UNIVERSITY OF MANITOBA

**MECH 4860 Engineering Design**

Final Design Report

EMTEQ

# Low-Cost Tooling for Repeatable Hand-Trim of Composite Interior Panels

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# EXECUTIVE SUMMARY

With the existing manual trim procedure of the composite panel for interiors of airplanes, EMTEQ has encountered quality issues in maintaining thickness uniformity during the trimming process of the composite panels. EMTEQ would like to improve the whole trimming process for the panel. The current process requires an operator to trim the panel manually using a die grinder with a combination of carbide bits, cut off wheels and drum sanding bits. There is a scribe line machined into the mold, which is transferred to the finished panel during the manufacturing process. The operator then uses this line as a guide in the manual cutting operation. Design engineering group eight was given the task of designing a low cost tool for the composite interior panel trimming process for EMTEQ. In order to come up with a low-cost tooling that satisfied the requirements of EMTEQ, the engineering design team had a concept development phase that resulted in a final concept that is broken into two major components.

The design team deemed that the final design would be subdivided into two sections:

- Trim Process
- Panel Restraint Method

The concepts developed in the concept analysis, were weighted against each other using a screening and scoring, quality function deployment. These methods were weighted against criteria modeled after the Customer Needs. The resulting final design concept for the trimming process for a composite panel is a vacuum table which is used for the panel restraint method of the process. The incorporation of a slide guide to the vacuum table, and a tool guide attached to a manual drill will finalize the entire process. The panel will be held down using the vacuum table, trimmed with a drill with a tool guide and manipulated by the operator. The drill will be kept in constant contact to the slide guide except when rounding corners. The design group considers the trimming process will improve on accuracy, repeatability, and also minimize the cost of the process should this new process be implemented.

# 1. INTRODUCTION

Engineering design group eight was assigned the task of designing a low cost tool for the composite interior panel trimming process for EMTEQ, the data collected has been summarized in the following sub sections: Introduction, Problem , Project Objectives, and Overall Expectations of Design. EMTEQ Inc. is a worldwide leader in the production and supply of innovative aviation products, and is a Transport Canada (TC) Design Approval Organization (DAO) able to approve aircraft design data in avionics, interior systems, structures, and flammability, providing comprehensive manufacturing and maintenance solutions around the globe [1]. Currently, EMTEQ produces low volume composite interior panels that are manually trimmed. With an anticipated increase in production requirements, EMTEQ partnered with the University of Manitoba to enlist engineering students to improve the existing process. The existing process produces a composite interior panel that is made from multi-layered fiberglass over a foam core. The interior panel is produced in a heated mold illustrated in Figure 1. The part is created by applying layers of fiberglass that are pre-impregnated with a heat activated resin (pre-preg) to the fixture, then circulating hot water through and internal tube network that heats the entire tool consistently. The heat activates the resin and after a set time, the panel cures.


**Figure 1 Existing Fiber Glass Mold [2].**

This process is advantageous because it does not require a large and expensive autoclave. Once the panel has hardened there is an excess amount of material around the perimeter of the panel that must be manually trimmed. The current process requires an operator to trim the panel manually using a die grinder with a combination of carbide bits, cut off wheels and drum sanding bits. There is a scribe line machined into the mold that is transfers to the finished panel during the manufacturing process. The operator then uses this line as a guide in the manual cutting operation.

## 1.1. PROBLEM

With the existing manual trim procedure, EMTEQ has encountered quality issues in maintaining thickness uniformity during the trimming process because of operator trimming with no aid along the scribe line. EMTEQ would like to improve the trimming process for the panel illustrated in Figure 2, as well as future panels. The task is to provide a design fixture that doesn't rely on large equipment with long cycle times, which will allow EMTEQ to increase productivity to meet future production demands, of 34 interior aircraft panels every seven manufacturing days. Currently, EMTEQ produces approximately 1 panel every 3 days.

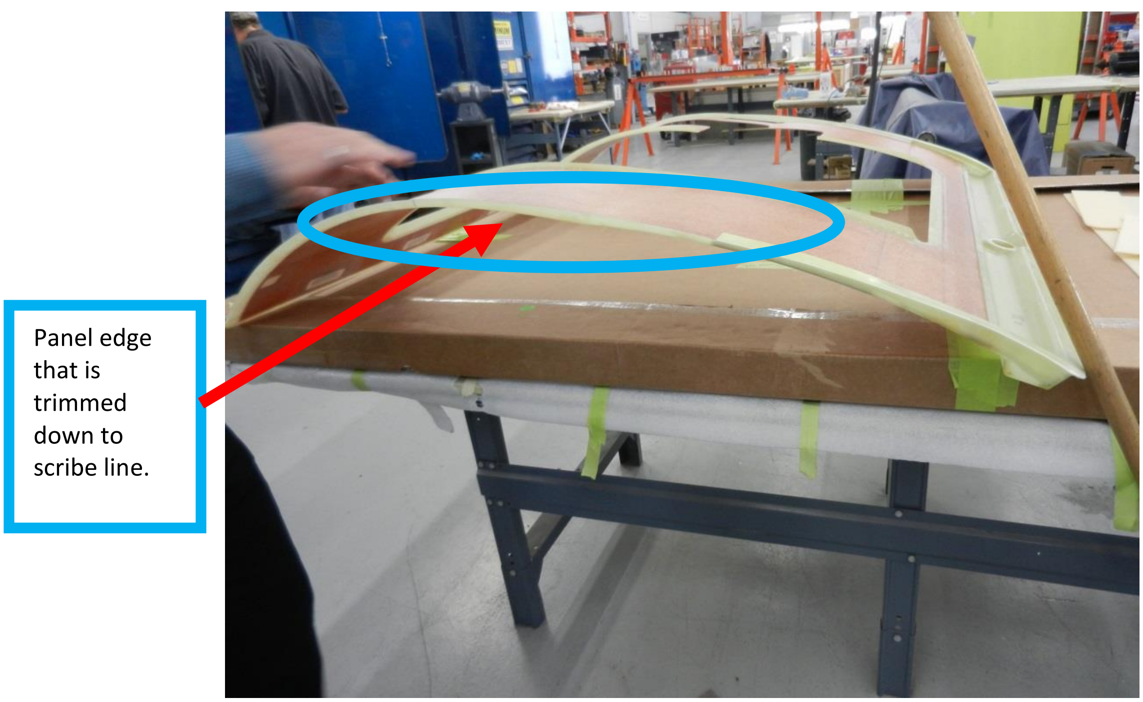


**Figure 2: Typical Finished Panel [3].**

The main purpose of this project is to define tool and equipment designs in order to facilitate the standard operating procedure for the employee, resulting in consistency and repeatability. In the meantime, the quality of the product should be improved and the work environment should be safe.

The final design was selected as the last step taken prior to have gone through the previous steps discussed in the following sections that are found in the Appendix: Concept Design Research, Preliminary Concept Design, Project Scheduling and Concept Design Outcome. The final design facilitates the hand- trimming of the outer edge of the panels. The areas to be trimmed can be seen in Figure 3. All the details of the design must be illustrated and justified. The concept design must be complete enough that EMTEQ can use the process for implementation without having to fill any major gaps.

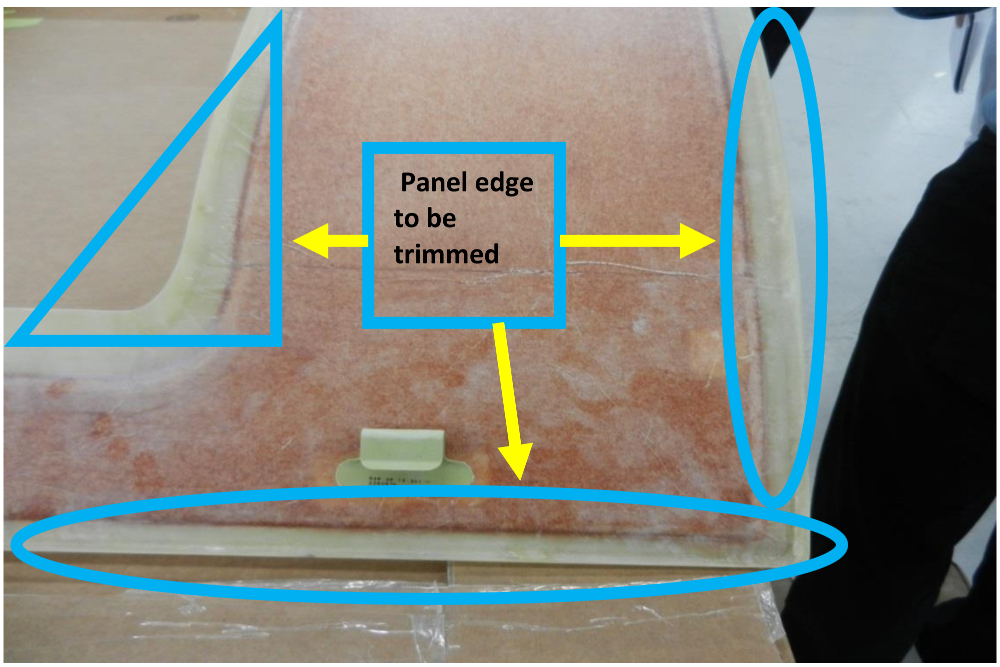


**Figure 3: Example of Trimmed Panel [4].**

To facilitate the requirements for new production rates, EMTEQ has been exploring options that involve either using large, automatic vacuum-assisted cutting machines, similar to what other aerospace companies use, or smaller tooling that can clamp panels that are being cut manually.

