Conceptual Design Report

Distraction of Students due to the Size of Lecture Hall Tables

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1. Introduction

This document is a response to the design brief titled “Design Brief Report” which presents the need for a solution for the problem that the structure and size of lecture tables “do not provide enough space for individual students to place all the supplies that they may need during a lecture”. This document will first asses the design brief and will reframe, remove, and add to the design brief as needed and justified. It will then discuss the process used to come up with 4 different solutions to this design brief. Finally, it will compare the 4 different solutions using three multiple criteria analysis methods to select the best solution of the four.

2. Design Brief Assessment

The “Design Brief Report” was good in that it gave background information that allowed a reader to better understand the problem and the needs for any usable solution, and critically analysed an existing solution in such a way that a designer can understand what to avoid in future designs. However, the “Design Brief Report” lacked a clear problem statement, contained an error, lacked a proper definition for the key term “workspace”, lacked metrics or criteria with which to assess the fulfillment some of the objectives or DfXs and contained metrics, criteria, and constraints with no associated objected or DfX, and contained a DfX whose criteria are out of the scope of the concept design report.

2.1 Ambiguity of the Problem Statement

The problem which the “Design Brief Report” wanted solved is ambiguous in the design brief. The design brief states that its purpose is “to inspire the need to construct a tangible, practical solution to the presented problem”. However, it never clearly states the “presented problem”. The main objective of the design brief is to “increase productivity of a student during the lecture” and the brief begins with the statement that “students need to pay full attention during a lecture”. Neither statement clearly states what problem related to the productivity or to the attention of a student needs to be solved. In reading the introduction of the design brief, our team found that there were 4 key sentences in the middle of the introductory paragraph that most probably specified the problem that the authors of the design brief wanted solved. They were: “Many of the lecture tables in the University of Toronto’s lecture halls, however, do not provide enough space for individual students to place all the supplies that they may need during a lecture”, “The width of a lecture table in one of the university’s lecture halls … is much less than the width of regular line paper”, “As a result, students are forced to keep other supplies inside their backpacks and take them out in the middle of a lecture when necessary which causes a brief moment of distraction”, and “[the] size and structure of U of T lecture tables decrease productivity of students during a lecture.”. Based off of these statements, we believe that the problem the design brief was written to inspire the need to solve was:

> Students are distracted due to the lack of sufficient space on which to take notes and of quick and easy access to their supplies due to the small size of tables in some lecture halls.

This problem statement agrees with what the authors of the design brief reported to be the detailed objectives of any solution to their problem statement.

2.2 Definition of Workspace

The design brief states as one of its’ detailed objectives to “increase the amount of workspace for a student”. However, it does not define the term “workspace”. Since the work done by a student in a lecture is generally note-taking, we defined “workspace” as the space that can be used on which to take notes.

2.3 Error

We identified one error within the design brief. The width lecture table in University of Toronto’s lecture hall SF1101 is 18cm, not 8cm.

2.4 Additional DfXs and Criteria Needed

Many of the constraints and criteria provided in the design brief did not have a related objective or DfX and many of the objectives and Dfxs did not have a related metric or criteria. As such, the DfXs of Adaptability and of Ease of Manufacturability should be added in our consideration of designs, and several metrics and criteria should be added to aid in our assessments of designs.

2.4.1 Additional Needed DfXs

2.4.1.1 Adaptability

Several of the constraints and criteria outlined in the design brief were related to the adaptability of the device ("Must be compatible with different types of chairs in lecture hall", "Must be able to accommodate different types of resources", "Number of different lecture halls the design can be used: More is better"). As well, a student commonly uses many different lecture halls in their school week. Because of this, we believe that the addition of the DfX: Design for Adaptability is an appropriate in this conceptual design report.

2.3.1.2 Ease of Manufacturability

Ease of manufacturability is an important consideration of the manufacturer, supply company and user of the device (key stakeholders) because a device that is easier to manufacture generally costs less [1] and companies and users prefer to spend less money. The design brief states as a criteria "the cost of the design ($): Less is better". It is not possible in the conceptual design stage give a number for the cost of each design, as many key considerations for cost, such as the material from which the design is made, have not yet been chose. As such, designs will be compared based on ease of manufacturability as opposed to on cost in dollars. Ease of manufacturability will be compared using the metric of number of parts, as the number of parts in a design is a key indicated of its ease of manufacturability [1].

