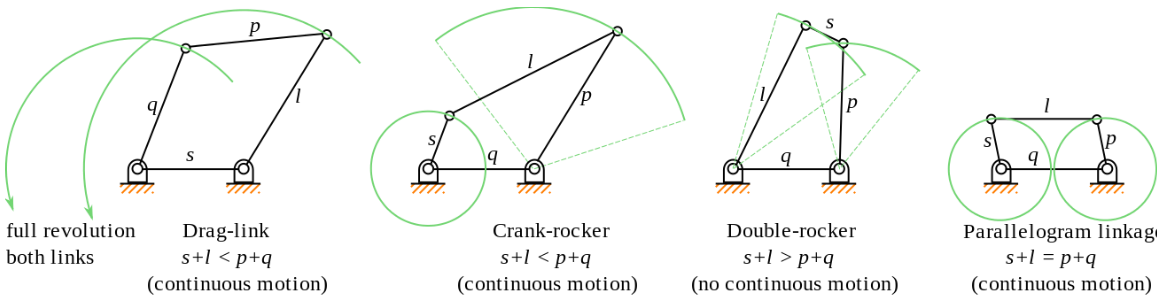

Figure 10 Four Bar Linkages

The above diagram illustrates the four bar linkages which can be of various types by changing the link lengths and angles between the lengths. It is a single degree of freedom linkage and the simplest mechanism. Hence also known as Planar four-bar linkage. (12)

Similarly, we can add more links to make our mechanism more complex and to achieve a greater degree of freedom and motion. Specific linkage variations are used for achieving a specified motion path.

A Five-bar linkage is a prime example of such a mechanism with two-degree of freedom with five links connected within a closed loop structure. This linkage can be further varied to convert it into a one-degree of freedom structure by adding two gears within the mechanism.

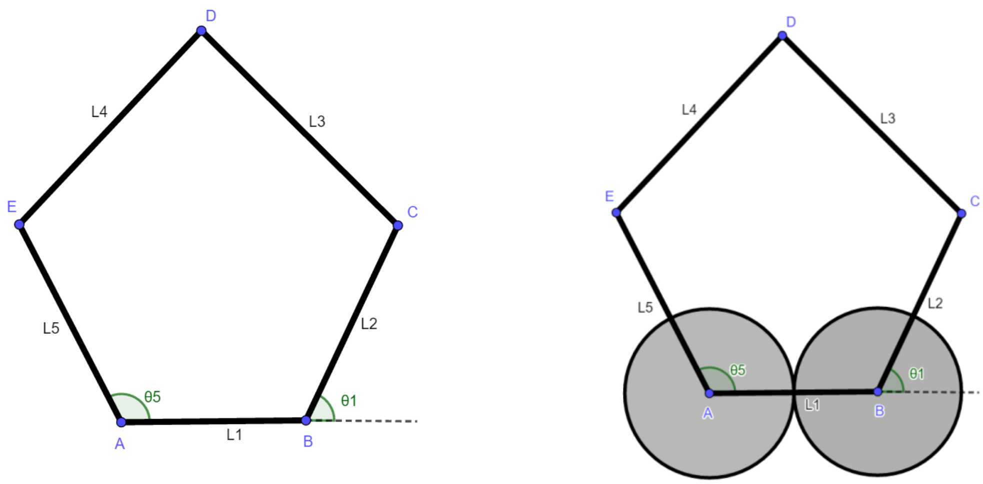

Figure 11 Five Bar Linkage

These linkages are important in identifying the structure that will sit atop the umbrella and eventually drive the motion path of the umbrella sheet during opening and closing of the umbrella.

After a detailed market survey, we narrowed down the most frequently used link structures are the following two.

1. Myard Linkages
2. Simple Planar Linkage

The former, Myard linkages, is a five-bar mechanism but an over constrained linkage to restrict the motion. The original Myard linkage is symmetric and planar with its motion being replicated on either end of the chains.

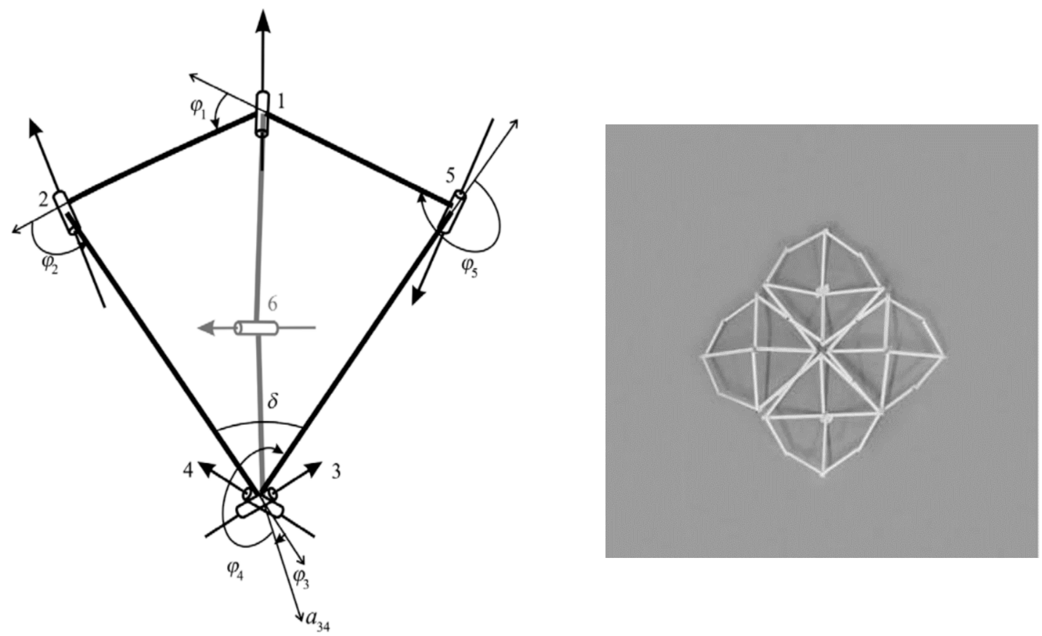

Figure 12 Myard Linkage

Myard five-bar linkage is a combination of two rectangular “Bennet Chains” with one link given a phase angle with respect to the other. To ensure mirrored linkage and symmetric motion of the 5R linkage. (13)

The latter is a simple planar mechanism, which is usually planar and comprises of four-bar linkage and has single degree of freedom. The four-bar linkage is highly adaptable and can be used in both rigid and moving components. It is generally simple in design and application and can achieve a wide variety of motion with minor variations in the design of the linkage.

The diagram below shows the schematic of a simple planar umbrella with a center-pole design.

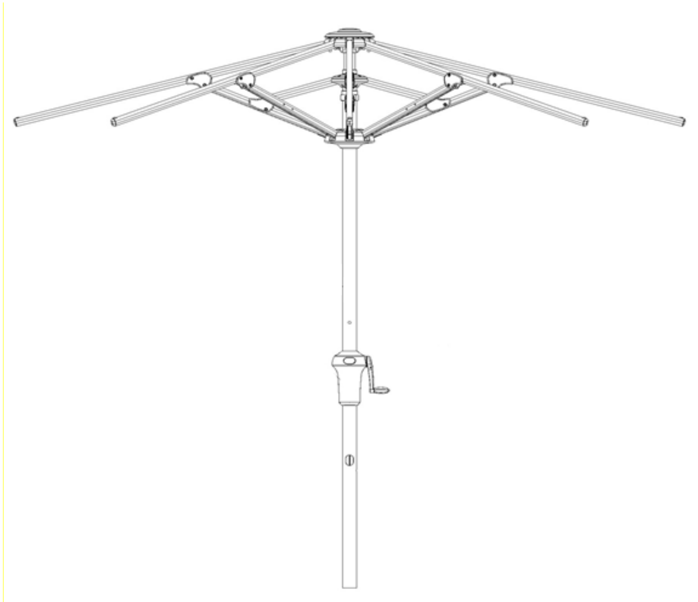

Figure 13 Simple Planar Umbrella

Some simple variation of four-bar planar mechanisms are as follows:

Slider-Crank Mechanism:

This type of mechanism is configured in a way that it translates rotary motion into linear sliding motion that is bounded by the length of the rocker arm attached to the crank.

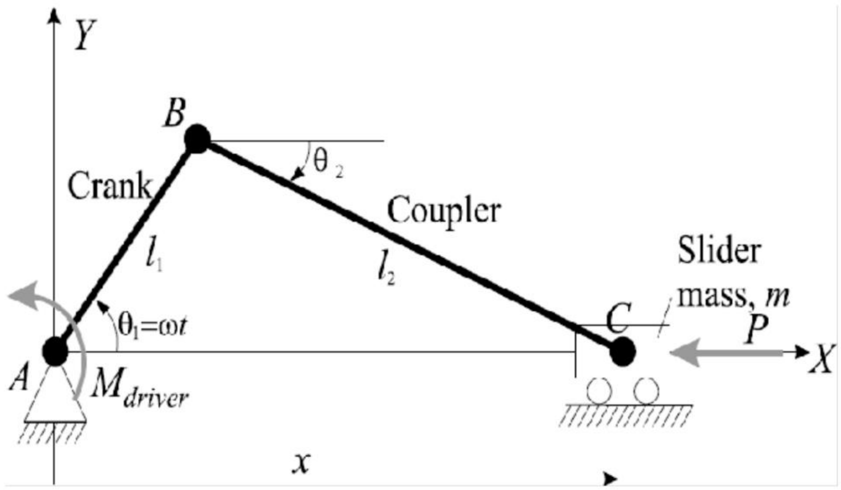

Figure 14 Slider Crank Mechanism

Spherical and Spatial Four-bar linkage:

If we configure the linkage such that the links are hinged at axis to intersect at a single point then the motion that is achieved is rotary motion with a wide variety of applications including but not limited to universal joint and bennet four-bar linkage.

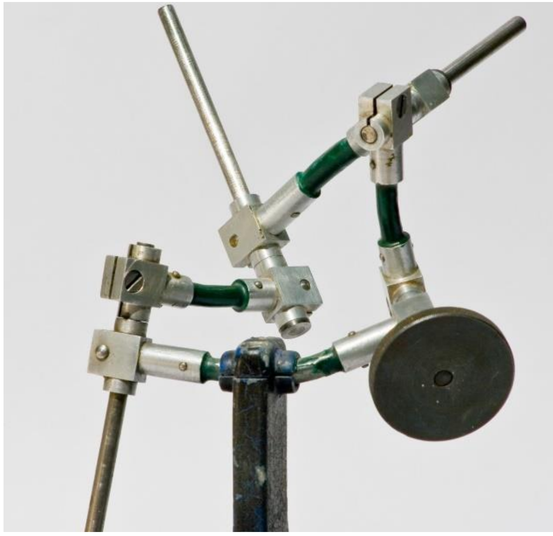

Figure 15 Bennet Four Bar Linkage

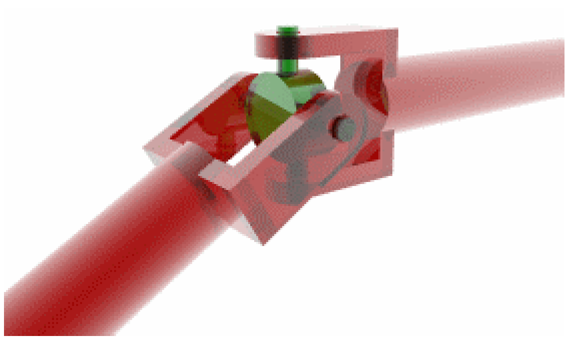

Figure 16 Universal Joint

Traditional umbrellas and even commercial products in the market have been using simple planar linkage in majority design solutions. The simplicity and flexibility of the design that it offers.