EMTEQ wishes to avoid using the large automatic devices because these types of machines typically need to be permanently affixed to the ground. In addition, large devices typically require lot of setup time. EMTEQ has explored smaller tool fixtures with clamp down capabilities, but they are prone to panel damage due to human error. EMTEQ requires a solution designed that has the flexibility of a hand tooling option while also retaining the quality that can be found from using the large automated equipment. The panels that EMTEQ currently fabricates, and future incorporations of panels, vary in shape and size. These panels range from 1x2 feet all the way up to 14x3 feet. Since these are panels for the aerospace industry, consistency in trimming of the end product is of important [5].

## 1.2. PROJECT OBJECTIVES

This section of the report aims to outline the expectations and objectives of the cutting tool project. The Engineering design team has developed different concepts designs in order to come up with a low-cost tooling that satisfied the requirements of EMTEQ, which is explained in further detail in the following subsection.

### 1.2.1. OVERALL EXPECTATION OF DESIGN

EMTEQ's expectation of the group and the report is to develop a concept for a trim process designed to employ hand trimming of composite panels. EMTEQ would also like detailed explanations of the concept designs and why our final design concept was selected. In this report, EMTEQ's ideal result would be a design that could be immediately incorporated in their composite panel manufacturing process.

The Engineering design group developed a low cost cutting tool which involves a hold down method and an efficient cutting process of the excess material. The customer needs have been taken into account for the data collection with the end goal of improving the current trimming process. The customer needs are outlined in TABLE I. The group's main focus was the pursuit of the final concept for the trimming process of panels. The concepts developed in the Appendix of this report helped to create a final design that could potentially be employed by EMTEQ in their panel trimming process.

### 1.2.2. CUSTOMER NEEDS

During a tour at EMTEQ, the design team was able to observe the work area and equipment that need to be enhanced to improve the trim process. The design team was also able to question the operators involved with the current trim process and the engineer in charge of the overall implementation of the current trim process. From the discussions with the people involved in production of the composite panels and from internal design team deliberations, the team was able to create a list of customer needs. With input and acceptance from EMTEQ the final customer needs list is as follows, in order of importance:

**TABLE I: LIST OF CUSTOMER NEEDS IN PRIORITY SEQUENCE.**

| Customer Needs | |
|---|---|
| **1.** | Low cost. |
| **2.** | Process needs to be repeatable |
| **3.** | Safety. |
| **4.** | Ergonomics. |
| **5.** | Quality. |
| **6.** | Trim Panel Fixture. |
| **7.** | Trim panel Layout design. |
| **8.** | Quick set up time and tear down time. |
| **9.** | Cycle time. |
| **10.** | Simple, easy procedure and requires minimal training. |
| **11.** | Minimize resources. |
| **12.** | Interchangeable between different processes. |
| **13.** | Design of optimal workflow layout and create SOP. |
| **14.** | Create preventative maintenance. |

To reiterate and bring context to the list, a quick summary of each customer need will be commented on. Cost refers to the product resulting in a budget significantly lower than the project budget of $100,000 for the interior panels. Repeatable means that the trim process must be a continual process with limited downtime and consistent cuts. Safety states that the process must take operator safety into account. Ergonomics denotes that the trim process must not prompt operator fatigue. Quality is ensuring the trim process is within engineering specified tolerances. Layout refers to the amount of the space the table and trim process take up. Quick set up and tear down time translates to the process have minimal time allocated to these processes. Cycle time means the process must have low production time and high output. Ease of use and minimal training is the trim procedure having a process that can be easy to teach and easy to learn. Minimizing resources of the trim process must limit amount of wasteful product. Interchangeability is when the trim process can be adapted to other interior panels that could potentially be manufactured by EMTEQ. Optimal workflow layout is the process having an easy procedure to follow. Finally, a preventative maintenance schedule must be implemented to limit downtime.

### 1.2.3. TECHNICAL SPECIFICATIONS

Due to the amount of operator importance and input in the trim procedure, it is hard to quantify all the technical specifications to the corresponding customer needs. In addition, the trim procedure involves the overall process of the interior panel coupled with a specific tool redesign; therefore, not all the technical specifications are quantifiable and the engineering design team will require customer feedback. The design team devised the best quantifiable metrics, units and ideal values for the technical specifications of the customer needs. The Technical specifications are in TABLE II listed on the next page.

**TABLE II: TECHNICAL SPECIFICATIONS.**

| | Metrics | Technical Specification | Imp | Units | Ideal Value | Marginal Value |
|---|---|---|---|---|---|---|
| **1.** | Low cost. | Process must have low capital cost. | 5 | $ | $5,000 | $10,000 |
| **2.** | Process needs to be repeatable. | Process must have minimal production time of non-composite panel parts. | 5 | Engineer Input | Exceptional | Satisfactory |
| **3.** | Procedure must be safe. | Process must not result in lost work days due to injury. | 5 | Days | 0 | 0 |
| **4.** | Ergonomic design. | Process must not result in lost work days due to repetitive injury. | 5 | Days | 0 | 0 |
| **5.** | Quality. | Process must be within engineering tolerances. | 5 | inches | ±.015” | ±.030 |
| **6.** | Trim panel Fixture. | Tool required that affixes the panel during trimming process. | 5 | $ | $2,000 | $4,000 |
| **7.** | Layout design. | Process must have small work area. | 4 | $m^2$ | 15% Reduction | No Change |
| **8.** | Quick set up time and tear down time. | Process set up and tear down time must have minimal allocated production time. | 4 | Minutes | <10 | 25 |
| **9.** | Cycle time. | Process must have low production time and high output. | 4 | Minutes | <50 | 96 |
| **10.** | Ease of use and minimal training. | Process must have minimal allocated time to training. | 3 | Days | 1 | 3 |
| **11.** | Minimize resources. | Process must have limited amount wasteful product. | 3 | $ | 0 | $500/part |
| **12.** | Interchangeable between different processes. | Process must have capacity to be implemented in different panel designs. | 3 | Engineer Input | Exceptional | Satisfactory |
| **13.** | Design of optimal workflow layout. | Process must have an easy to follow procedure. | 2 | Operator Input | Exceptional | Satisfactory |
| **14.** | Preventative maintenance schedule. | Process must have limited down time to overall maintenance. | 2 | Days/Mth | 2 | 4 |

Again due to the nature of the design project, which blends manufacturing process with tool design, it is ~~very~~ difficult to quantify all the technical specifications with hard values. Input is required from the operators and engineers involved with this process. Correspondence with an EMTEQ representative was kept during the design process and the design team felt the non-quantifiable metrics were discussed and considered during these conversations to continue with the final design.

## 1.3. CONSTRAINTS & LIMITATIONS

The customer, EMTEQ, provided a list of constraints and limitations that were pertinent to their facility and process requirements. In addition, the design team was able to compile constraints and limitations to the project through observation of the facility and through conversations with operators in the facility.

In a meeting with an EMTEQ representative, an agreement with EMTEQ representative concluded that the observed constraints were, that the process and new tool design must fit in an existing facility and the process must have minimal machine dependency. EMTEQ, commented that the use of 5-axis milling machines and other numerically controlled machines should be avoided due to their large size and cost.

An 'operator and facility friendly transition' constraint was a criterion from the EMTEQ representative. They proposed that, any process that is to be implemented that the operator safety should be paramount and that injury due to repetitive processes be eliminated. In addition, transition from old to new process must be simple, require minimal training, and have minimal impact to overall production in the facility. This means that the implementation process will not be an impact on the operations of the facility and operators will be able to continue working in the facility while process changes take place.

Another constraint is the ability for any tool to be implemented to handle the tough manufacturing environment is needed. The tool designed for the process must be able to have a long running life and not be easily damaged. This ties into having a consistent manufacturing process; that is, the quality of the panels must not be compromised by low quality tools, in other words the tool must be rugged and require low maintenance.

Tying in with the constraint of having an operator friendly process, a sole operator should be able to handle all equipment and tools that are required for the new standard operating procedure. This means that the operator should not have to rely on; forklifts, cranes, jacks or any other machine that would require additional maintenance and additional space allocation.

## 1.4. TECHNICAL ANALYSIS OF TRIMMING PROCESS

EMTEQ has placed high priority on this project remaining low-cost. They have emphasized that rather than having a specific budget in mind for this project, the design should consist of low-cost materials. For example, the fixture that holds the panel should be made of wood or foam instead of metal.

EMTEQ provided the design group with three video clips to illustrate the existing method of trimming the panels. From the video clips, the current procedure was analyzed. The existing procedure for restraining the part is accomplished by holding the panel by hand and stabilizing it with the operator's knee. The panel is first rough cut to an approximately the scribe line. The next operation is hand sanding the rough edges left by the die grinder cut-off wheel. The current method of panel trimming and finishing can be seen in Figure 4.