2.3.2 Metrics and Criteria Related to Objectives and DfXs

The objectives of the design report and the DfXs of design for usability and design for ergonomics did not have associated metrics or criteria that could be used to assess and compare the fulfillment of these objectives. In order to compare our different proposed design solutions, we have come up with metrics and criteria with which to assess the fulfillment of this objective.

The objective of increasing the amount of writing space for a student was given the metric of space (in cm^2) on which it is possible to write comfortably.

The objective of increasing the amount resources within reach of a student in a lecture was given the metric of amount of space (in cm^3) of additional space available for the storage of resources in lecture.

The objective of decreasing the chances of resources being dropped in lecture and disrupting the lecture was given the metric of number of additional features that prevent the dropping of resources and the metric of time required to retrieve the device when resource is dropped.

The DfX of Design for Usability was given the metric of time to set up.

The DfX of Design for Ergonomics was given the metric of additional features that increase the ergonomics of the device.

2.5 Removing Design for Durability as a DfX

The durability of a device is dependent mainly on the choice of materials for the device, the decision of what to reinforce, and the care instructions and maintenance schedule. The design choices are out of the scope at what is being looked at in a conceptual design report and is therefore being excluded.

3. Method of Idea Generation and Choosing of Candidate Solutions

In order to come up with viable solutions to this problem, our design team used functional decomposition and several other methods of divergent thinking.

3.1 Functional Decomposition

We functionally decomposed the problem into:

3.1.1 Providing easily accessible storage space for materials

By decreasing the amount of space on table used to store resources, the amount of space available to write on increases. As such, easily accessible storage space for materials would fulfill the refined problem statement. This idea was further divided into:

3.1.1.1 Shelf

Of the many designs in this category, the "The Rigid Container Solution" was chosen as one of the 4 candidate solutions.

3.1.1.2 Pockets

Adding Pockets to vests, pants, shirts, hats, and other pieces of clothing was thought of. Any solution in this category would most probably a chindoku.

3.1.1.3 Pods

Of the many designs in this category, the "Octopus Arms" was chosen as one of the 4 candidate solutions

3.1.2 Adding a flat surface

By adding a flat surface, there is both more space to write on and more space to store resources. This idea was further divided into:

3.1.2.1 A flat surface attached to body

Of the many designs in this category, the "Lap Desk" was chosen as one of the 4 candidate solutions.

3.1.2.2 A flat surface attached to the desk

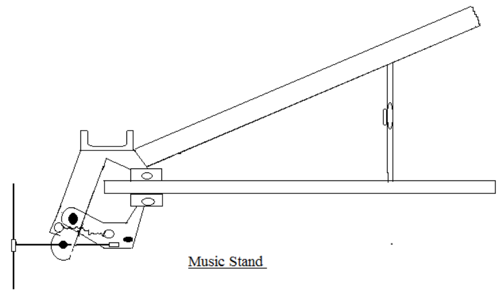
Of the many designs in this category, the "Slanted Desk" extension was chosen as one of the 4 candidate solutions. The generation of the "slanted desk" idea was aided by the method of divergent thinking of challenging assumptions. Using this technique, we realized that the flat surface did not need to be perpendicular to the ground.

3.1.3 Optimizing the use of the given table space

Ideas that had been come up with in this category were unfeasible.