2.2.4 Components:

The key components used in the project are Arduino, sensors, motor and links. The brief note on each of them is written below.

- **Arduino Mega:**

It is a microcontroller board. It consists of 54 digital I/O pins, 16 analog inputs, a USB connection, a power jack, and a reset button. It has an operating voltage of 5v. It has a clock speed of 16MHz. It is recommended for robotics projects where a lot of RAM and memory is required.

Figure 17 Arduino Mega

- **Motor and Pulley:**

Two pulleys are attached at the top of the pole. DC Planetary Gear Motor is used to pull the slider upwards to deploy the umbrella. It has a maximum torque of 14.7Nm, which is more than enough in this case

- **Rain Drop Sensor:**

It works on the principle of resistance. It monitors weather conditions and measures the amount of moisture in the atmosphere. It sends output signals when the set amount of moisture exceeds. (14)

Figure 18 Rain Drop Sensor

- **NTC Thermistor:**

It is used as a temperature sensor. A normal NTC Thermistor has accuracy from -40℃ to 150℃.

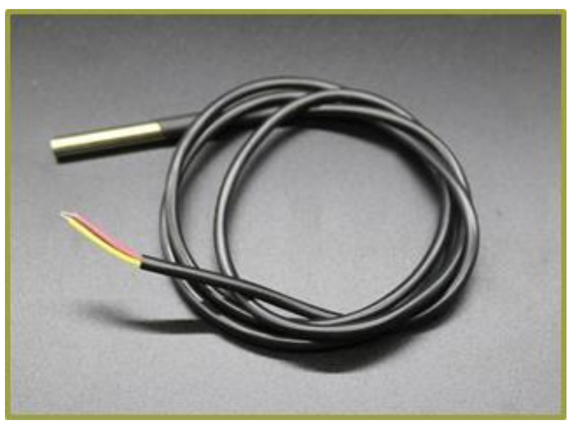

Figure 19 NTC Thermistor

- **Grove-Sunlight Sensor:**

It can detect sunlight directly and has a wide sunlight detection range. It has an operating range of about -45℃ to 85℃. (15)

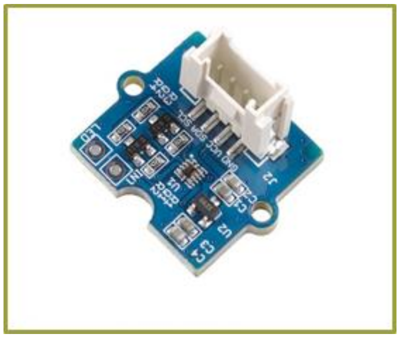

Figure 20 Groove Sunlight Sensor

- **Pull-Push Solenoid:**

It is a type of linear actuation that involves electromagnetism. When the current is passed through the solenoid, it becomes a magnet and pulls the plunger. This is used in the locking mechanism of the umbrella when it is in deployed state. (16)

Figure 21 Pull-Push Solenoid

CHAPTER 3: METHODOLOGY

3.1 Sheet Material Selection:

To make sense of all the data presented in the literature review, we implemented the decision matrix approach where we compiled all relevant material properties and requisites and assigned a weightage to them in order to decide which component best fits all of our requirements. Before implementing the decision matrix however we dropped PVC as a viable candidate since it did not meet the basic general properties required for our umbrella and since we had a better composite version of PVC in the form of Polyester sheets. We applied the decision matrix to our three candidates; Nylon, PTFE and Polyester sheets.

As it can be seen in the table below, the cost of the material was a secondary concern as if other properties of the material make it more durable and design friendly then the initial investment can be required with time easily. Similarly, the weightage of friction coefficient and density is given a higher value because the sheet serves the purpose of being repellent to water and dust. Density is directly linked with the mass of the product and the applied stresses so it was considered to be of paramount importance as well

Decision Matrix:

Table 3 Umbrella Sheet Decision Matrix

	WEIGHTAGE (%)	**PTFE**	NYLON	POLYESTER SHEETS
COST	15	**3**	4	5
FRICTION COOFFICIENT	20	**5**	2	5
DESNITY	25	**4**	5	2.5
GENERAL CHARACTERISTICS	20	**5**	3	3
TOUGHNESS	10	**3**	3	5
FATIGUE	10	**4**	3	3.5
TOTAL	100%	**24**	21	23
WEIGHTED TOTAL		**4.15 (OUR CHOICE)**	3.6	3.68

According to the above decision matrix, PTFE was the best choice for the sheet material of the umbrella according to the requirements set out by us.

3.2 Structure Material Selection

The next decision was to select the material for the main structure of the umbrella. The key considerations while choosing the structure were the yield strength, the effective loading on the umbrella and the von mises stresses. The primary candidates for the structure material were Aluminum 1060 and Stainless Steel AISI 304. In order to decide we did all the main analysis for both the structure materials and then selected the best fit.

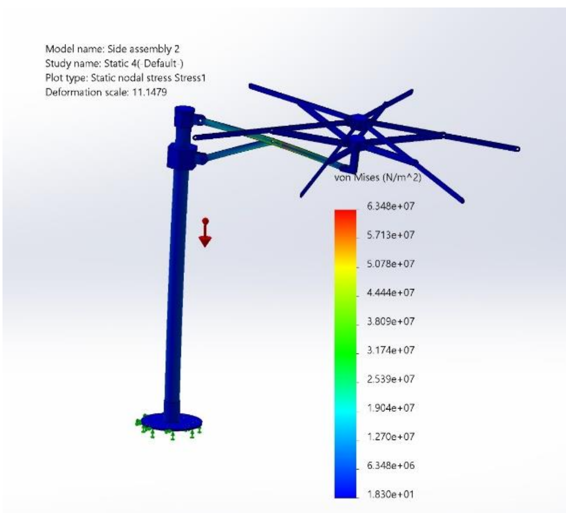

Figure 22 Aluminum 1060

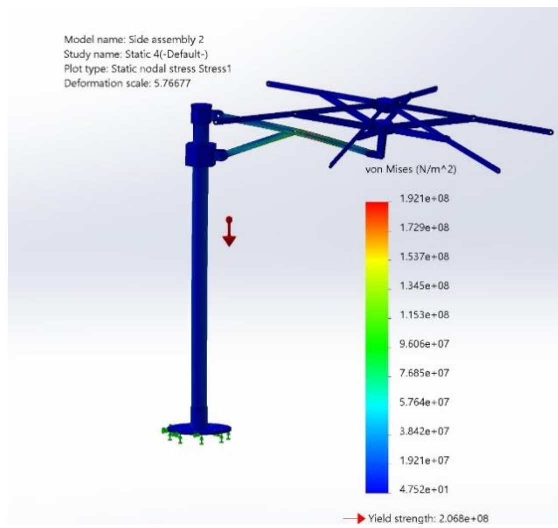

Figure 23 SS AISI 304

Although stainless steel AISI 304 has a higher yield strength than that of Aluminum 1060, it can be traded off as the effective loading on SS AISI 304 was 398 kg while it was just 125 kg in the case of AL 1060. Since the effective loading on the umbrella is directly proportional with the cost of the product and because one of our primary objectives was to design a cost-effective solution, we chose AL 1060 as the material for the structure of the umbrella. This was because even though SS AISI 304 has a higher yield strength but as it can be seen from the analysis both of the designs do not yield so it was easier to choose a solution that was more cost effective.

3.3 Design

3.3.1 Initial Design

Initially we planned to make a centre poled umbrella similar to the traditional use umbrellas as the first stage design below indicates

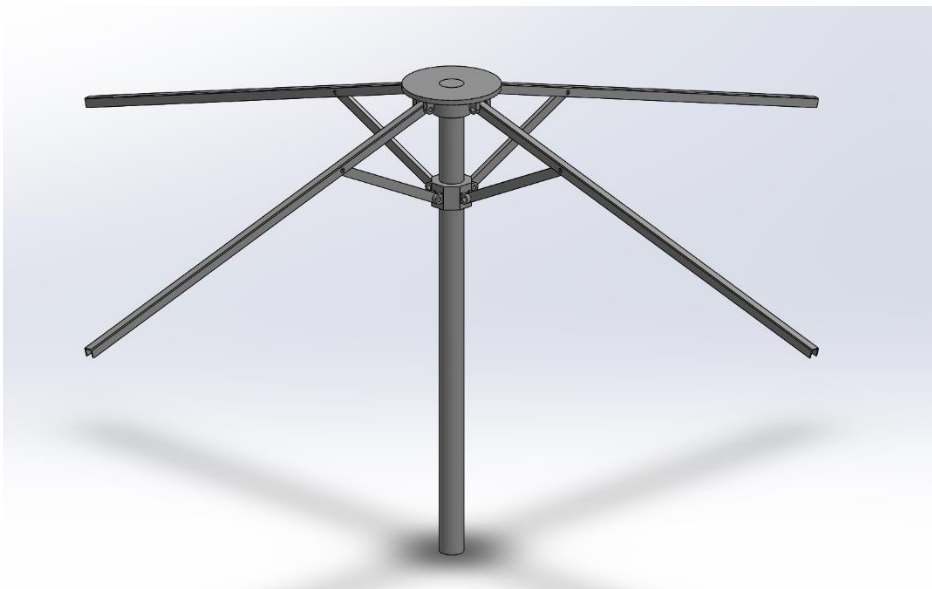

Figure 24 Centre Poled Design

However, we soon realised in order to make a centre pole umbrella majorly for the restaurant sector, we would have to seat people with tables that have a hole in order to fit the product through it. As this was not feasible and also limited the seating options, this design idea stopped looking attractive and we had to change our plan to solve this problem. That is why we shifted towards the side pole umbrella assembly as will be shown in our final design. This allows the product to be attached away from the table and the movement of people and yet be able to provide shade to them.