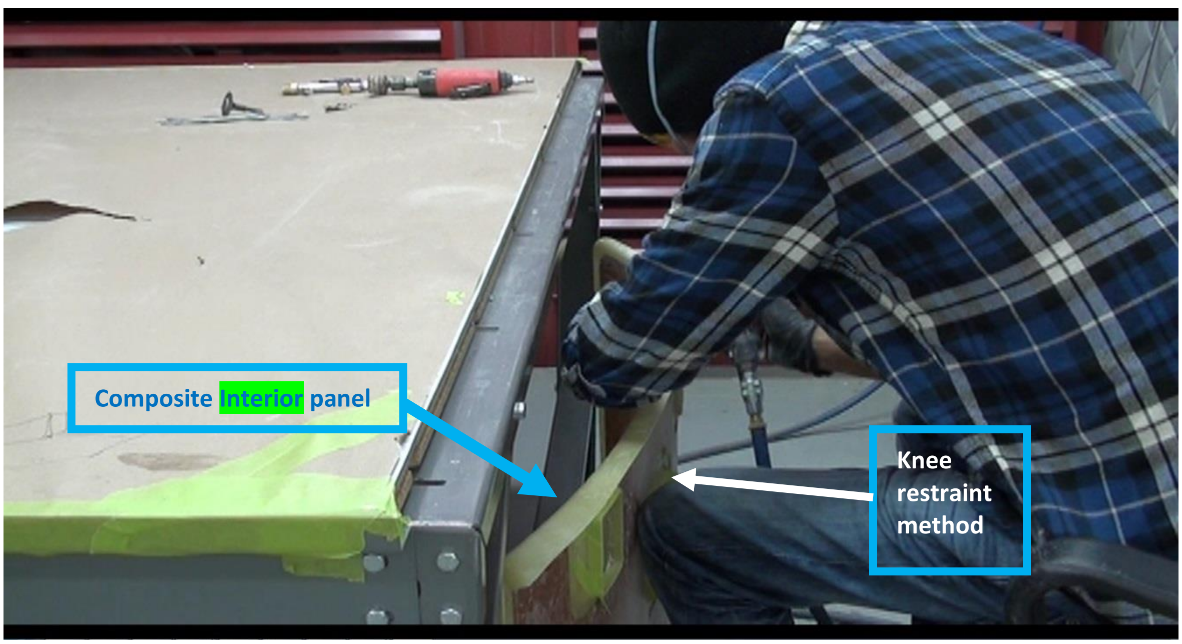


**Figure 4: Existing Method of Finishing [6].**

Typically, a panel takes 2-4 days to complete fabrication--assuming that the average current output of a panel is 0.33 panels per day. EMTEQ is aiming to increase production to a maximum of 4.9 panels per day. The concept proposed in this report will reduce cumbersome handling of the panel and reduce the finishing operation time drastically by reducing the amount of finishing after the cutting procedure. The operator would only be required to remove the sharp edges and not try to blend the material down to the scribe line. EMTEQ currently produces two panels using this procedure but the analysis in this section focuses on the larger more costly panel. The concept presented in this report can be used for a panel of any size.

The total project budget for the two panels is $100,000. The technical specifications required, the problem, constraints and limitations result in a process that must improve upon the existing process at a minimal cost in reference to the project budget.

# 2. DETAILS OF DESIGN

The engineering design team has subdivided the details of design into: Features of the Design, Features of the Slide Guide Design, Tool and Carbide Burr, Vacuum Table, Body Mount, Guide for Die Grinder, Dust Collection, and Design's Operation which are described in detail following a brief introduction.

The final design recommended in the report has two major processes, the hold down method of the interior panel and the trim method to cut the interior panel. The hold down method refers to how the panel will be safely immobilised while the trim process is in progress. The trim method is how the interior panel will be cut to tolerances. From these two major process considerations, four major components were finalized in the design with one recommended component to be considered for the final design. The four necessary components are the vacuum table, guide rail system, tool body mount, and trimming tool. An added value component not previously required but though to be necessary is a cleanup system while trim process is in progress.

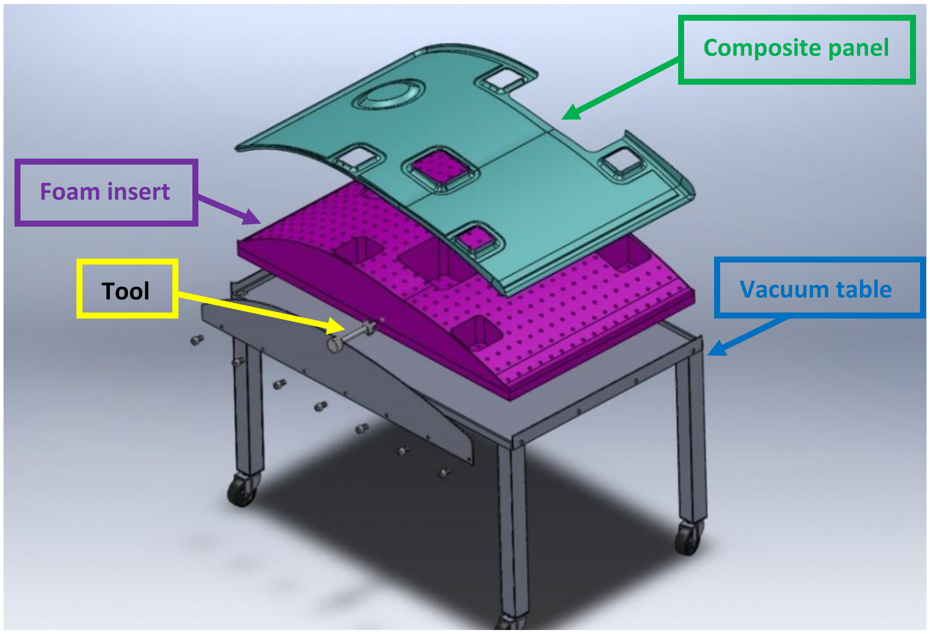


Figure 5: Exploded View of Trim Equipment

The vacuum table immobilises the interior panel as it is being trimmed through a vacuum pump, foam core and hosing. There is a perforated hole on the top on the vacuum table that provides suction and the interior panel adheres to the vacuum table due to the pressure differential between the vacuum chamber and the ambient air pressure. The guide rail is located around the perimeter of the vacuum table that sets the drill tool on a path that leads to consistent cuts. The tool body mount is what connects to the drill tool and provides the guidance of the tool along the guide rail. The drill tool is the actual device that does the cutting of the panel. The one other consideration is a cleanup method. The cleanup is not necessary to machine the panel but helps lower clean up times and ensures a clean work area.

When all four major components are combined the design group feels that operator safety, repeatability, consistency, quality and process time will be improved. The safety of the operator is thought to be improved because the previous hold down method shown in Figure 4. allows the panel to move during trimming. Repeatability, consistency and quality are believed to be improved because the cutting line is set due to the guide rail and body mount on the drill tool. At the end, overall process time is considered to be reduced because of the elimination of buffering and sanding required in the new process; unlike, what is required in the current process. Also, the design group considers this trim method easy to adopt, would require minimal training and is a low cost alternative to CNC machining processes.

## 2.1. FEATURES OF THE SLIDE GUIDE DESIGN

The final design for this report is comprised of four major design categories and one recommended design feature. The four major components the design group thought was necessary for a low-cost, repeatable, hand trim of composite panels were the tool used to cut the trim, the hold down method of panel, the guide around the periphery of the composite panel, and a body mount for the tool and guide. A added value feature to cut the panel that is to be discussed is a dust collection method to reduce the amount of clean up time required for the process.

### 2.1.1. TOOL AND DRILL BIT

The tool and drill bit are readily available equipment that can be purchased or ordered from a typical tooling vendor. The tool is, shown in Figure 6: Dynabrade 51756 Pencil Die Grinder Extension Tool a drill that uses a pneumatic motor for operation and the drill bit is an Onsrud 67-003 carbide drill bit specifically designed for fiber glass and composites. The tool and bit are ideally suited for the application of the design because of its weight, versatility, tolerances, overall shape, cutting abilities and cost.

[redacted]

**Figure 6: Dynabrade 51756 Pencil Die Grinder Extension Tool [7]**

The overall weight of the tool 0.8 pounds [7], this low weight means that operator fatigue will be minimal and the manoeuvrability and versatility of the tool will be increased. The drill bit tolerances is ±0.0002" which works well with the tolerances required by the design. The design calls for tolerances of ±.015". Note the overall shape of the pencil die grinder in Figure 6: Dynabrade 51756 Pencil Die Grinder Extension Tool has an elongated shaft that works in advantage of the concept because of the body mount to be assembled on the tool. For details on body mount assembly refer to Figure 88. The elongated shaft allows the mount to be fitted securely on to the tool with room for the operator to still handle the drill [8]. The cost of the drill is also a benefit because the listed price of procurement is $369.35which is well below the $100,000 project budget for the interior panels.

The drill bit used to cut the panel is a 1/8" carbide burr specialized for cutting of fibreglass, and composites. The drill bit should be operated to ensure that saturation of the composite interior panel and drill does not occur. The cost of the carbide drill bit when purchased from the manufacture is $28.60 per bit [8]. This drill bit combined with the tool, in comparison with the project budget, is a small fraction of cost.

## 2.1.2. VACUUM TABLE

The composite panel to be trimmed will be secured on a vacuum table. This will eliminate the movement of the panel, to improve repeatability, quality of cuts and to ensure operator safety. The vacuum table materials necessary to build it can be purchased from a vendor and then built in house.