3.2 The "Slanted Desk"

Figure 1:



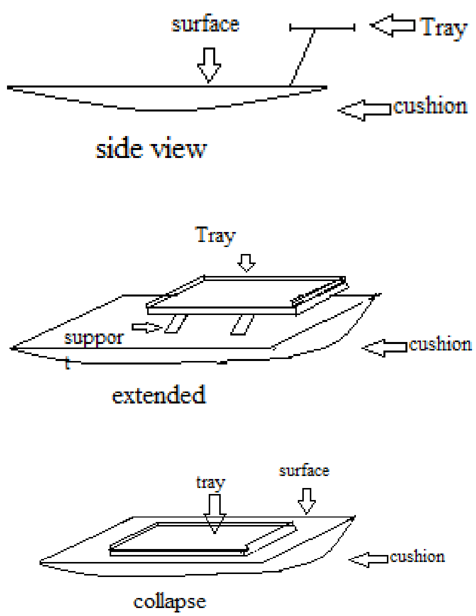
Key Features

- Slanted Flat Surface (20cmx30cm)
  - Made out of a solid piece of hard metal or plastic.
- Indentation in bottom piece
  - For storage of pencils, pens, and other slender resources.
  - To catch resources that roll down desk.
- Adjustable Stand
  - To allow student to adjust it to their preferred angle.

- Screw Clamp
    - To connect "Slanted desk" to lecture hall table.

3.3 "The Lap Desk"

Figure 2:



Design Overview

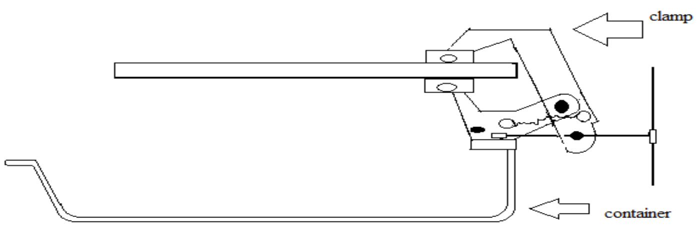
One possible solution for this problem can be solved by placing a hard surface on the lap. This solution, which increases the amount of available workspace will be made of several components. The first component will be the hard surface upon which the student, or user, will write on and take notes on. Underneath the hard surface are cushions so that one may be able to use the solution for an extended period of time without facing too much discomfort. On the top of the surface, there is another hard surface, a tray, that one can place stationary and excess materials. This tray is collapsed, as seen in Figure 1. This makes it much easier to transport and carry around, especially when moving from class to the class. The collapsible tray enables the student to carry around the device in their bag, much like how one might carry around a laptop. It would occupy, approximately, the same amount of space as a laptop and weigh approximately the same as well.

Key Features

- Flat Surface (20cmx30cm)
    - Made out of a solid piece of hard metal or plastic.
- Collapsible Tray
    - For storage of pencils, pens, and other materials
    - Has a ridge surrounding the edge to prevent materials from falling
    - Can fold down until it is parallel to the hard surface, allowing easy transport
- Cushions
    - Allows the device to be used for extended periods of time with reduced discomfort

3.4 The Rigid Container Solution

Figure 3:



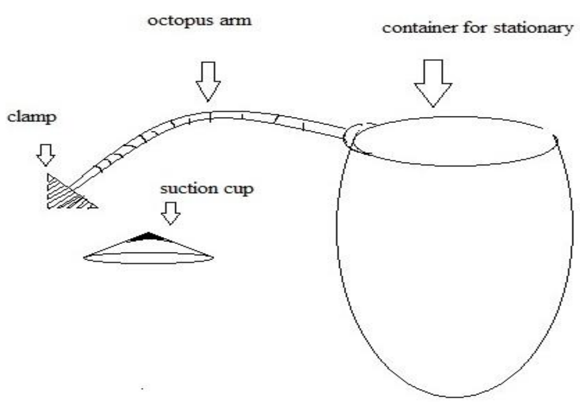
Design Overview:

Unlike the other designs specified the RCS is designed to provide the user with the best availability of resources. During a lecture a student may want to store and access a variety of different materials so as to compile the most thorough notes. This device will allow the user to store multiple binders, books, and note-taking materials while addressing the detailed objectives specified in the design brief.

By attaching a containment space below the desk, this provides the student with and added volume of space to store materials and thereby increases the amount of available workspace for the student. In addition, the student will no longer have to place all of their materials on the sface of their desk and this provides the student with more available space for writing. Commonly, the lack of available space on the desk surface increases the likelihood that materials will fall as it becomes more difficult to maneuver and organize notes. By decreasing the number of resources that must be placed on the desk surface during the lecture this will decrease the likelihood that materials will fall. The clamp component of the design references the quick adjustable clamp [8].