3.3.2 Final Design

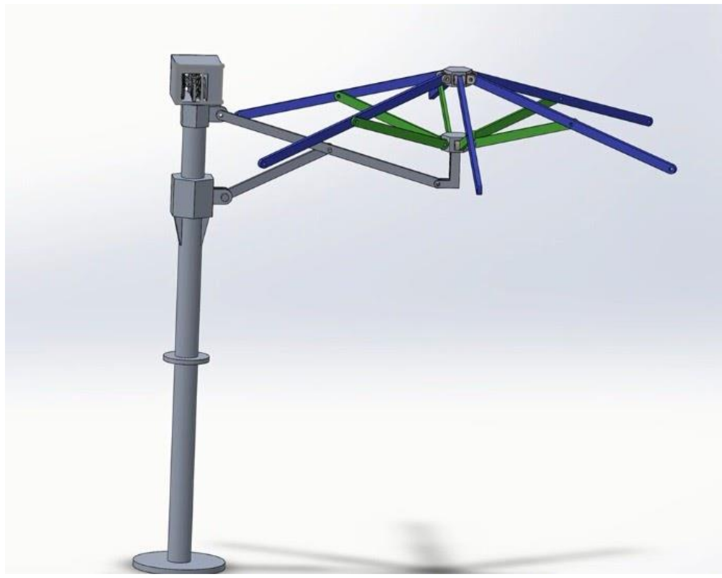

Figure 25 Side Pole Design

The final design of the side pole umbrella can be seen above along with the two-dimensional projections. The mast stands at a height of 3090mm which contains a base plate for the slider that moves up and down this mast when it is pulled by the motors attached to the top of the mast. A wedge is also on the mast which is used for the locking mechanism of the slider. The connector link of 810mm connects the large link of 1560mm to the bottom translator. The bottom translator then distributes the force exerted through the slider evenly to all the umbrella links each of length 1550mm.

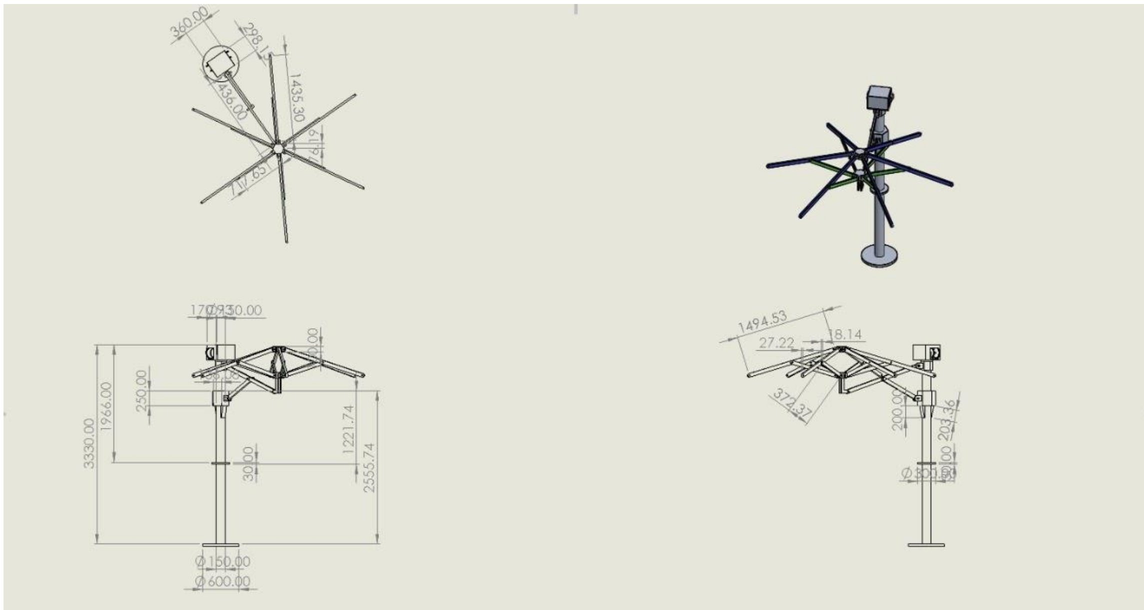

Figure 26 Side Pole Projections

A constraint was applied in SolidWorks to limit the top plane of the top translator to the top plane of the whole assembly as wire could not have been shown in the software. The umbrella is suitable for a seating of 6 to 8 people.

3.3.3 Components of the Umbrella:

In the figure below, the key components of the final umbrella design are labeled.

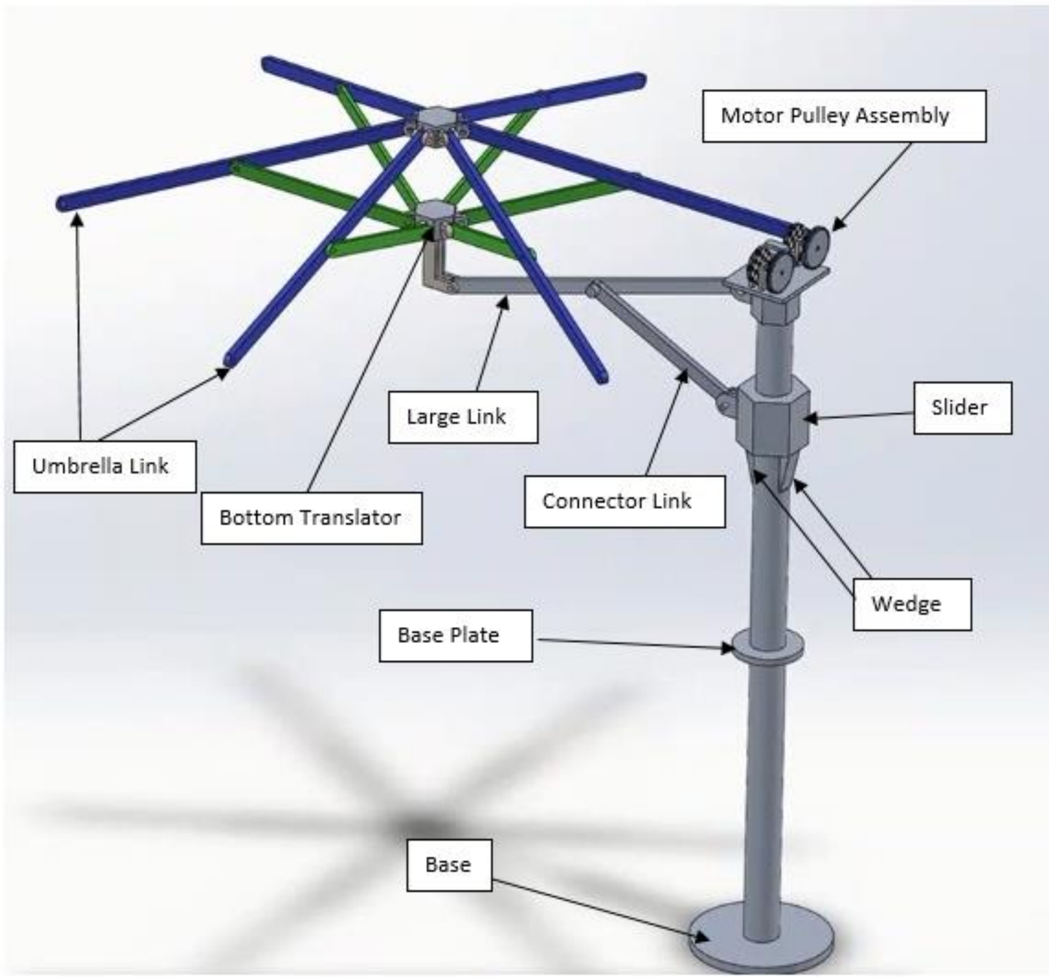

Figure 27 Components of the Umbrella

3.3.4 Cost Analysis:

Through a market survey, we determined the cost of each of our components. A cost analysis is done and a total estimated price for the final product is found.

Table 4 Cost Analysis

Component	Quantity	Unit Cost (PKR)	Cost (PKR)
Aluminum Links	105kg	250/kg	26250
Motor	2	2300	4600
Sensors	3	-	1860
PTFE sheet	8.456m2	500/m2	4228
Push Pull Solenoid	2	1230	2460
S.S. Cable	4m	175/m	700
Pulleys	2	85	170
Arduino Mega	1	1900	1900
Miscellaneous	-	-	5000
Production Cost	-	-	5000
		Total Cost	**52,168**

3.4 Deployment Mechanism:

The opening and closure of our product is majorly dependent on the motion of the slider on the mast of the umbrella. The linear movement of the slider up and down the mast essentially deploys and closes the umbrella. The slider block is attached with the connector link that is in turn linked to the large link. The large link is connected with the bottom translator which as the name suggests translates and distributes the movement into the upper ribs. When the slider block moves linearly upwards, the connector link also pushes the large link upwards. This causes the bottom translator to be pushed in vertical direction and hence the umbrella opens and vice versa. In order to make the deployment mechanism fully automated we will make use of a control system that will control the motors.

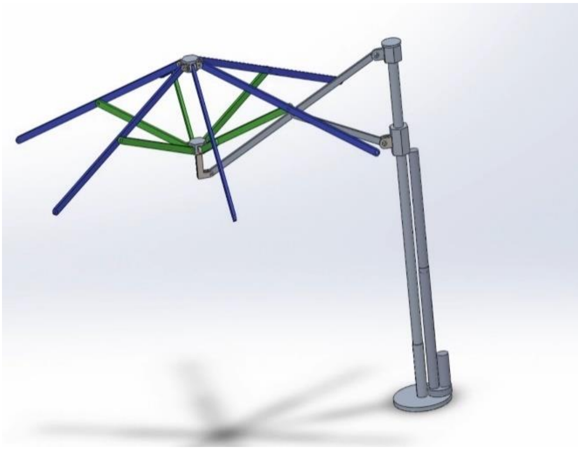

Figure 28 Deployment with Linear Actuator

The initial plan was to make use of a linear actuator that converts rotational motion into linear motion by making use of gearboxes and power screws and applying a constant push on the bottom surface of the slider block. Although this solution allowed us an easy fix for automated deployment and automatic locking, electric actuators were very expensive as the effective arm length of the outer tube had to be customized in accordance with the height of the umbrella.