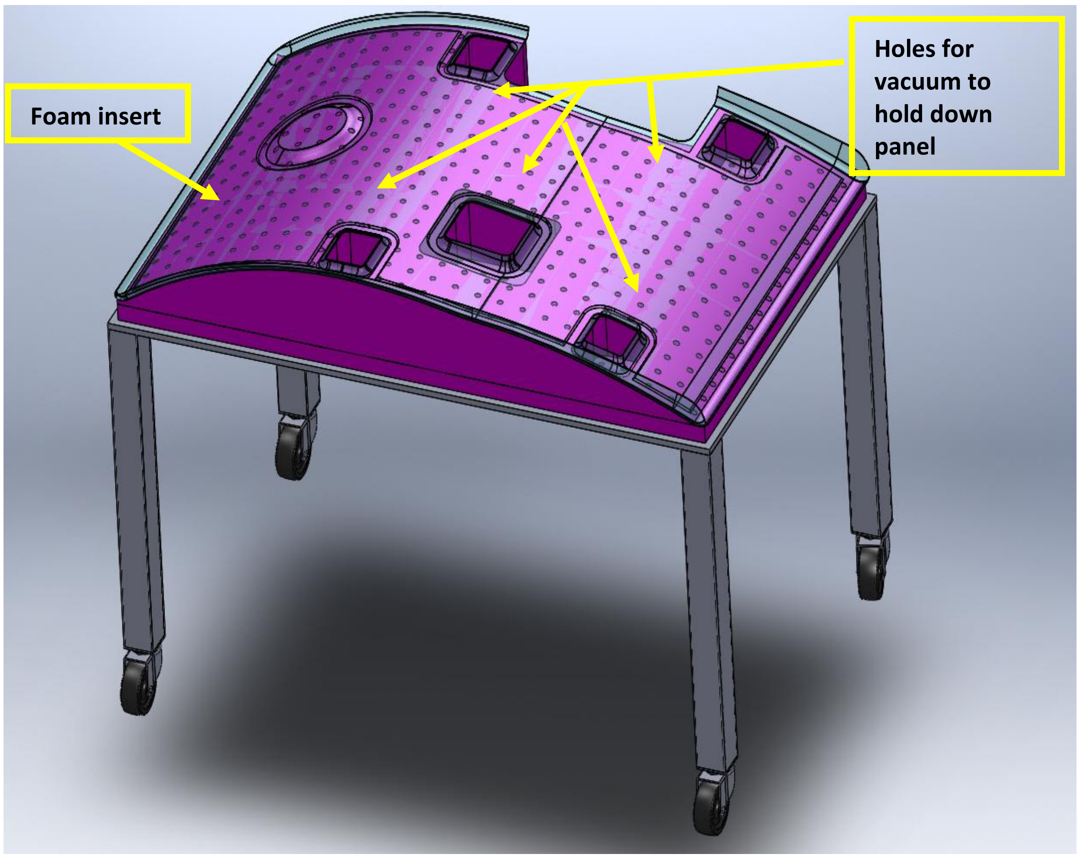


**Figure 7: Vacuum Table.**

In this particular vacuum table lay out, it can be seen that there are holes on the table top that are enclosed by a rubber material. This is an enclosed area of rubber is where suction occurs. These holes are connected to hosing directly underneath the vacuum table that is connected to a vacuum that secures the panel to the table top (hosing and vacuum not shown in Figure 7). The pressure difference between the suctioned areas and the ambient air pressure keeps the panel secure to the table.

Two possible ways to procure the vacuum table are to build the vacuum table in house or to send the interior panel CAD model to a vendor to have it built by the vendor. In a correspondence with EMTEQ, a vendor quote was previously obtained and estimated to be between $10,000 and $20,000. Alternatively and recommended by the design group is to build the vacuum table in house. The materials for the table top, foam insert, vacuum, hosing and rubber lining can be acquired from a vendor and built at the EMTEQ facilities. This in house cost estimate is approximately $615.39.

## 2.1.3. BODY MOUNT

The body mount is the device used to securely hold the tool shown in Figure 68, which will allow smooth movement of the drill along the guide around the perimeter of the panel. The body mount also houses a bubble level that the operator uses as reference so the drill stays level in the lateral direction.

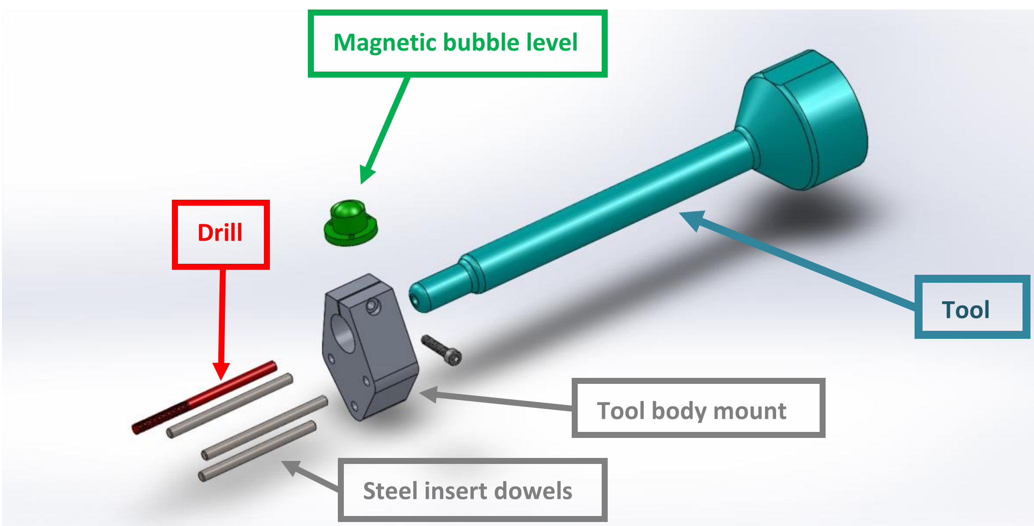


**Figure 8: Body Mount.**

The body mount can be machined in house and uses aluminum for the main body component. The aluminum material is used to allow for easy machining of the main body. Three holes are drilled parallel to the drill bit for steel to be fitted. One hole is drilled perpendicular to the two dowels so that the body can be clamped and screwed together to allow for a secure fit of the body mount and die grind. A magnetic bubble level is the added to the body mount for operator reference while drilling.

As mentioned earlier, the protrusions on either side of the body mount are steel dowels that are pressure fit into the holes machined into the body mount. The main purposes of the dowels are to allow movement and guidance of the drill along the laser cut steel guide for the drill. The material steel is used to nearly eliminate the amount of deflection experienced by the dowels and to eliminate any plastic deformation or environmental wear that could occur if a softer metal were used.

The estimated cost of the body mount is assumed to only be a matter of material cost. It is assumed that the manufacturing cost is negated by the fact it is to be assembled and machined in house. The material cost for the body mount is estimated to be $40.00 in 6061 aluminum.

### 2.1.4. GUIDE FOR DIE GRINDER

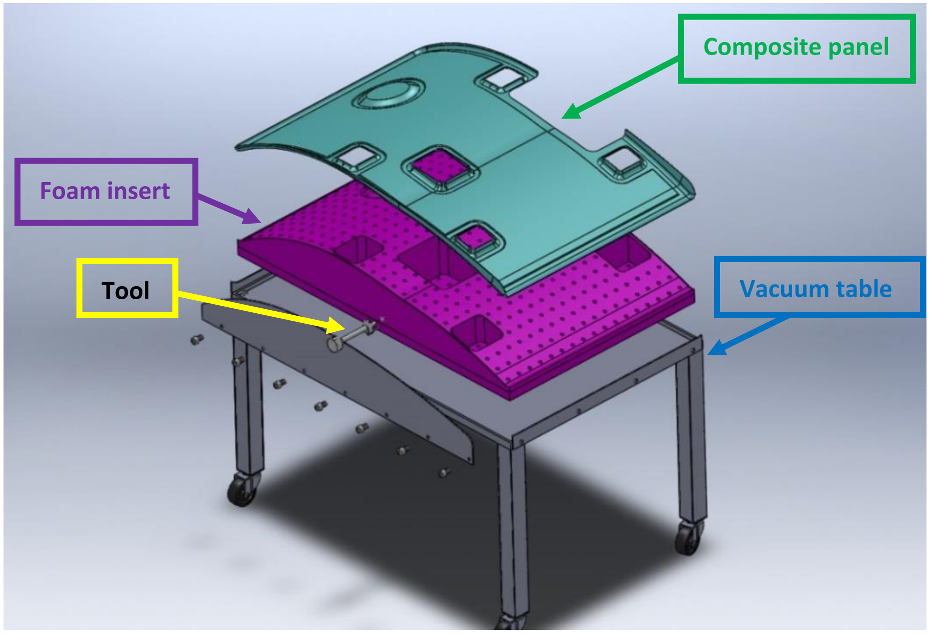


Figure 9: Guide for Die Grinder.

The guide for the die grinder is a laser cut steel sheet that runs around the perimeter of the panel. The steel guide would be non-removable once it is set within the panels' tolerances. This set position would allow for a repeatable and precise cut for every panel. This means that panels' tolerances would be kept for every panel once the steel sheet is set in place. The steel guide would have to be laser cut either in-house or through an appropriate vendor and assembled in-house. Regular checks would have to be employed to make sure the guide is still within tolerances. Once the guide is set in the assembly with the vacuum table, the die grinder and body mount, the entire system will need to be assembled and checked for tolerances. Again, steel is used to reduce the chances of the guide rail being damaged or compromised due to the manufacturing environment.

The expected cost of having the guides laser cut by an outside vendor is approximately $60.

### 2.1.5. DUST COLLECTION

An added value feature for fabrication of the panel that can be employed to reduce clean up time is the use of a dust collector. The dust collector could potentially be attached to the body mount to allow for material clean up as the part is being trimmed. The vacuum would be a standalone system that would simply collect dust as the panel is being cut.

The vacuum and hosing equipment necessary for the dust collection can be purchased from a vendor and assembled in shop. Depending on operator preference, the vacuum could be connected to the main body mount or can be used separately after the trim process has taken place. A quick estimate on the price of a shop vacuum and hosing gives an approximate cost of a $190.00 [9].

## 2.2. DESIGN'S OPERATION

With the major design features in mind, a zoomed in view of the assembly is shown in Figure 9. The vacuum table (purple) secures the panel (aqua) and the slide guide (dark grey) is rigidly set along the edge of the table. These are the major components that assist in the support of the operator as they cut the panel. The carbide burr bit will be fitted with the body mount, dowels, and possibly the vacuum tube.