3.5 "Octopus Clamp"

Figure 4:



Key features:

- Simple design that has uses a bendable "octopus arm," a clamp attachment device (or a suction cup) and a container, as shown in the Figure 4
- The idea is uses biomimicry to emulate the function of an octopus arm that has 360˚ of motion in all directions—similar to the JOBY GorillaPod with the exception that this design only requires a single extension. [5]
- On one end of the arm it is a clamp or a suction cup so that the user can attach the device onto a variety of different desk surfaces.
- The containment region can be used to stored stationary to increase the amount of available workspace for the student in the lecture hall
- This optimizes the desk space as this minimizes the amount of stationary that needs to be placed on the desk

Generally a student requires the following stationary during a lecture; a pen, eraser, calculator and ruler. [2] The largest pencil case in U of T book store (the largest supplier of stationary for a U of T student according to the design brief), is 2.5' x 7.625' x 1' inches (6.35 x 19.36 x 2.54 cm) and the largest calculator available in U of T bookstore is 15 x 7.5 x 1.5cm. Therefore, the container must be large enough to hold the calculator and the pencil case at the same time. For the flexible arm component, it must be long enough to reach from underneath the desk, to outside of the desk so the user can access to the stationary as fast as possible. For the clamp and the suction cup holder, they are removable from the flexible arm so that the device can be adapted to different lecture hall. More detail for this part is in later section.

4. Justification for Comparison of Designs

The four candidate designs in this brief were compared based on how well they accomplished the detailed objectives and how well they were designed for the aforementioned DfXs. In the comparison of designs, the "slanted desk" design is used as a reference design.

4.1 Increasing the workspace of a student

The reference design would increase the amount of space that is available to write on by 10cm in width length for the smallest desk found on the University of Toronto St. George Campus, that in SF1101. However, it would not increase the space available to write on for the larger tables and may even decrease it due to the reference design's fixed size.

The lap desk would increase the same amount of available workspace as the reference design. It would work for all lecture halls, except for those with immobile desks. Most desks can be stowed away by the armrest of the chair, thus freeing up space for those using the lap desk. However, immovable desks would obstruct the user from taking full advantage of the increase in desk space.

The RCS and the Octopus arm do not increase as much work space as the reference design. The increase in space due to the RCS or the Octopus Arm is dependent only on the amount of resources that no longer are stored on the table; there is no increase of surface area. In addition if the Octopus arm is attached to the surface of the desk (and not underneath the desk) there is a slight decrease in surface area.

4.2 Increasing the number of resources available to a student

The reference design would allow for the storage of pencils, pens, and other slender objects, in the indented piece at the bottom front of the "music stand" desk extender. This reference design would also allow for storage between the slanted flat surface of the "music stand" and the table itself.

The lap desk can increase more resources than the reference design. The tray on the top of the lap desk will allow the student to increase the number of resources available. The student may store stationary, loose papers, and other additional resources on the tray that would normally not fit on the lecture hall desks. Even other notebooks could be placed on it, without obstructing the student's writing space.

The RCS and the octopus arm increase the number of available resources much more than the reference design. The RCS and the octopus arm are specifically designed to store these resources during the lecture. The RCS, however, offers more extra storage space than the octopus arm.

4.3 Decreasing the chances of resources being dropped and disrupting the lecture

The reference design would decrease the chances of resources being dropped because the slant of the "Slanted Desk" design would lead objects placed on the "Slanted Desk" to tend to fall towards the seat due to gravity where the object would get caught either by the writing utensil holder or by the small indent before this holder. Should the falling objects happen not to get caught in either of those two features, it is quicker to retrieve objects that have fallen on ones lap than those that have fallen on the floor.

The lap desk would decrease the chances of dropped resources by approximately the same amount as the reference design. The tray would have a slight ridge surrounding the edges so that any resources that would roll towards the edge could be caught by the ridge. However, if any resources do fall, it will be very difficult to retrieve, as the lap desk will restrict movement.