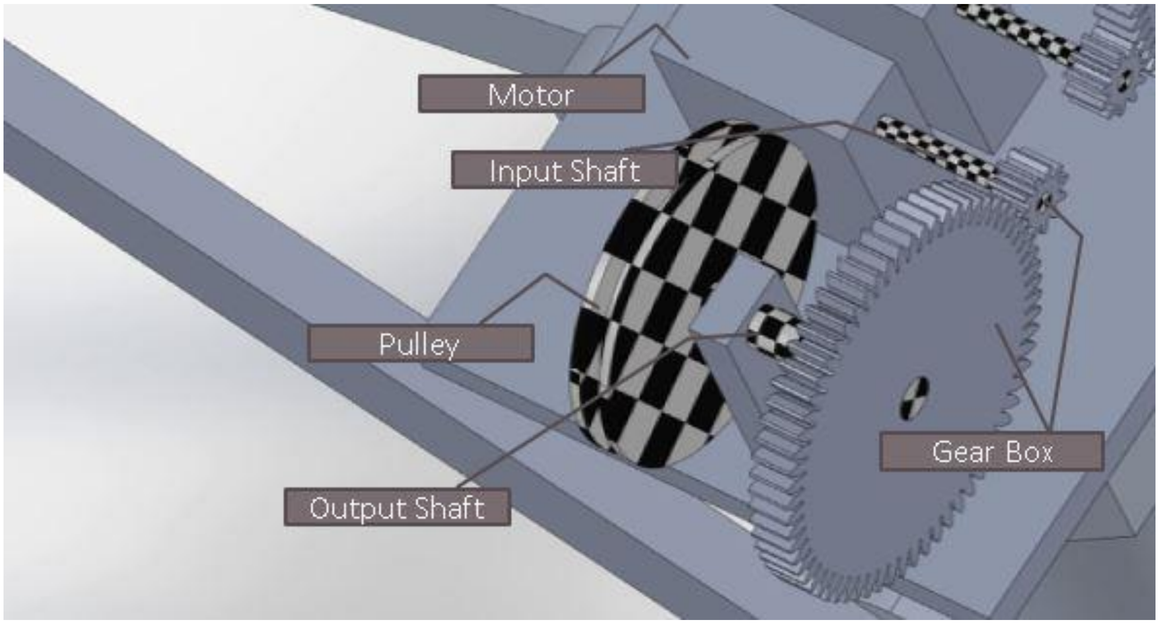

Figure 29 Motor and Pulley

In order to keep in line with our objectives of making this product at a more cost-effective price than the current solution available in the marketplace, we shifted towards a cable pulley deployment mechanism. In this configuration, the slider block is lifted from its horizontal edges from both sides by a cable run through a pulley attached at the top of the umbrella mast. At each side, a motor is controlled by the installed control system mechanism, drives the pinion through the input shaft. Gearbox of a gear ratio of 4 was made use of in order to step up the torque available on the output shaft. The output shaft then runs over a pulley having a diameter of 12cm attached on the top of the mast. As the pulley turns, the cable coils and the tension in the cable lifts up the slider from bottom most position to top most position. Similarly, during the closing of the umbrella, the slider moves down due to the effect of gravity. However, motors still run at a lower RPM during closure in order to ensure controlled and slow closure of the umbrella keeping in mind the safety hazards involved with abrupt closing of the umbrella structure when the slider moves freely under gravity.

3.4.1 Effective load calculation.

The effective load had to be calculated for two reasons

1. To find suitable wedge parameters that could hold up the slider and essentially lock the mechanism after the deployment.
2. To find the value of motor torque required to lift the slider and deploy the umbrella.

The effective load of the linkage structures was calculated at the closing position of the umbrella as this is the position for maximum effective load since the small connector link essentially transitions to a more vertical orientation as the slider travels down.

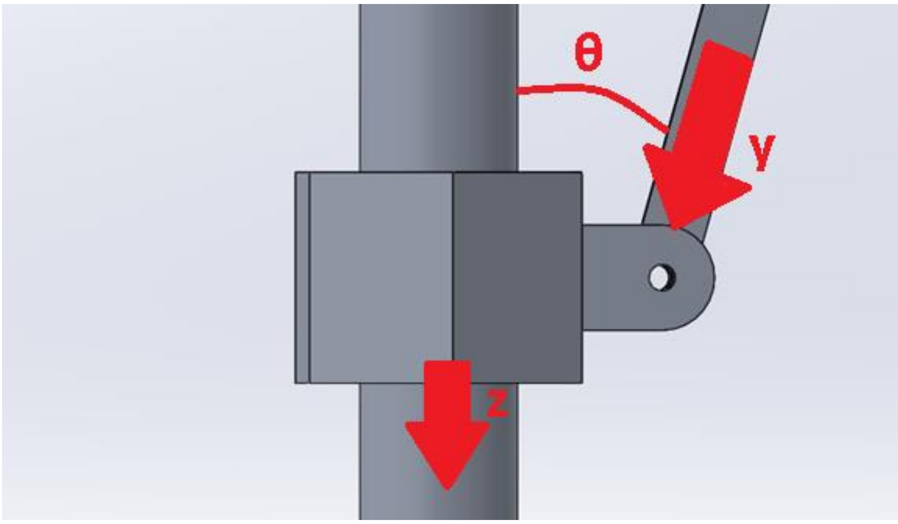

Figure 30 Effective Load Calculation

The effective load was calculated by considering the triangle as shown in Figure / by using trigonometry.

$\Theta = 27.67°$

Z= 23.216g

Y= 52.519g

Effective Load = (52.519g × cos27.67) + 23.216g = 684.04 N

Factor of safety of 1.5

Effective Load = 1.5 × 684.04=1026.06N

3.4.2 Motor Selection:

Another task at hand was to select a motor that could fulfill the torque requirements needed to lift the slider easily. Following calculations needed to be done for making the final decision.

Effective load on the slider using a FOS of 1.5 = 1026.1 N

$Load\ on\ each\ motor = \frac{1026.1}{2}$ N

Load on each motor = 513.05 N

$T_{OS} = F \times d$

$d = radius\ of\ the\ pulley = 6cm$

$\therefore T_{OSt} = 513.05 \times 0.06$

$T_{OSt} = 30.78$ Nm

$T_{IS} = \frac{Toutput\ shaft}{GR} = \frac{30.78}{4}$

$T_{IS} = 7.695$ Nm

However, considering the efficiency of the gearbox of being 80%, we get:

$$T_{IA} = \frac{Tinput\ ideal}{\eta} = \frac{7.695}{0.75}$$

$T_{IA} = 10.26$ Nm

Thus, we needed a motor that provided a torque greater than 10.26Nm. On this basis we choose the following motor with the efficiency of 80%. (17)

Model Number:	GMP42M755/775, DC planetary gear motor
Certification:	ce, RoHS, UL, FCC
Torque:	Max 150kg.cm

Figure 31 DC Planetary Gear Motor

It has a maximum torque of 150kg.cm which is equal to 14.7 Nm.

3.5 Locking Mechanism

After the deployment mechanism, the next matter to tackle was the locking of the slider when the umbrella is fully deployed in order to hold the links in position and also the respective release of the slider when the umbrella has to be closed. As the product we are designing is fully automated the slider has to be automatically locked when it is at the top most position and then consequently release the slider automatically when the umbrella has to be closed. This requirement was kept in mind when designing our product. The slider was used with a clearance with the mast and a linear ball bearing was used between them in order to increase the product life and to prevent friction and resulting wear. Near the top most position, there is a slot in the mast from which a wedge-shaped structure is protruding out. When the slider is moving upwards it slips nicely over the wedge as it pushes it inside.

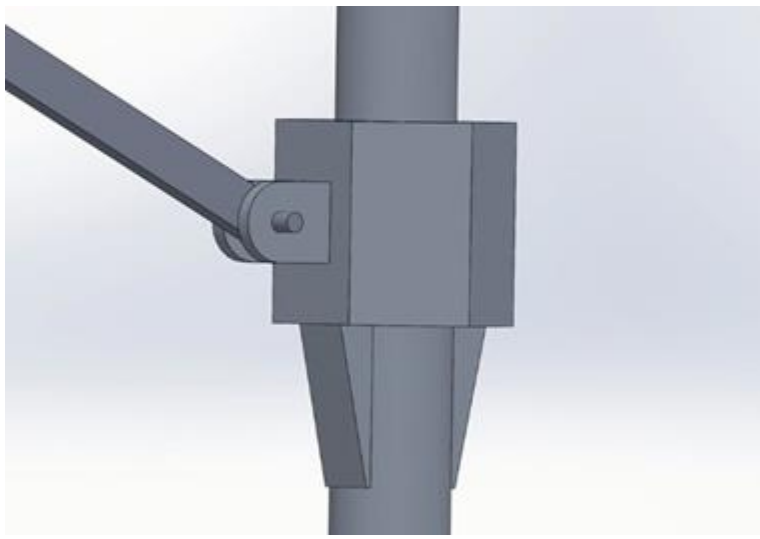

Figure 32 Locking Mechanism: Wedge

However, when it reaches the top most position, the slider gets locked at that position as it rests on the triangular base of the wedge structure when it is held in its protruding position by the use of a Pull-Push solenoid. Furthermore, when the umbrella has to be closed, the solenoid becomes an electromagnet and pulls the wedge inside the slot and that releases the slider.

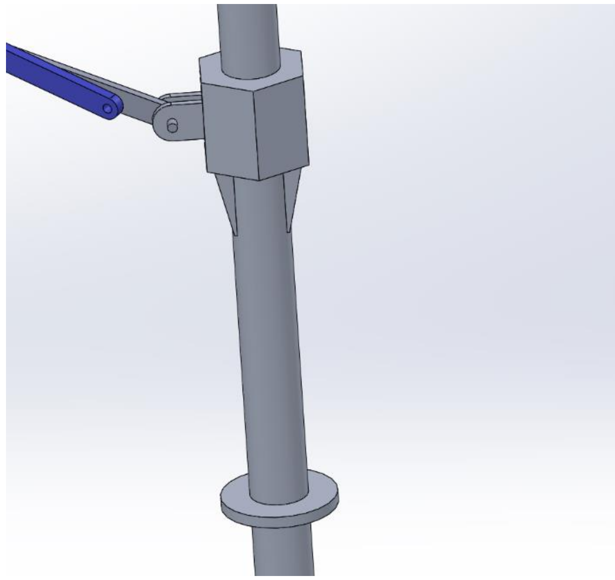

Figure 33 Base Plate

For the closing position of the umbrella, the locking mechanism is rather simple and not complex. A base plate is constructed at the lowest point of the slider to hold the slider. Since the slider is not required to go below this level for the effective movement of the linkage structures and the overall deployment and closure poses, a simple base plate approach seemed reasonable.