To give an account of the entire operation a simplified operation walkthrough will be discussed. First, the panel is securely fitted on the vacuum table. Once the panel is securely set in the vacuum table, the die grinder is hand held and the operator simply places the steel dowels on the steel guide and slides the drill along the guide while constantly maintaining contact with the steel guide. The operator also uses the bubble level to make sure the drill does not pivot and stays on the guide

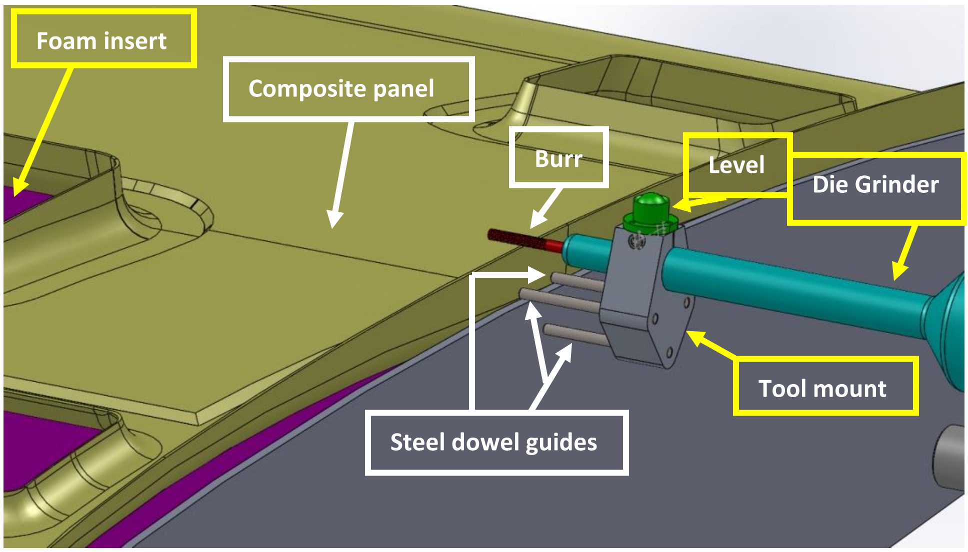


**Figure 10: Design's Operation.**

Shown green in Figure 10, the bubble level must be in the middle to ensure no pivoting of the drill happens, this is especially important in the corners where the operator will have to manually cut along the scribe line.

If implemented in the body mount, the dust collector simultaneously cleans the panel as the operator runs the tool along the guide. Once trimming of the excess panel is completed the vacuums are shut off and the panel is removed from the vacuum table. Supplementary cleaning must be done to ensure the vacuum table does not get clogged with material. The process is then repeated for any other panel in queue.

This method of low-cost repeatable, hand trimming would be panel specific and the entire process of machining, procurement and assembly of a new trim process would have to be repeated for a new panel assembly.

# 3. COST

EMTEQ has placed high priority on this project remaining low-cost. They have emphasized that rather than having a specific budget in mind for this project, the design should consist of low-cost materials. At the direction of EMTEQ the vacuum table was assumed to be sourced from an outside vendor. Costs for a vacuum table from an outside vendor are expected to range from $10,000-$15,000. Another option would be to produce the table in house. Producing the vacuum table in-house, while outside the scope of this report would be significantly less costly when compared to an externally sourced unit. Given the low weight and large surface area of the panel a low-cost in-housed produced vacuum table would be the recommendation of this report.

This report is focused on the locating and trimming of the F195 Cargo Door Panel and as such the costs discussed in these subsequent sections will only reflect the locating and trimming parts. The funds listed in the following sections are in United States Dollars (USD).

## 3.1. COST ANALYSIS

EMTEQ has provided the design group with the following information on the costs associated with this part:

- Total project budget for the two panels was $100,000.
- Fabrication cost is roughly $1500.
- Each panel requires 2-4 days for fabrication.
- Sale price for both panels is or $3120.

Given the current methods of fabrication, it is not feasible for the hold down method alone to achieve a ~1500% increase in production. The trim process is not indicative of the entire panel fabrication process time; however a reduction in trim cycle time, suggested in the technical specifications will increase the productivity process of the panel.

From data required from industry suppliers of a hold down table to restrain the part during the cutting operation can range in cost from $200-$20,000 CAD. The design selected in this report could be easily fabricated in house by EMTEQ and would cost $615.39 in material. Assuming the final product costs $5,000 CAD, expected simple payback would be within two parts or 8 days. The simple payback period is so short, that it makes further comparison using (Internal Rate of Return) IRR, Net Present Value (NPV) and other methods unnecessary. This payback only considers the material cost as we assume the labor is a sunk cost in the project budget. [9]

## 3.2. OVERALL COST

For the purpose of this project, any in-house manufacturing costs (labor, consumables, and machine wear and tear) are assumed to be zero. The total cost for the materials outlined below in section Bill of Materials is found to be $1,128.99 for the complete unit. This cost is in line with the expected cost and metrics proposed in section 1.5 of this report as well as the overall goal of providing a "low-cost" cutting fixture as requested by the client. The only consumable in this design is the Onsrud 67-003 carbide burr, with a typical feed rate of 60 Inches per minute, the burr will last an expected 30 panels. With an anticipated increase in production of 34 panels every seven manufacturing days this equates to an expected annual cost of $1,200 or $0.95 per panel which is an acceptable cost based on the high panel margin. This price could be further reduced with bulk order incentives from the manufacturer.

## 3.3. BILL OF MATERIALS

TABLE III is an itemized bill of materials for all the parts required for construction of the cutting fixture. All of the prices in the bill of materials are listed in USD and does not include shipping costs. The most expensive items are the Dynabrade die-grinder and the Rencast foam. Dynabrade provides a lifetime warranty on all of their tools so the pencil grinder is expected to be used in perpetuity. The Rencast foam comes in a 19 liter pail and is expected to produce enough foam to make two bases for the panel.

**TABLE III: BILL OF MATERIALS.**

| Part Number | Part Name | Pkg | Qty. | Unit Price | Total |
|---|---|---|---|---|---|
| 98381A479 | 1/8" Dia. 1-3/4" long alloy steel dowel pins | 50 | 1 | $14.15 | $14.15 |
| 98381A178 | 1/8" Dia. 1-5/8" long alloy steel dowel pins | 1 | 1 | $5.67 | $5.67 |
| 98381A480 | 1/8" Dia. 2" long alloy steel dowel pins | 50 | 1 | $13.78 | $13.78 |
| 09008 | Rencast Foam for Base | 1 | 1 | $449.67 | $449.67 |
| - | Table Legs | 1 | 4 | $13.70 | $54.80 |
| 2834T37 | Casters | 1 | 4 | $12.73 | $50.92 |
| - | Right Guide | 1 | 1 | $15.00 | $15.00 |
| - | Left Guide | 0 | 0 | $15.00 | $15.00 |
| 91251A710 | 1/2"-13 Socket Head Cap Screw | 10 | 3 | $11.57 | $34.71 |
| - | Front Guide | 1 | 1 | $15.00 | $15.00 |
| - | Back Guide | 1 | 1 | $15.00 | $15.00 |
| 67-003 | Fiberglass Carbide Burr | 1 | 1 | $28.60 | $28.60 |
| 51756 | Dynabrade pencil grinder | 1 | 1 | $369.35 | $369.35 |
| - | Mount Body | 1 | 1 | $40.00 | $40.00 |
| 91251A208 | 4-40 Socket head Cap screw | 25 | 1 | $10.30 | $10.30 |
| 2308A8 | Surface Mount Bull's-eye Level | 1 | 1 | $12.04 | $12.04 |
| | | | | **Grand Total:** | $1,128.99 |

# 4. CONCLUSION

To reiterate EMTEQ has tasked the design group with developing a tool that is low-cost, with a greater degree of accuracy than the existing process in anticipation of an increase in current production. With the existing trim procedure, EMTEQ has encountered quality issues in maintaining thickness uniformity during the trimming process. The resulting design would provide a hand cutting fixture that doesn't rely on large equipment with long set-up times which will help facilitate their anticipated increase in production. EMTEQ has emphasized that in addition to the resulting concept being low-cost it should utilize a hand held cutting operation. The design must be strong enough that EMTEQ can use for implementation without having to fill any major gaps.

In conclusion, the Engineering design team eight deemed that the final design were subdivided into the trim process and panel restraint method. The concepts developed in the concept analysis, were weighted against each other using: Screening and Scoring Quality Function Deployment, found in the Appendix. These methods were weighted against criteria modeled after the Customer Needs. The resulting final design for the trimming process for a composite panel, required by EMTEQ, is a tool with a tool guide for cutting and is coupled with a slide guide on a vacuum table for the restraint method. In theory, the panels would be held down by using the vacuum table and trimmed with a tool similar to the one the operator currently uses.. The final report includes a detailed model of the vacuum table and the slide guide for the manual tool process. A photo graph of the slide guide system is show in Figure 11.