The RCS largely decreases the chances of dropping a resource. It is superior to the reference design in this regard due to the placement, and design of the RCS. By placing objects in a closed container that is placed under the desk, the chances of resources dropped are significantly lessened. Materials will not fall as they are in closed container, and will not simply roll off the desk.

The octopus arm also decreases the chances of resources being dropped like the RCS by storing objects in a closed container. The octopus arm can also decrease the chances of resources being dropped if they are placed at the back of the desk, physically stopping some of the larger objects from falling.

4.4 Design for Ergonomics

A slant of 15° is the most comfortable writing angle for many students [3]. The adjustability of the height of the "Slanted Desk" allows for the student to his or her preferred slant.

The lap desk is not as ergonomic as the reference design. Though, the lap desk is ergonomic in that it has cushions on the bottom of the surface so that students does not have to face the discomfort of a hard object resting on their lap, leaning forward may cause back pain due to incorrect posture [9], or may aggravate already present back pain [10]. Additionally, the lap desk restricts the ability of the student to adjust his/her seating position, forcing them to sit with both feet flat on the ground when the lap desk is in use.

The RCS is not as comfortable as the reference design. Depending on the distance from the bottom of the desk to the student's lap and width of the student's legs, the RCS may press down and exert pressure on the lap, causing the student discomfort, especially during longer lectures.

The octopus arm does not add to or take away from the ergonomics of a lecture hall chair and table.

4.5 Design for Portability

This reference design does not perform well in terms of portability. Only the stand of the reference design is collapsible. It therefore does not reduce its' size for easier storage in a backpack or bag.

The lap desk would fare better in portability than the reference design. The tray on the lap desk is collapsible so that it rests on the surface when not in use. This allows for easier transport; however, the cushions on the bottom may be bulky and take up more space.

The RCS is on par in portability with the reference design. It is not easily transportable, due to the rigid nature of the device and the inability to collapse for easy transport.

The Octopus arm, can be easily stored and by changing the shape of the device so that it can take up less space

4.6 Design for Usability

This reference design requires the following tasks to be performed in order to work the device: attach the clamp to the desk by screwing it and adjust the height of the stand.

Not as much work is required to set up the lap desk: place device on lap and push back the tray.

The RCS requires the user to adjust the width of the clamp depending on the height of the desk surface. Therefore this set-up period is an inconvenience for the student and takes time away from the lecture.

The octopus arm requires only to be attached to the desk or some other surface by a clamp or the suction cup.

4.7 Design for Adaptability

The reference design works with all the known different tables and chairs in the University of Toronto. However, there is no gain of workspace when the reference design is used with tables larger than its dimensions. As well, the reference design does not provide anywhere to store larger resources, such as laptops and notebooks, except on top of the desk.

The lap desk is adaptable in far more situations than the reference design. As long as the student as a seat, whether it be in lecture or on the subway, the student may use the device, as it simply needs to be placed on the lap. However, it will not work as efficiently for lecture halls with immovable desks, like SF 1101.

The RCS implements the use of two quick adjustable clamps so that the device is versatile. Since the height of the desk surface varies in each lecture hall, the clamp feature enables the user to easily fix the net to the desk surface by manipulating the clamp.

Due to the flexibility of the octopus arm it excels in adaptability. Firstly it can be manipulated depending on the user's reach and the different conditions in each lecture hall. For example, in some lecture halls, the desk surface is too thick to apply a clamp on it. Therefore, the clamp can be removed and the suction cup can be put in its place. In using suction cup, the user can attach the octopus arm anywhere on the desk.

4.8 Design for Ease of Manufacturability

This reference design contains at least 5 separate parts, excluding the parts in the clamps and the adjustable stand.

The lap desk is on par with the reference design for ease of manufacturability. The lap desk design consists, at the minimum, of the following parts: a tray, a hard surface, cushions, and two metal struts that can pivot about the surface and the tray (allows the tray to rest parallel to surface – see Fig. 1.).

The RCS require at least 2 parts: adjustable clamps and a rigid container.

The octopus arm is made up of at least 4 parts: the suction cup, the clamp, the container, and the flexible arm.