3.5.1 Working Principle of Pull-push solenoid:

The pull-push solenoid works basically on the same principle as that of electromagnetic arrays. This solenoid is used to convert magnetic energy to usable mechanical work of pull or push. When the electrical current is passed through the coil windings in the solenoid, it behaves likes an electromagnet and causes a magnetic pull on the plunger that in turn causes the attached spring to contract. This pull-push solenoid is a type of a linear actuator as it can be used for linear directional movement and the action of the plunger. (18)

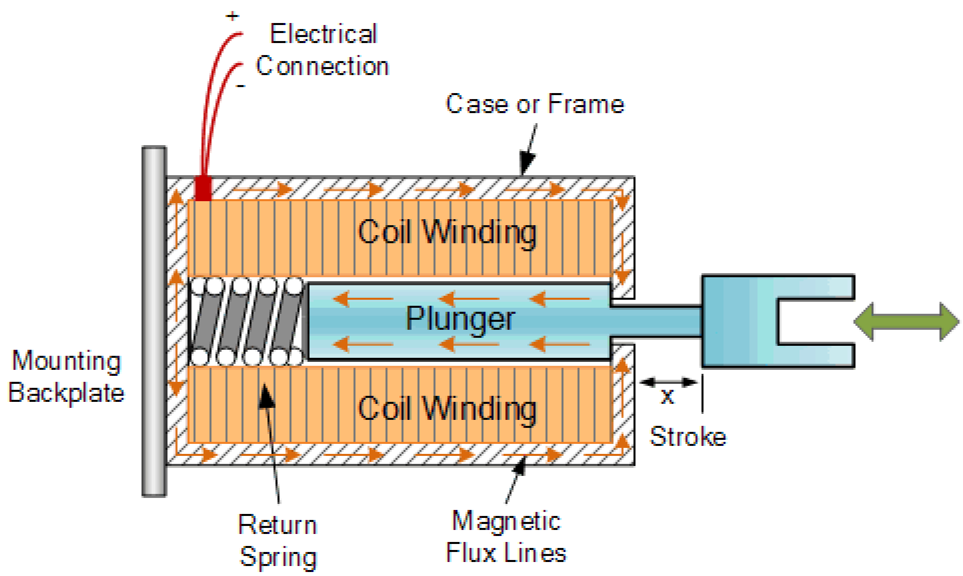

Figure 34 Working of Solenoid

3.5.2 Static Analysis:

We had to perform static analysis on the wedge block separately as it was necessary to ensure that it will be able to withstand all the loading and respective stress that may be allowed on it. The effective load was calculated in the deployment mechanism which was 1026.1 N with a factor of safety of 1.5. This is the effective load of the slider along with the linkage structures and the wedge used for the locking mechanism is designed to hold up this effective weight in order to effectively lock the slider at the deployment position. A stress and strain analysis of the wedge was conducted to ensure the wedge does not yield under the application of the effective load and that the loading does not result in a significant deformation which might end up damaging the overall umbrella and disengage the locking mechanism. The analysis was conducted on SolidWorks, the base of the mast was set as a fixture and the effective load was applied on the top of the wedge as an external force.

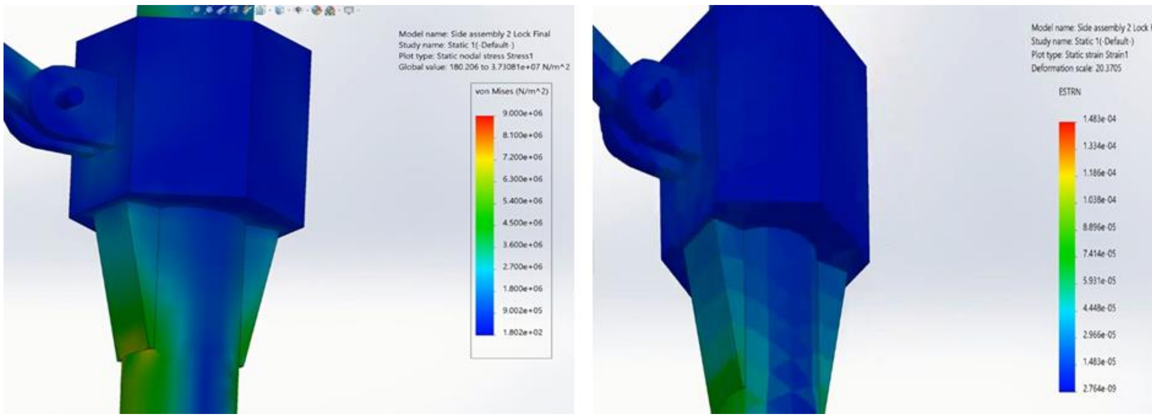

Figure 35 Static Stress Analysis

The figures show that the wedge is effectively able to hold the slider and the linkage structure as it does not yield under the applied effective load and stress. The strain analysis in Figure / also shows and indicates that the wedge is not subjected to an immense and considerable amount of deformation that may lead to the failure of the locking mechanism.

3.6 Control System:

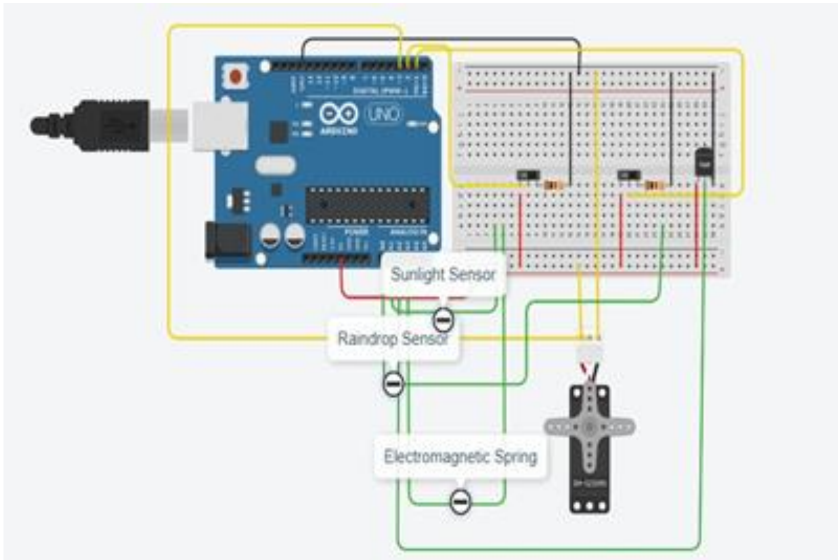

Figure 36 Schematic Diagram

3.6.1 Design Parameters

One of the main motivations of our project was the fact that we wanted to design and build an umbrella that was fully automated. Existing market solutions that we found were not fully automated and were only providing the necessary service of shade and protection from rainfall. In order to make this product automated, we required the use of a control system to govern and control the deployment of our umbrella. Since the deployment of this umbrella solely depends on the motion of our slider as per our linkage configuration, the motion of the slider was the target of our control system which would control it using the motor pulley assembly.

A control system essentially manages, controls and regulates the actions and behaviour of a system in order to produce a prescribed output. In the current scenario, our prescribed norm depends on the motion and position of the slider. The output that we required from our control system was to deploy the umbrella on the deployment conditions such as sunlight and rainfall and vice versa for the closure running the code in a loop to monitor the conditions at all times during its utilization. Our control system essentially authorized the motor which governed the pulley via a gear box ultimately controlling the slider.

Multiple sensors were used to achieve the necessary output, Rainfall sensor and the sunlight groove sensor were used to detect rainfall and sunlight respectively. Initially we finalized on these two sensors as they cover the conditions for the deployment of the umbrella. However, after some research we found a potential restraint with this configuration which was basically related to sunlight during special circumstances e.g. during winters when sunlight is not considered an annoyance and is actually desired instead. To cater for this exceptional feasible case, a temperature sensor is introduced which would aid us in dealing with this event. Apart from the sensors which measure the environmental conditions, the control system is also responsible for controlling the solenoid push and pull to release the slider which is essentially activated whenever the umbrella is to be closed. The sensors and the control system were integrated using an Arduino Mega.

3.6.2 Code Working Principle:

The working principle of the code is rather simple and not complex. The code initially checks on the vital conditions of deployment by collecting data from the rainfall, sunlight and temperature sensors. For rainfall the code is direct which goes as monitoring the data from the rainfall sensor, if rain is detected then operate the motor and deploy the umbrella. If rainfall is not detected then activate the solenoid push and pull for 2 seconds allowing the umbrella to close.

It is however important to note that the code operates the motor by directing the speed and its rotations in angle degrees and as such the motor is also activated at a significantly low speed during the closure of the umbrella to ensure that the slider does not fall solely by the force of gravity resulting in a quick drop which would be catastrophic in terms of safety and overall damage to the umbrella itself. Moreover, as previously mentioned the solenoid push and pull is activated for 2 seconds whenever the umbrella is to be closed which essentially releases the slider from its deployment position.

For sunlight, the code initially checks the data from the temperature sensor and records the value and then moves onto the data provided by the sunlight groove sensor. The code has a limit on the temperature in degrees, when the limit is crossed the sunlight data is ignored. The limit is essentially a temperature value in degrees and the code is constructed in such a way that when the temperature is below this certain value, the sunlight sensor data is disregarded e.g. 5°C as used in the code attached in the appendix. Since we have made our product user friendly both for the customer and the consumer, we have given our customer the authority to decide the temperature limit as per his preference keeping in mind that weather conditions vary from location to location. Additionally, we have prescribed a standard value for the temperature limit which is set at 5° C. However, as mentioned before, the limit can be altered by the customer. Regarding the case when the temperature is above the limit, the code inputs the data from the sunlight sensor and if sunlight is detected then the umbrella is deployed and vice versa.

Apart from the automated control over the slider and the umbrella deployment using different sensors, we introduced another condition on the code after realizing that we needed to account for rare exceptional demands of our consumers since we are aiming for a user-friendly product. To overcome this necessity, we integrated a manual switch in our umbrella to ensure that if the user is not satisfied with the automated outputs of the deployment, then they could operate the umbrella at their preference. The final code then initially checks for the state of the manual switch, if the manual switch is turned on then the data from the sensors is ignored and the code checks the umbrella operation switch, if the switch is in the on position, then the umbrella is deployed and vice versa. If the manual switch is off then the code takes input from the sensors and deploys and closes the umbrella according to the inputs of sunlight, rainfall and temperature as discussed in the preceding paragraphs. The complete code has been attached in the appendix section of the report for reference.

3.7 Design Validation Study

For the feasibility of our umbrella, we had to conduct a complete design study. The design study included a complete stress, strain analysis to validate the design, performance and durability of the umbrella at the expected working conditions. Moreover, stress and strain analysis are fundamentals for assessing the viability of any mechanical assembly in terms of material. To validate a design that involves motion using links such as this umbrella, a detailed kinematic analysis becomes crucial and pivotal for verifying the practicality of the motion involved in the assembly. Our design validation study also included a buckling and drop test analysis for the validation of the individual parts of the assembly i.e the mast and the slider respectively. A design validation study of a mechanical assembly would also include a frequency analysis to measure the chance of resonance in the normal operating conditions, in our case this corresponded to the natural frequency of the wind.

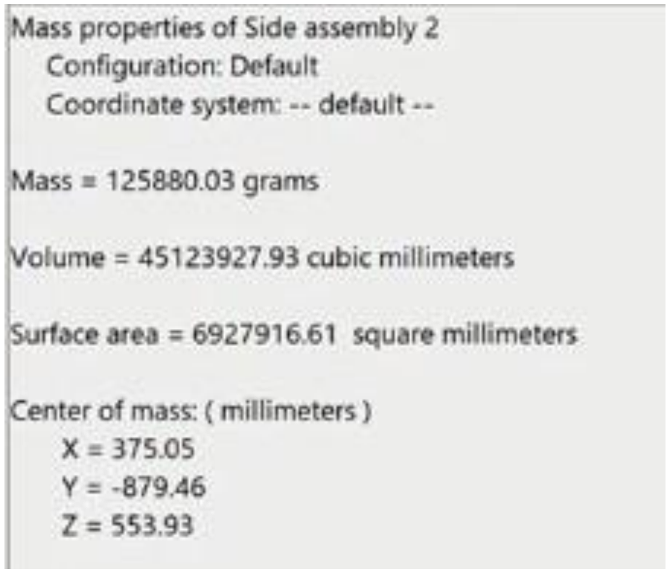

Figure 37 Mass of Product

Figure 37 displays the mass properties of our complete umbrella. Furthermore, for the selection of the base mass, we found out by researching about general cantilever umbrellas which suggested that there is a general rule to select the mass of your base which is to multiply the radius of your umbrella shade in feet by 10 and the resulting value would be the mass of the base in pounds. The mass of the base was set to be 24.6 kg corresponding to a 1560 mm radius. All the analysis were performed on SolidWorks as the software had the option to compute all the necessary required analysis with reasonable and reliable accuracy. Moreover, the software offered many options to further detail our analysis with less complexity. For our boundary conditions for the analysis, we made the bottom of our base fixed. Initially we were confused regarding the forces to be used as our umbrella is essentially not being subjected to any force. However, we later realized that for the analysis, the only significant force would be the force of gravity acting in the entire umbrella and we had to center our analysis on the basis of this gravitational force.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Von Mises

It is important to check the von mises stress for our umbrella to ensure that the material would not fail, fracture or yield under the conditions it is operating. The analysis was conducted in SolidWorks for both the extreme positions of our umbrella which are the opening and the closing positions.