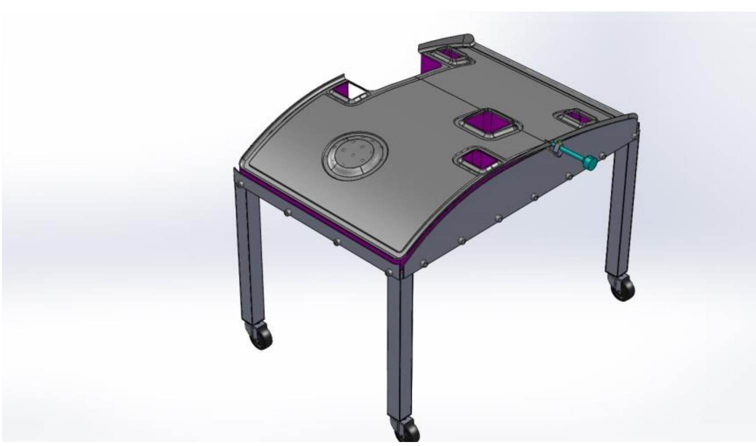

**Figure 11: Slide Guide Design with Vacuum Table**

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# APPENDIX

# APPENDIX

## Contents



## List of Figures



## List of Tables

# 1. INTRODUCTION

Engineering design group eight was assigned with the task of designing a low cost tool for the composite panel trimming process for EMTEQ, the data collected has been summarized in the following sections: Concept Design Research, Preliminary Concept Development, and Concept Design Outcome.

# 2. CONCEPT DESIGN RESEARCH

For the concept design research the engineering design group number eight collected data through a systematic structure approach with both an internal and external search.

## 2.1. INTERNAL SEARCH

The internal search was Conducted by the Engineering design team by contacting the client to coordinate a meeting and visit the manufacturing site. The trimming process of the composite panel was observed and the client was able to elaborate on the project specifications and their needs. The design team also received a video tape that documented the current procedure. This allowed the design group to create additional metrics and values to take into consideration.

EMTEQ follows the standard of ISO 9001:2008, our product should continue to hold this standard adopted by EMTEQ. This standard overall scope is to “consistently provide product that meets customer and applicable statutory and regulatory requirements” [1]. From this it can be extrapolated that our final design should improve upon the existing trim process and meet Manitoba and Canada labour laws for safety.

The design group organized a brainstorming session direct to create the concept generation phase, which yielded various concept design solutions. The bottle necks, limiting of the current trimming process were identified and trim process improvements were designated to be implemented in the concept design.

During these session, eight concepts (Trim Process ) were developed by the Engineering design team. The methodology used to select the final design concept is detailed in: Screening and Scoring, Concept Selection.

## 2.2. EXTERNAL SEARCH

External searches were performed to benchmark how competitors where conducting the trimming process procedure. This provided the design team additional approaches in improving current trimming procedure. The external research conducted was aided through internet searches of existing trim methods, by talking to EMTEQ operators and engineers. The external search result yielded large automated equipment which drifts away from project scope of low cost tooling for EMTEQ.

For a particular example of a similar procedure, a patent from the Boeing Company on hand trimming was looked at. This particular trimming method employed a guided saw for cutting an airplane panel [2]. This hand trimming method sparked an idea that the group would look into a guided system for the handing trimming method. This eventually led to the final design of a guided trim method that is recommended in this report.

# 3. PRELIMINARY CONCEPT DESIGN

In the preliminary concept design the engineering design team eight brainstorm to develop the following subsections: Concept Generation, Concept Analysis, Trim Process, Restraint Method, Screening and Scoring, Concept Selection, which are indicated below in further detail.

## 3.1. CONCEPT GENERATION

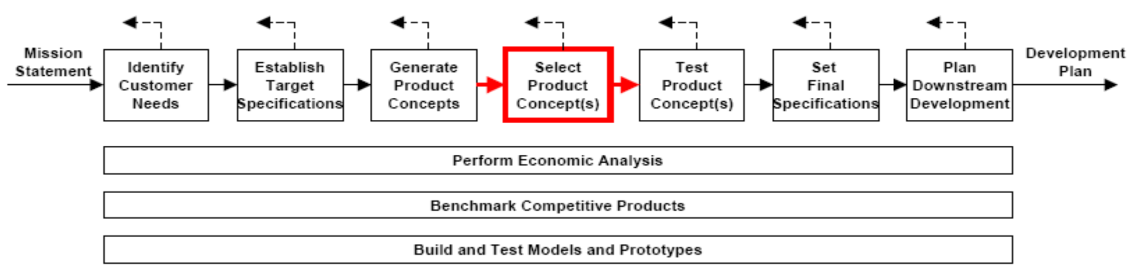


**Figure 1: Concept Development [1].**

From the generated concepts, there were two major themes that the design team decided that should be included in the final design. The two major points finalized were the hold down method of the composite panel and the cutting process of the excess material. The hold down method includes how the panel will be secured and what it will be secured to when the cutting process begins. The cutting process includes what type of tool will be used to cut the panel, what type of measures will be used to improve accuracy and what will be used to finish/polish the panel.

The hold down method entails how the panel will be secured so it will not move when being trimmed. The current method employed by EMTEQ allows movement in the panel when trimming which could potentially result in operator safety issues and tolerances issues. The design team felt that this could potentially be a major area of improvement in the trim process. If an appropriate method were employed this could address the customer's needs, and technical specifications could be improved.

The cutting process was the second major component that the team felt could significantly improve the metrics of the report. The cutting process used by EMTEQ employs a hand held processes. The design team deemed that working with the current hand held tools would be best suited for the cutting process. This will ensure smooth process transition for operators into the new standard operating procedure and will also maintain concept generation within constraints imposed by EMTEQ which was low cost tooling. The team deemed that the cutting process could be improved, if the hand held tool had some guide system for repeatable and accurate cuts. After watching the trim process at EMTEQ, the team considered that the cutting of the trim may actually be increased but the finishing/buffering would be improved to the extent that the overall trim process time would be reduced.

Additional processes to be included in the final report are refining the concept for ergonomics, increased safety, and process versatility for multiple panels. The design team deemed that these components should be considered in the preliminary concept design but the actual processes should be addressed in the final report. Therefore, the initial concept design took into consideration these other contributions, but how to specifically address the other contributions is not detailed in this report.

## 3.2. CONCEPT ANALYSIS

This section outlines the eight concepts created by the design group. The eight concepts are subdivided into two categories, hold down method and trim method. Each design was analyzed in this section to show the pros and cons, and afterwards the concepts were scored and screened in section Screening and Scoring.

## 3.3. TRIM PROCESS

The trim process consists of removing the excess material of the composite panel up to the scribe line, reference engraved to the panel during the manufacturing process.

### 3.3.1. CONCEPT ONE: ARTICULATING FLAP

In Figure 2, the concept design number one allows the tool design to have a 270 degree movement from the hinge point. The flap is meant to reduce the amount of vibration and jerking movement in the hand by sliding across a surface. The operator would be able to move the flap to adjust the angle of the carbide bit for ease of cutting. The benefits to this particular tool is that it is easily implemented into existing tools, low machining cost, quick set up time, and easy to change  from manual trim tools. Some disadvantages of the design concept, may result in safety issues, if there is no safeguard against slipping across table, quality of cuts may be compromised and the product may be cumbersome.

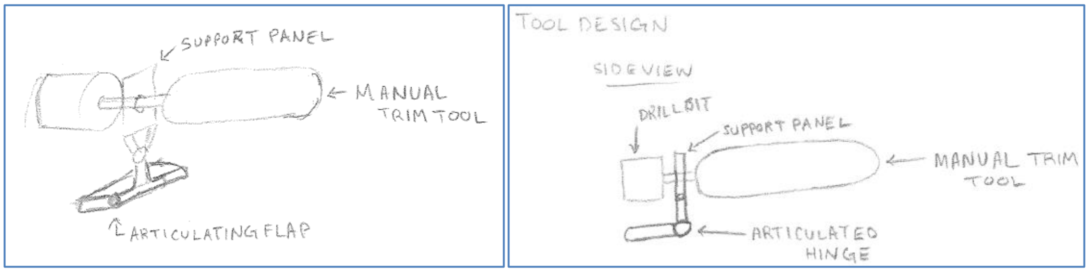


**Figure 2: Articulating Flap for Trimming Process.**

## 3.3.2. CONCEPT TWO: CELL STRUCTURE ARM GUIDE

In Figure 3, The concept design number two has a full circular rotation of 360 degree about fixture of the tools structure and is meant to secure the manual trim tool, which will result in reduction of vibration and operator fatigue. At the joints, the tool is viscous to reduce jerking motion and is meant to help the operator cut the panel. The benefit to this design concept allows for a safe procedure, it is ergonomic, it reduces the foot print of the operation, and the process has a good workflow. Some of the detriments would be the implementation cost, the quality of cuts would be compromised due to the arm reducing operator's visibility of the product during the trimming process, and the tool has a set area and size of panel it can handle.