5. Multiple Criteria Decision Making and Analysis

5.1 Ordering Dfx Importance:

To assign weighted values to the Dfx's addressed in this design a pairwise comparison was implemented. The values were assigned in accordance to the table outlined in Appendix 2.

5.1.1 1st MCDA Comparison

To rank the importance of the dfx's the first differentiation method is to identify whether the dfx relates to a specific constraint. The rationale for this separation is that if a device is designed where the specified constraint is not met, then the device will be deemed an unsatisfactory solution. Therefore, it is possible to assign ergonomic performance and usability a lower weighting than portability, ease of manufacture and adaptability/versatility. It states in the criteria that ergonomic performance is measured by the number of ergonomic features that the device possesses and usability is determined by the amount of time that it takes to set up the device for use during a lecture. However, these two dfx's do not have an associated constraint. Although it would be preferred (as per the criteria) that the device in question have as many ergonomic features as possible and be set up in the shortest time frame, devices that have 0 ergonomic features (as the least upper bound) and require a long period of time to set up (relative to other designs) are still considered viable solutions as it is still possible for designs these such designs to meet the constraints.

EP, U < P, EM, AV

Now, the two subsets EP, P and P, EM, will be compared and ranked accordingly.

5.1.2. 2nd MCDM Comparison, EP vs U:

Ergonomics constitute an important part of occupational health and safety and are used primarily in the implementation of standards and regulations for the “development, design, use, management and improvement of work systems” (CSA Group) [6]. Although this device is not required to meet these regulatory guidelines since it is not designed (for the purpose of this design brief) for a workplace environment it is evident that ergonomic performance is a key factor in design decisions. If using this device is uncomfortable due to biomechanical stress or anthropometric misconfiguration then the device will be deemed unsatisfactory.

Additionally, in the context of this design, usability is quantified by the amount of time to needed to set up the device. This is a critical feature as it specifically addresses the problem statement by attempting to prevent students from becoming distracted. As the time needed to assemble the device is decreased the device comes closer to reaching optimal conditions for usability. If the student using the device needs an extended period of time to set it up this is distracting them from the lecture and the fundamental objective is not being addressed.

To quantify whether ergonomics is more important than usability in this design is relative and can only be evaluated on a case-by-case basis. As time needed to set up the device increases, usability may outweigh ergonomics. If the device is sufficiently uncomfortable or difficult to use then ergonomics may outweigh usability. Therefore to assign a higher weighting value to one over the other would fail to express “the real preferences of the decision maker.” (Temesi 2006)

Therefore the relationship between EP and U is 1:1

Therefore: **EP = U < P, EM, AV**

5.1.3. 3rd MCDA Comparison, P, EM, and AV

To analyze these three dfx’s their relative importance to the design in terms of the constraints and criteria they address in the brief will be examined.

The ease of manufacture is used as an estimate to quantify the cost of the device and will be determined using the metric number of parts. The cost of manufacturing an item is directly correlated to the price at which the product can be sold. Lessening production cost is a key factor “in order to make pricing decisions,…[and] determine if a product should be…initiated and other product related decisions" (Tanner) [4]. If a product cannot be devised in such a way that it is profitable the product will fail. To demonstrate this constraint quantitatively, the product must be designed to not cost more than $50.

Additionally, the portability of the device addresses the dimensions and weight of the product and therefore encompasses two constraints that must be met. Similarly, the adaptability/versatility of the device addresses two constraints in that the device must not require a redesign of the chair and that it must be compatible with different types of chairs in the lecture halls.

Although cost is always a key factor in any design decision the device must work before it can be marketable. No matter how inexpensive a product may be, if it does not work it will not succeed in the marketplace. Therefore P and AV are valued higher than EM.

Therefore EP = U < C < PV, AV

5.1.4. 4th MCDM Comparison P vs. AV.

According to the American Occupational Therapy association “an overloaded backpack can cause injuries to students...[and] a backpack should weight no more than 10 percent of a student’s body weight…[7]” Oversized backpacks can lead to a collection of issues including curved spines, neck and shoulder pain, back pain, and pinched nerves. Therefore as the weight of the product increases, the likelihood that a student will be inclined to implement the device decreases. If the product is too heavy it will become a burden to carry around and the student will not use it.