Figure 38 Von Mises – Open Position

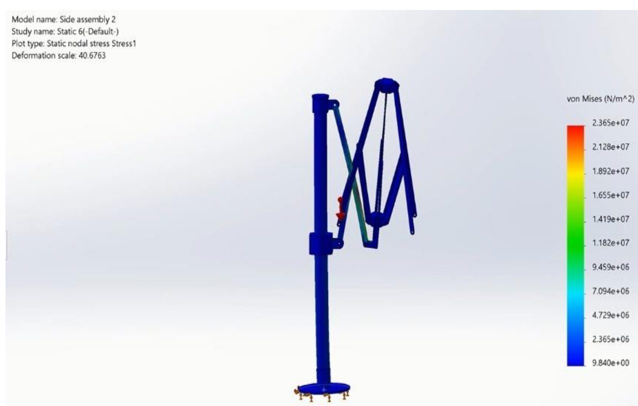

Figure 39 Von Mises – Close Position

As can be observed by the stress gauge in Figure 38 the overall stress that the umbrella is subjected to is less than the yield stress. A similar feat could be observed in Figure 39 which is the von mises stress analysis for the closed position for the umbrella. The material that we used is Aluminum 1060 alloy which has a yield strength of 27.5 MPa. The majority of the umbrella is shaded blue which means it is subjected to a stress of around 1 to 4 MPa. None of the stress values exceed 27.5 MPa.

4.2 Strain

A strain analysis was carried out to ensure that the umbrella does not deform significantly as to damage the umbrella during its working and under the load applied on it. Similar to stress the analysis was carried out for both the open closed positions.

Figure 40 Strain – Open Position

Figure 41 Strain – Close Position

Once more we observe that the strain values are pretty safe making our umbrella stable as can be seen by Figure 40 and 41. Most of the umbrella is again shaded in blue which corresponds to the smallest values hence indicating the safety and feasibility of our umbrella. It is however important to note that the deformation that can be observed in the Figure 40 and 41 is exaggerated as indicated by the deformation factor on the top left of the image, 11.83 and 40.68 for the open and close positions respectively, the deformation is exaggerated for the sake analysis essentially making it visually possible to observe how the umbrella would deform.

4.3 Displacement

A displacement analysis was conducted for a similar purpose to the strain analysis which was to verify the deformation of the umbrella, this time analyzing the individual deformations of the different parts at the open and close positions.

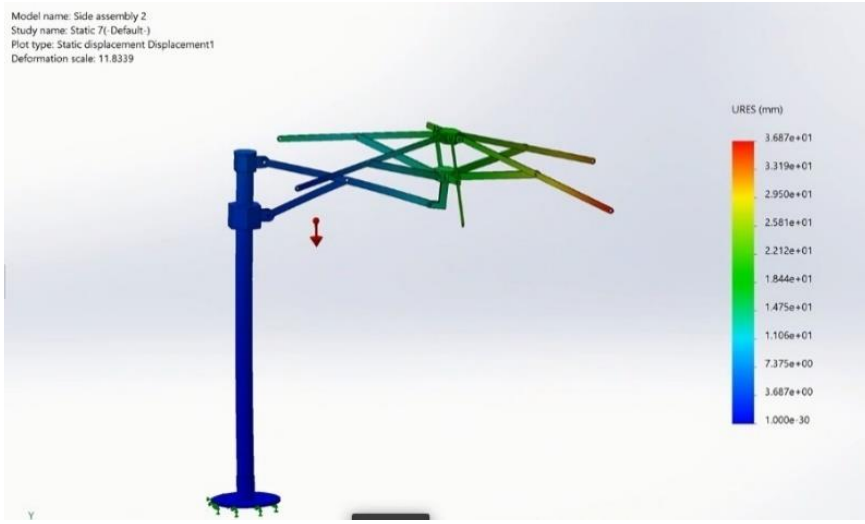

Figure 42 Displacement – Open Position

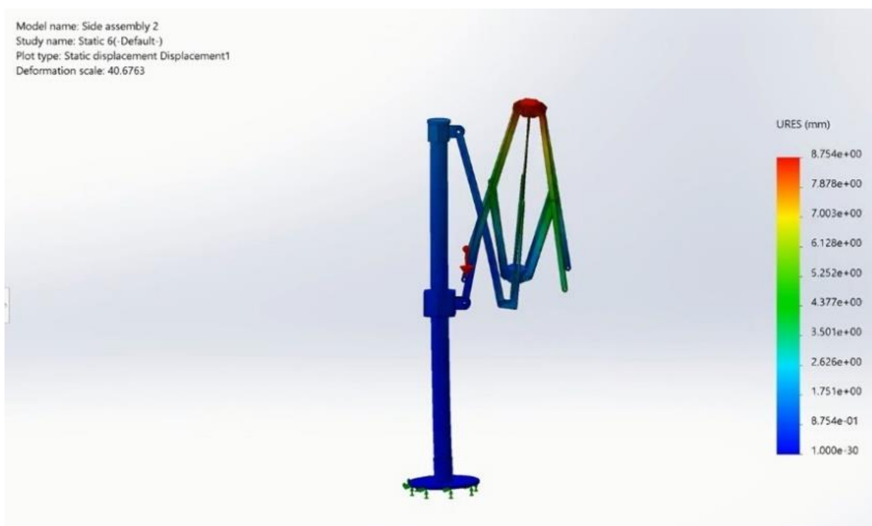

Figure 43 Displacement – Close Position

Similar to stress and strain, both Figure 42 and Figure 43 validate the feasibility and safety of the umbrella. None of the parts are significantly deformed and all the parts are in the acceptable safe region. Once more the deformation has been exaggerated to make the deformation visible for the naked eye as indicated by the deformation factor of 11.8 and 40.7.

4.4 Buckling

The phenomenon of buckling is a serious problem in vertical columns which basically is the sudden large deformation due to a load applied axially on the column. Since our mast is a vertical column, it will be subjected to buckling. Although our mast, which is the vertical column here, is not directly subjected to a normal force on its top surface but since the mast will subjected to loads at different parts, which essentially are the parts where the linkage structures are connected to the mast, we ended up carrying out a buckling analysis to ensure the safety and feasibility of our umbrella. To validate the buckling safety, we separately analyzed our mast part file in SolidWorks and applied a load equivalent to the entire weight of the umbrella on the mast.

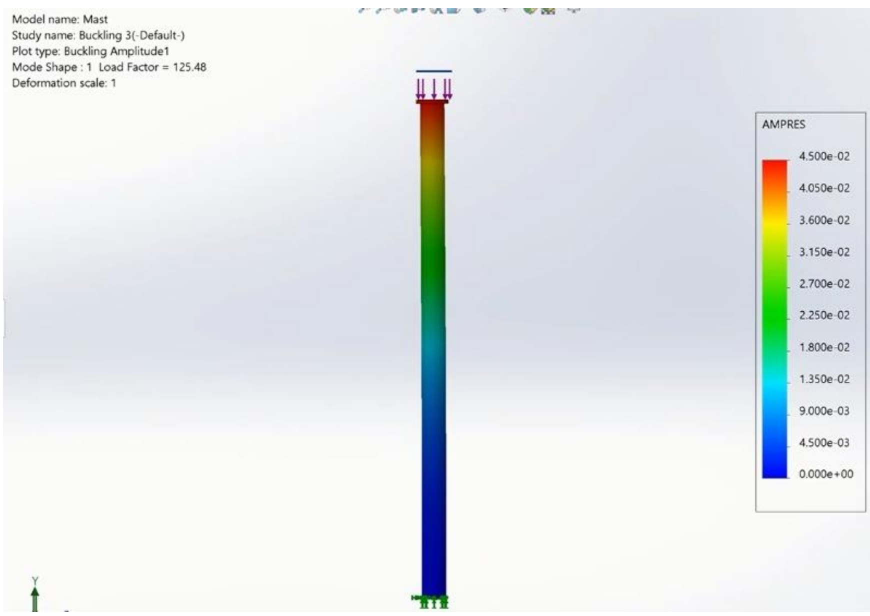

Figure 44 Buckling Analysis

Even after applying the entire weight of the umbrella, the results of our analysis as shown in Figure 44 indicate that the mast is safe from buckling. This is shown by the load factor at the top left of the figure of 125.48 which essentially means that if we increase applied load, which is the complete weight of the umbrella, by multiplying it by a factor of 125.88 then only will the mast buckle under the current conditions.

4.5 Frequency

A frequency analysis was also conducted to ensure that the umbrella does not resonate due to natural vibrations of the air. Resonance is disastrous for any mechanical assembly and as such it was vital to verify the safety from resonance under the normal working conditions of the umbrella. The natural frequencies of the umbrella at all the 4 modes were compared with the average frequency value of wind to ascertain the feasibility of the umbrella at both the open and closed positions.

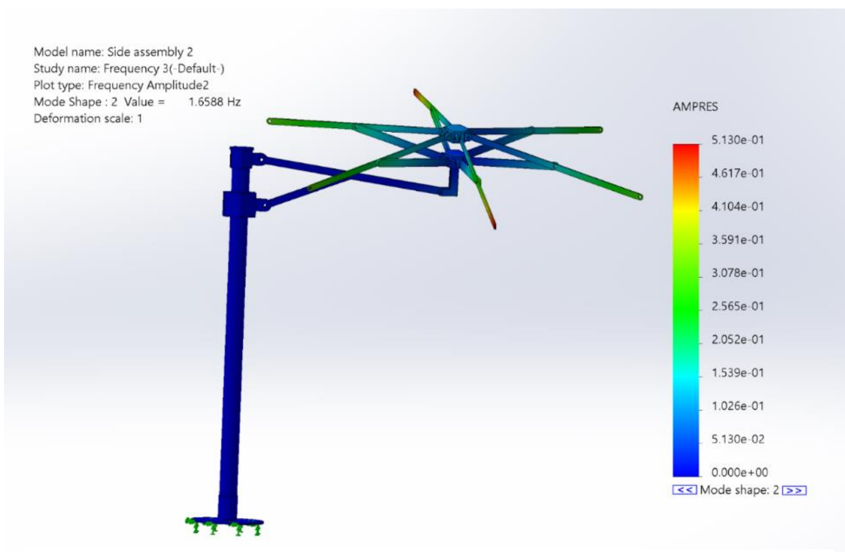

Figure 45 Frequency Analysis – Open Position – Mode 2

Mode No.	Frequency(Rad/sec)	Frequency(Hertz)	Period(Seconds)
1	4.1013	0.65274	1.532
2	10.234	1.6287	0.61397
3	16.621	2.6453	0.37803
4	22.63	3.6017	0.27765

Table 5 Frequency Mode Data

The 3rd column indicates the natural frequency values in Hertz. The average frequency of wind is around 10-20 Hz. Table / clearly shows that the umbrella is safe from resonance in the open position.