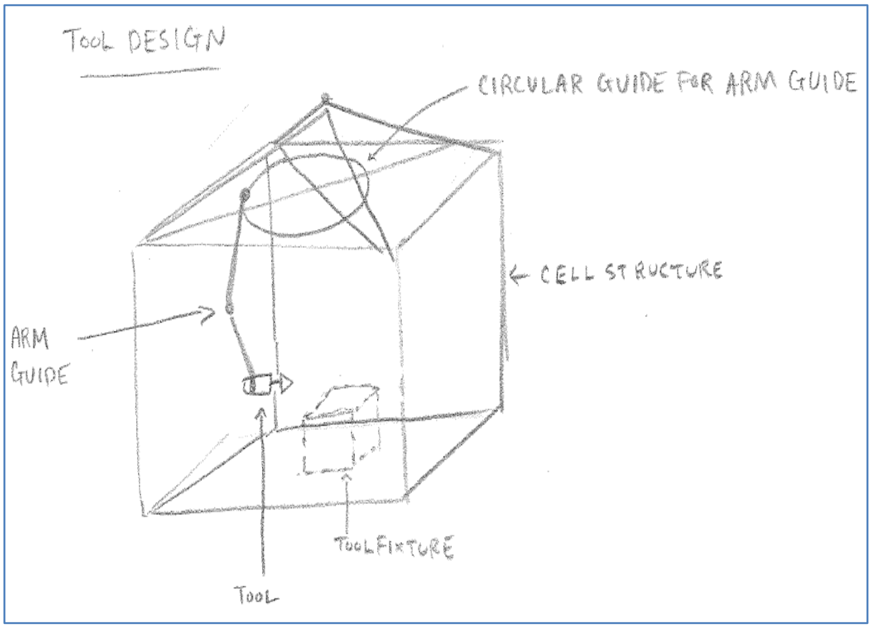


**Figure 3: Cell Structure Arm Guide.**

## 3.3.3. CONCEPT THREE: SLIDE GUIDE

In Figure 4, the concept design number three is a slide guide located around the periphery of the panel and can be adjusted to meet different trimming panel requirements. The guide simply helps the operator have a quick and consistent cut of the panel at a given height and angle. The guide works in conjunction with a support that is attached to the hand tool. The benefits to this design are that it could be inexpensive to implement, its quality of cuts are consistent, it's ergonomic, and it's safe and repeatable. Over time the quality of cuts could be compromised.

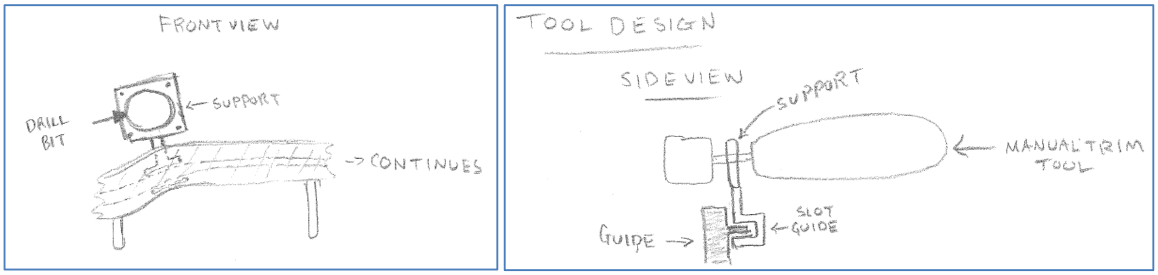


Figure 4: Slide Guide.

## 3.3.4. CONCEPT FOUR: MAGNETIC TOOL COMPASS

In Figure 5, the concept design number four is an articulating arm that revolves around an axis. This compass is designed to be moveable for the operator to have a better mobility around the panel. The arm is designed to be like the cell structure arm guide where it reduces jerking and vibration of the tool. The pros are that it can potentially have a quality cut and it is easily interchangeable between parts. The cons to the design are that it may be hard to manufacture, it may have a high capital cost, it may be cumbersome and it may increase cycle time because of the need to move the arm around.

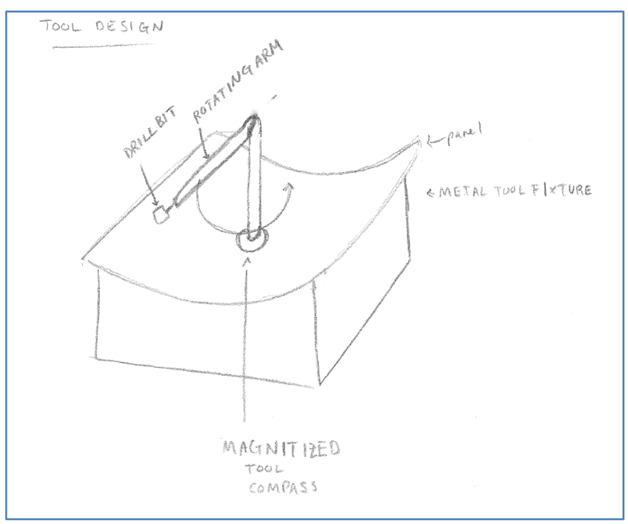


Figure 5: Magnetic Tool Compass.

## 3.4. RESTRAINT METHOD

The hold down method consists of the procedure in which the panel is fixed, which avoids vibration during the trimming process of composite panel.

### 3.4.1. CONCEPT FIVE: ARTICULATING FLAP

In Figure 6, the concept design number five is meant to hold the panel in place as it is being cut to allow the operator to handle the tool device. The panel will be held in place by a support panel. The benefits to the design are that it could decrease cycle time due to less part movement, low cost to manufacture and it can be easily implemented. The detriments are that the panel may shift if not supported properly and that the flap may interfere with cutting.

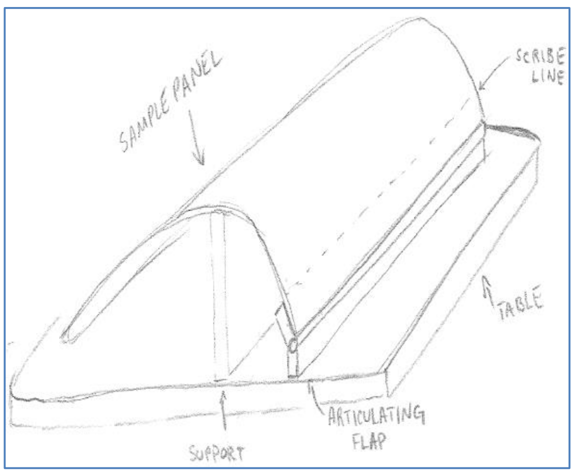


Figure 6: Articulating Flap for Interior Panel Fixture.

## 3.4.2. CONCEPT SIX: CELL STRUCTURE

In Figure 7, the concept design number six is a cell structure, which basically is a set area with an overhead clamp. The clamp compresses the panel on to a tool fixture and the operator can move around the entire structure to trim the panel. The pros are that the foot print of the trim area is set, and it is ergonomic. The downsides are that it may be expensive to manufacture, the clamp only supports the middle of the panel and not the edges, and the panel area is set.

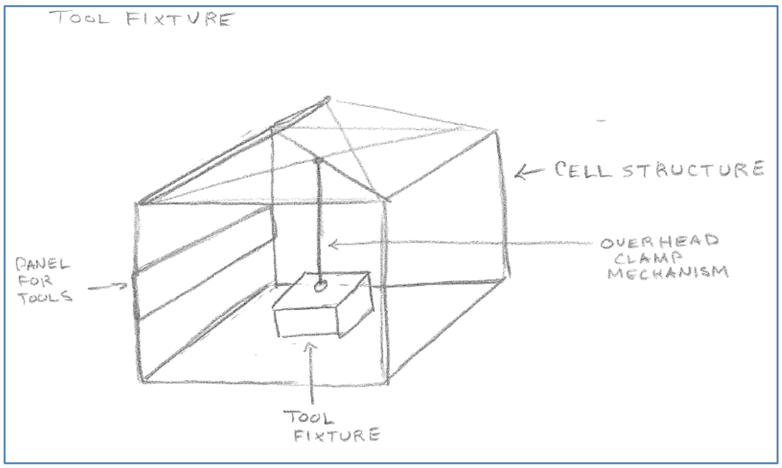


**Figure 7: Cell Structure.**

## 3.4.3. CONCEPT SEVEN: FOAM INSERT

In Figure 8, The Concept design number seven is a foam insert that conforms to different panels. It is set on and there is metal edge around the top to allow a guide to be placed on top. If the tool guide were on the periphery of the panel the metal edge would stop the foam from being damaged. The benefits to this are its low cost, reduces part vibration, it has quick set up time and minimal training is needed. The shortcomings of the fixture it is may be cumbersome to handle, it may be easily damaged hence it would require extra resources to fix and depending on the foam material it may be expensive to replace.

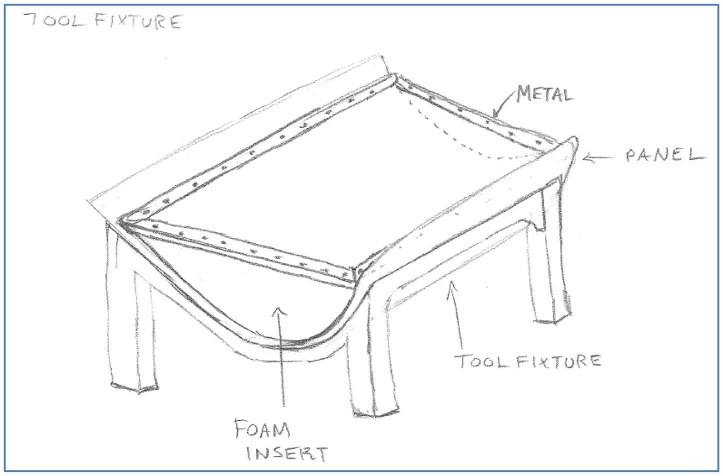


**Figure 8: Foam Insert.**

## 3.4.4. CONCEPT EIGHT: VACUUM TABLE

In Figure 9, The Concept design number eight is a vacuum table that uses air to hold the panel down. Hoses and an industrial vacuum would be needed to operate the fixture but the panel would be secure and resistant to movement wherever a suction area is located. The benefits are the high panel securing and no peripheral material interrupting the trim process. The shortcoming of the vacuum is the potential cost of replacement and the bulkiness of the fixture that may require extra lifting machines.