In terms of the adaptability/versatility of the device, the student must be able to use the device in all or almost all lecture halls for it to be useful. If the product does not work in most cases the student will not be inclined to use the device as it will add access unnecessary weight that the student must carry around.

From this analysis it appears that the justification for carrying around the device and implementing its use is derived from its adaptability. If the device can be used in many or all scenarios then carrying it around is justified. Therefore the adaptability/versatility of the device is slightly more important than its portability. However as portability becomes an issue (i.e. the product becomes increasingly massive) then portability outweighs adaptability/versatility.

To conclude, it can be said that AV is slightly more important than P. Therefore P vs AV is 3:1

Therefore: EP = U < EM < P < AV

Pugh Selection Process

Criteria	Design 1 (SD)	Design 2 (LT)	Design 3 (RCS)	Design 4 (OA)
EP	Same	-	-	-
U	Same	+	+	+
P	Same	+	0	+
EM	Same	0	+	+
AV	Same	-	0	+
∑+	0	2	2	4
∑-	0	2	1	1
∑S	0	0	1	3

Pairwise Comparison Matrix

	EP	U	P	EM	AV	Total	Weights
EP	1	1	1/3	½	¼	3.083	0.09
U	1	1	1/3	½	¼	3.083	0.09
P	3	3	1	2	½	9.5	0.26
EM	2	2	½	1	1/3	5.833	0.16
AV	4	4	2	3	1	14	0.39
						35.499	

Weight Comparison Matrix

Criteria	Weight	SD	LT	RCS	OA
EP	0.09	4	2.5	3	3.5
U	0.09	3	3	3	4
P	0.26	2	3	2	5
EM	0.16	3	3	3.5	3.5
AV	0.39	3.5	3	3.5	4.5
Weighted Total	1	3/5	2.9/5	3/5	4.3/5

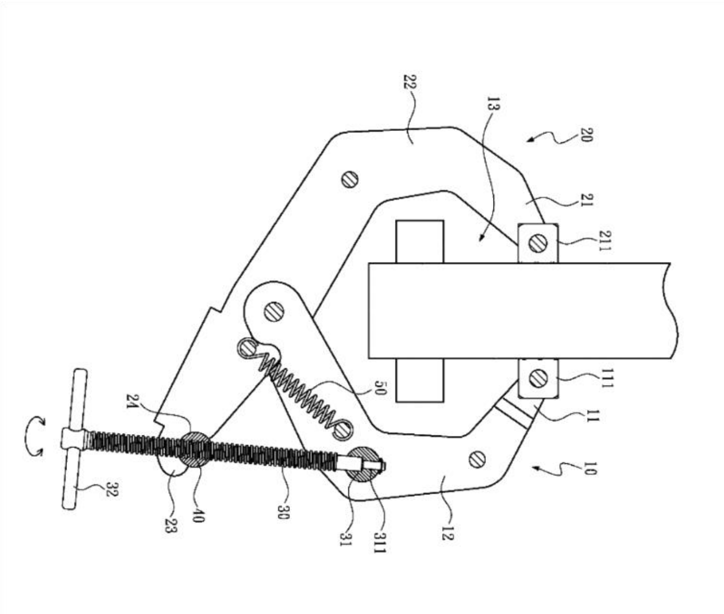
*Rankings out of 5

6. Conclusion:

Based on the multiple criteria decision analysis methods implemented the conceptual design chosen for further development is the Octopus Arm.

Key detailed design decisions are: material of container, type of clamp, length of arm, suction cup design.

Appendix 1:



The quick adjustable clamp (US 20120326375) uses a clamp jaw, a second clamp jaw, and a driving screw and nut to adjust the clamp so that it can be attached to any surface within the range of the maximum extension of the clamp. This sizing can be modified to meet the needs of the user (i.e. the width of the surface that the clamp must be affixed to).

Appendix 2:

The following scoring guide is used to assign a scale for the weighted values in the pairwise matrix. A more rigorous approach to defining the weighted values is discussed in *Pairwise comparison matrices and the error-free property of the decision maker* Temesi (2006).

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