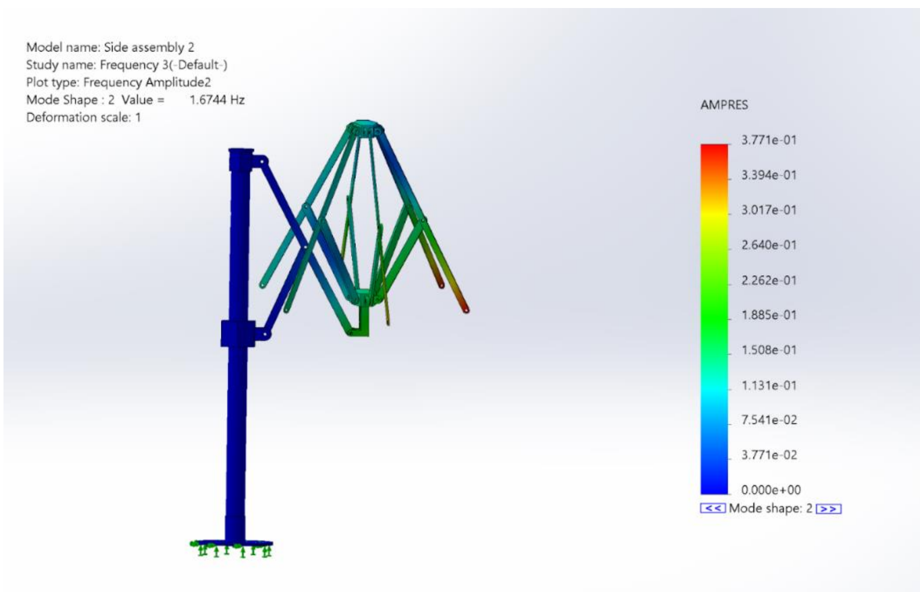

Figure 46 Frequency Analysis – Close Position - Mode 2

Mode No.	Frequency(Rad/sec)	Frequency(Hertz)	Period(Seconds)
1	6.4071	1.0197	0.98065
2	15.231	2.424	0.41254
3	24.857	3.9561	0.25277
4	32.807	5.2214	0.19152

Table 6 Frequency Mode Data

Similarly comparing the values of the 3rd column for the closed position. The average frequency of wind is around 10-20 Hz. Table / clearly shows that the umbrella is safe from resonance in the closed position.

4.6 Drop Test

A drop test was carried out on the slider in the extreme case of when the slider would experience a jerk resulting in a quick fall. We analyze the stresses that the slider would be subjected to in this case to ensure safety of the linkage structure and the slider at such an unforeseen event.

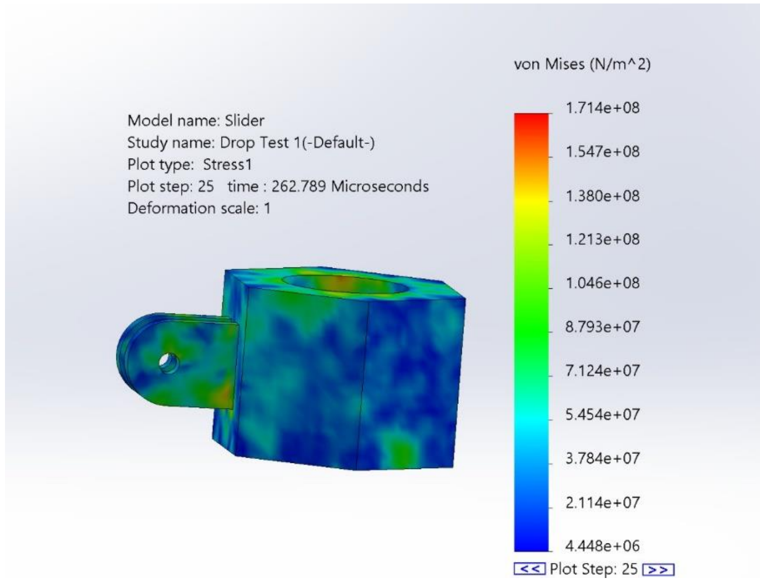

Figure 47 Drop Test Analysis

Figure / displays the stresses that the slider experiences, as can be seen the slider does not yield hence the linkage structure and the slider would be safe if such an unprecedented event occurs.

4.7 Kinematic Analysis

The kinematic analysis was highly significant in terms of mapping out the motion path of the umbrella structure. The kinematic analysis includes the displacement, velocity and acceleration analysis of various parts of the umbrella. We focused mainly on the Displacement analysis and the Acceleration analysis. The former because we needed to ensure that the deployment and closing path of the umbrella is safe and no collision will occur with the consumers and the latter to ensure that the acceleration developed by the motor motion does not produce unstable motion or any jerk during the motion.

The two parts identified for most critical conditions of the kinematic analysis are the umbrella link and the translator. The umbrella link makes up most of the structure and will define the area covered by the umbrella sheet whereas the translator determines the relative kinematic effect on major components of the assembly.

4.7.1 Umbrella link - Acceleration (Y-Axis)

The acceleration analysis of the umbrella link was performed first by varying the length of umbrella link itself and then by varying the connector length. The former results show that when you increase the lengths the accelerations also increase with them this occurs to the greater moment arm from the pivot where the connecting rod is applying the force on the umbrella link. Similar behaviour is repeated upon the acceleration analysis of the large link length of 2000 mm.

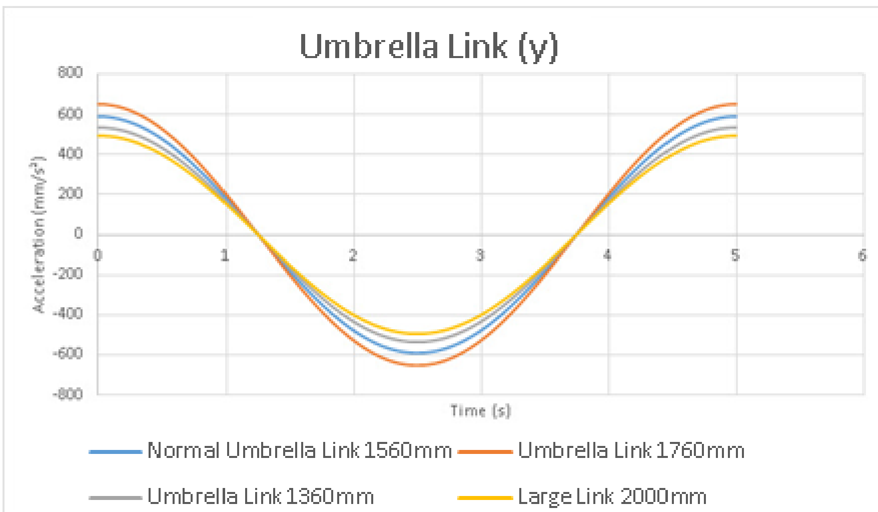

Figure 48 Acceleration – Time Graph for Umbrella Link

4.7.2 Large link - Displacement (Y-Axis)

The umbrella sheet will sit on the umbrella link and the deployment of umbrella link determines the path the structure will take during deployment and the position in space the sheet will occupy. Therefore, we carried out the kinematic analysis with varied lengths of the umbrella link to confirm the behaviour of the deployable height in open position to maintain a safe clearance between the consumers and the umbrella's height respectively. The results show that the lines overlap because the vertical path that the umbrella link follows does not vary with length this behaviour is due to the reliance of the umbrella link path on connector length instead of its own length hence the varied curve in yellow.

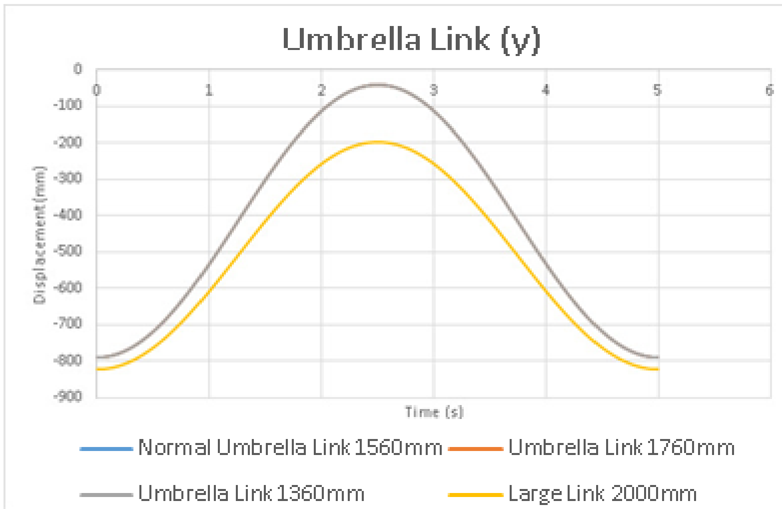

Figure 49 Displacement - Time Graph for Umbrella Link

4.7.3 Translator Acceleration:

The translator is of sheer importance because it anchors the kinematic behaviour of all linked parts. Its acceleration analysis was performed by again varying the length of the umbrella link. With increasing and decreasing the length of the umbrella links but there is no change in the behaviour with overlapping lines on the graph because it is dependent on the connector link and not on the umbrella link. The yellow curve refers to the behaviour of the translator with changes in connector link dimensions which exhibits a decreased curve from the original.

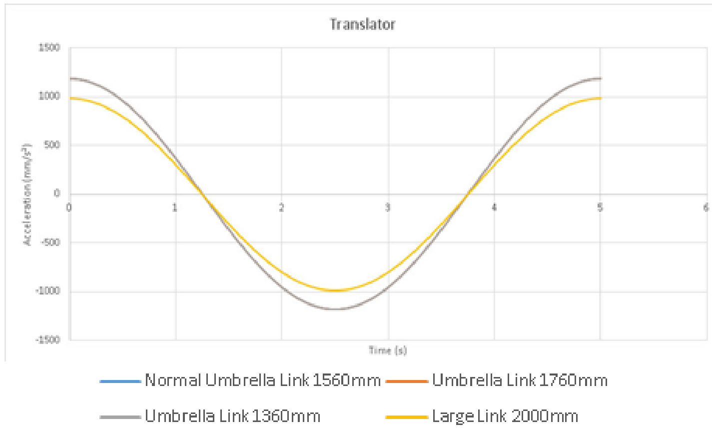

Figure 50 Acceleration – Time Graph for Translator

4.7.4 Translator Displacement

As discussed earlier, the dependency of the translator is solely on the connector link and not on the umbrella links so the displacement analysis with varied large umbrella length does not change the displacement path of the translator in the Y-Axis. However, the change in the large link length will decrease the deployed height of the translator with lower peak and the entire curve, in yellow, will be at a lower height.

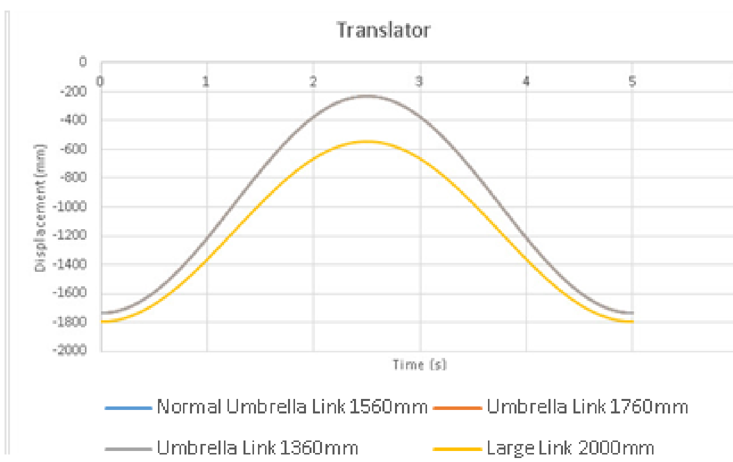

Figure 51 Displacement – Time Graph for Translator

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusions:

The following conclusions can be extrapolated from our project:

1. **Aluminum passes our material validation study:**

We performed a rigorous stress analysis on our final assembly under the primary loadings which arose due to the weight of the umbrella itself under the influence of gravity. The Von misses stresses that arose in the design were well below the yield strength range of the material thus the possibility of material failure is eliminated. Additionally, the material is the best possible choice because of its fringe benefits like corrosion resistant and light weight so buckling and drop test analysis which also passed the stress test.

2. **Vertical path is only dependent on the Large link:**

We concluded from the displacement kinematic analysis of the assembly that the maximum deployed height of the assembly is unchanged with the variation in length of the Umbrella link. And it only follows the changes in the Large link increasing the length of the large link decreases the maximum deployed height and vice versa.

3. **Acceleration of the Umbrella link is directly related to its length:**

The acceleration kinematic analysis of the assembly shows that upon varying the length of the Umbrella link the acceleration of the Umbrella link also changes with it. The relational behaviour that it follows is directly proportional increase in length increases the acceleration and vice versa. However, it is important to note that changes in other significant links like the large link do affect the acceleration behaviour of the assembly differently. We extrapolated from this analysis that we could only increase the length of umbrella link within a safe limit such as the acceleration does not increase significantly and risk of jerk does not arise.

5.2 Recommendations:

1. **Scalable Project:**

The grace of our project is such that it can be implemented in wide variety of applications and in a range of sizes. The project can be scaled up to the size of Masjid-e-Nabwi with a fully automated and sensor-based design solution for a deployable canopy. It can be implemented in northern areas where construction is a hassle and aesthetics a requirement. The simple design can be scaled and changed to fit the customer requirements with little to no effort.

2. **Marketing Strategy:**

With rising environmental concern especially in the corporate sector, the marketing of the product is relatively easy and can be marketed as an attempt to provide an environmentally friendly solution to a consumerist society with booming restaurants and cafe industry. Additionally, the marketing strategy can be marketed with respect to the Covid-19 pandemic since indoor seating is prohibited and demand for outdoor dining is increasing rapidly.

3. **Customizability:**

The design of our umbrella allows technological integration of the product such that we can provide premium features that are offered in high-end priced umbrellas manufactured and sold in America. Including but not limited to LED lights, LCD screen and charging slots thus eliminating any need for indoor sitting with the best of both worlds. Corporations spend a significant amount of money to get sunlight and open spaces in offices which our product addresses by providing the technology they need outdoors in an umbrella. Uniquely services sector can even use it as meeting places or working spaces.

4. Both Global and Local markets can be targeted:

Since we aim to manufacture the product at a much cheaper cost, we can target the existing western markets where the products are much expensive simply because these products are treated as luxury or premium rather than a market alternative for infrastructure. Additionally, there is significant room for implementing this idea locally and encouraging the services sector to implement. Since our pricing is competitive this can be viewed as a viable alternative for ever rising costs of building or renting commercial places.

REFERENCES

1. **Wikipedia.** [Online] https://en.wikipedia.org/wiki/Medina_Haram_Piazza#:~:text=Medina%20Haram%20Piazza%20Shading%20Umbrellas,extends%20to%20143%2C000%20square%20meters. .

2. **ShadeScape.** [Online] https://shadescapesamericas.com/.

3. **Offset Umbrella.** [Online] https://www.lowes.ca/product/patio-umbrellas/10-ft-square-offset-patio-umbrella-blue-808562.

4. **Umbrosa Spectra Contemporary Cantilever Umbrellas .** [Online] shadescapesamericas.com.

5. **Dielectric Manufacturing.** [Online] https://dielectricmfg.com/knowledge-base/teflon/

6. **Curbell Plastics.** [Online] https://www.curbellplastics.com/Research-Solutions/Materials/Nylon .

7. **Hifi Industrial Film.** [Online] https://www.hififilm.com/polyester-films/ .

8. **Augusta Free Press.** [Online] https://augustafreepress.com/advantages-and-disadvantages-of-pneumatic-systems/.

9. **Instrumentation Tools.** [Online] https://instrumentationtools.com/what-is-a-hydraulic-actuator.

10. **Progressive Automations.** [Online] https://www.progressiveautomations.com/blogs/products/pros-cons-of-hydraulic-pneumatic-and-electric-linear-actuators.

11. **China Electric Valves.** [Online] http://www.china-electricvalves.com/news/news12.html.

12. **Wikipedia.** [Online] https://en.wikipedia.org/wiki/Four-bar_linkage#:~:text=The%20configuration%20of%20a%20quadrilateral,links%20cross%20over%20each%20other.

13. *Design of Large Deployable Networks Constructed by Myard Linkages.* **Qi, Xiaozhi.** s.l. : Research Gate, 2011.

14. **Amazon.** [Online] https://www.amazon.com/Rain-Sensor-Arduino-Raindrops-Humidity/dp/B07JCTS5ZW.

15. **Seeed Studio.** [Online] https://www.seeedstudio.com/Grove-Sunlight-Sensor.html?__cf_chl_captcha_tk__=45a36a51ae3b5de8a01ea61f0999093884b1181c-1624167776-0-Ab2k16Qzzg9SaYIgzpsCOUx3vTYi3NqhTGMcNWnxXx619CtrPLl3R1866wT1WuXU57lKkZ6436cqhORoNLfPSoJRIcE3L2_ZshpWFAjT55hjb7QBT9U54ZjqInde.

16. **Alibaba.** [Online] https://www.alibaba.com/product-detail/Push-Pull-Solenoid-Push-Pull-

Solenoid_62332034716.html?spm=a2700.7724857.normal_offer.d_image.2d94bc6frFsh pg&s=p.

17. **Alibaba**. [Online] https://www.alibaba.com/product-detail/100-Motor-High-Power-Dc-12v_1600095903254.html?spm=a2700.galleryofferlist.normal_offer.d_title.4b1647c0Qt7pgS&s=p.

18. **Electronics Tutorials.** [Online] https://www.electronics-tutorials.ws/io/io_6.html.

APPENDIX I: CODE

Code:

```
// Include the Servo library
#include <Servo.h>
// Declare the Servo pin
int servoPin = 3;  //Servo attached to pin 3
int switchButton = 2; //On/Off for umbrella attached to pin 2
int overRideButton = 1; //Over ride states button attached to 1

// Create a servo object
Servo Servo1;
int baselineTemp=5;
int celsius=0;

// lowest and highest sensor readings:
const int rainSensorMin = 0;     // sensor minimum
const int rainSensorMax = 1024;  // sensor maximum
const int sunSensorMin  = 0;
const int sunSensorMax  = 1024;

void setup() {
```

```
  // initialize serial communication @ 9600 baud:
  Serial.begin(9600);
  // We need to attach the servo to the used pin number
  Servo1.attach(servoPin);
  pinMode(switchButton, INPUT);
  pinMode(overRideButton, INPUT);

  pinMode(A2, INPUT);//Temperature Sensor
}
void loop() {
  // read the sensor on analog A0:
  int overRideState = digitalRead(overRideButton);
  Serial.println(overRideState);
  //Use Button to open/close umbrella
  if(overRideState==1){
      int switchState = digitalRead(switchButton);
    if(switchState==1){
        Servo1.write(6222);
    }
    else{
      //Slowing the motor during closure
      for(int i=0;i<10;i++){
        Servo1.write(30);
```

```
    }
        emspring.switch('on',5)
  }
}
//If not override then use sensors to open/close
else{

int rainSensorReading = analogRead(A0);
int sunSensorReading = analogRead(A1);

// map the sensor range (four options):
//ex: 'long int map(long int, long int, long int, long int, long int)'
int Rainrange = map(rainSensorReading, rainSensorMin, rainSensorMax, 0, 5);
int sunRange = map(sunSensorReading, sunSensorMin, sunSensorMax, 0, 5);

  if(Rainrange<1){
      //Serial.println("Not Raining");

  //Slowing the motor during closure
    for(int i=0;i<10;i++){
      Servo1.write(30);
    }  //Close Umbrella
```

```
    emspring.switch('on',5)
  }
  else{
       //Serial.println("Rain Warning");
     Servo1.write(6222); //open Umbrella
  }
celsius = map(((analogRead(A2) - 20) * 3.04), 0, 1023, -40, 125);
//Serial.println(celsius);
  if (celsius < baselineTemp) {
  //Slowing the motor during closure
    for(int i=0;i<10;i++){
      Servo1.write(30);
    }// close umbrella
}
  else{
if(sunRange<1){
      //Serial.println("Sunlight!");

  //Slowing the motor during closure
    for(int i=0;i<10;i++){
      Servo1.write(30);
    }  //Close Umbrella
      emspring.switch('on',5)
```

```
  }
  else{
      //Serial.println("Sunlight too much!");
     Servo1.write(6222); //open Umbrella
  }
 }
delay(1000);  // delay between reads
}
}
```

APPENDIX II: PROOF OF WORK:

Google Drive link containing the media of umbrella simulation as a proof of work. As well as all the static analysis pictures attached in the report.

https://drive.google.com/drive/u/0/folders/1NczMANsU0aI3iKnI5J34wU_t5RO4M4lG