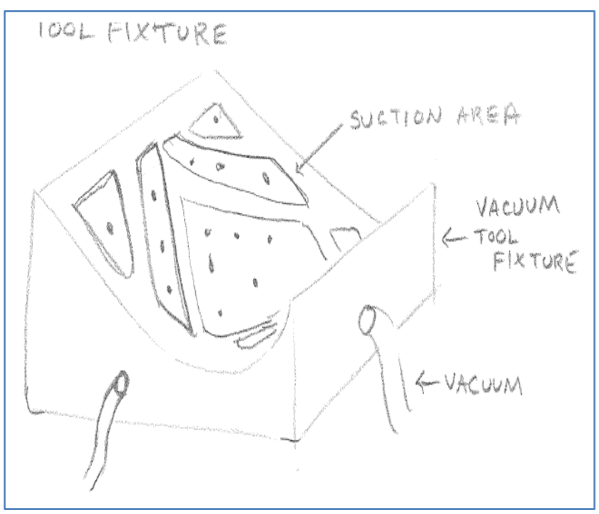


**Figure 9: Vacuum Table.**

## 3.5. SCREENING AND SCORING

In order to objectively evaluate the concepts presented in this report an unbiased selection matrix was employed. The eight concepts presented in this report were compared to the process that EMTEQ uses presently. The selection criteria used to evaluate the concepts was taken from: TABLE I We can see that eight concepts were evaluated against the existing process. The top two in each category will be evaluated in the weighted matrix.

**TABLE I: CONCEPT SCREENING.**

| | Concepts | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Trim Method | | | | Restraint Method | | | | |
| Selection Criteria | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Current |
| Low Cost | 8 | 4 | 8 | 3 | 4 | 3 | 7 | 3 | 5 |
| Repeatability | 4 | 6 | 6 | 3 | 5 | 6 | 6 | 8 | 3 |
| Safety | 6 | 5 | 7 | 4 | 5 | 6 | 6 | 7 | 3 |
| Ergonomics | 6 | 6 | 8 | 5 | 5 | 5 | 6 | 7 | 5 |
| Quality | 5 | 5 | 6 | 6 | 5 | 4 | 6 | 6 | 3 |
| Fixture | 5 | 7 | 6 | 5 | 6 | 8 | 6 | 8 | 3 |
| Layout | 7 | 5 | 8 | 4 | 6 | 5 | 4 | 5 | 3 |
| Setup Time | 4 | 4 | 4 | 3 | 6 | 6 | 5 | 5 | 5 |
| Cycle Time | 5 | 4 | 7 | 3 | 6 | 6 | 5 | 5 | 5 |
| Ease of use | 4 | 5 | 6 | 2 | 5 | 5 | 4 | 4 | 5 |
| **Net Score** | 54 | 51 | 66 | 38 | 53 | 54 | 55 | 58 | 40 |
| **Rank** | 2 | 3 | 1 | 4 | 4 | 3 | 2 | 1 | 8 |
| **Continue** | Yes | No | Yes | No | No | No | Yes | Yes | No |

The two top concepts in each category were selected and evaluated against each other. Trim Process, and Restraint Method. We can see that the Concept three: Slide Guide and the Figure 8: Foam Insert.

Concept eight: Vacuum , are the best choice for this project when the weighted rankings of selection criteria were applied.

**TABLE II: WEIGHTED EVALUATION MATRIX.**

| | | Trim Method | | | | Restraint Method | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Concept 1 | | Concept 3 | | Concept 7 | | Concept 8 | |
| Selection Criteria | Weight % | Rating | Weighted Score | Rating | Weighted Score | Rating | Weighted Score | Rating | Weighted Score |
| Low Cost | 0.16 | 8 | 1.28 | 8 | 1.28 | 7 | 1.12 | 3 | 0.48 |
| Repeatability | 0.14 | 4 | 0.42 | 6 | 0.84 | 6 | 0.84 | 8 | 1.12 |
| Safety | 0.13 | 6 | 0.52 | 7 | 0.52 | 6 | 0.78 | 7 | 0.91 |
| Ergonomics | 0.12 | 6 | 0.72 | 8 | 0.96 | 6 | 0.72 | 7 | 0.84 |
| Quality | 0.1 | 5 | 0.50 | 6 | 0.60 | 6 | 0.60 | 6 | 0.60 |
| Fixture | 0.09 | 5 | 0.45 | 6 | 0.54 | 6 | 0.54 | 8 | 0.72 |
| Layout | 0.08 | 7 | 0.56 | 8 | 0.64 | 4 | 0.32 | 5 | 0.40 |
| Setup Time | 0.07 | 4 | 0.28 | 4 | 0.28 | 5 | 0.35 | 5 | 0.35 |
| Cycle Time | 0.06 | 5 | 0.30 | 7 | 0.42 | 5 | 0.30 | 5 | 0.30 |
| Ease | 0.05 | 4 | 0.20 | 6 | 0.30 | 4 | 0.20 | 4 | 0.20 |
| **Total Score** | **1** | **54** | **5.23** | **66** | **6.38** | 55 | **5.77** | **58** | **5.92** |
| | **Rank** | 2 | | 1 | | 2 | | 1 | |
| | **Continue** | No | | Yes | | No | | Yes | |

## 3.6. QUALITY FUNCTION DEPLOYMENT

The quality function deployment (QFD), is a systematic approach to product development which captures:

1. Voice of customer.
2. Interactions of metrics.
3. Importance of criteria.
4. Benchmarking.
5. Metrics.
6. Etc.
7. Targets.

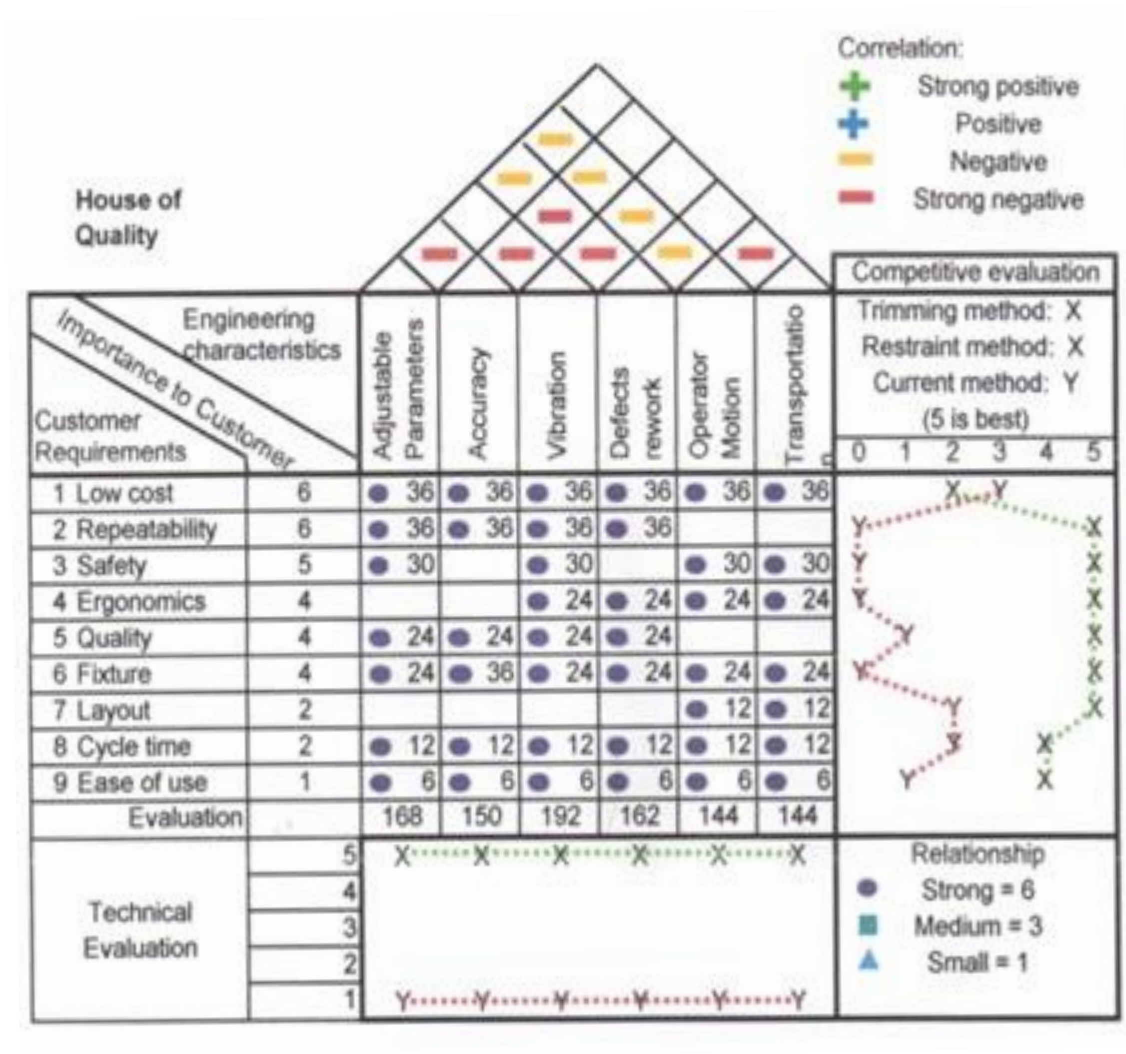


**Figure 10: Quality Functional Deployment (QFD).**

## 3.7. CONCEPT SELECTION

From the scoring and screening process, it is clear that the vacuum table and the slide guide were ranked the highest in their respective methods. The group had originally thought that the vacuum table would be too expensive to implement but the benefits outweigh the initial cost. The preferred hold down method initially was the foam insert with the metal edges but the detriments outweighed the ease of repeatability which the group thought would win out. The slide guide was thought to be the best choice of the trim processes. The scoring confirmed the group's thoughts.

Going forward, the team plans to use the vacuum table and the slide guide for the final design. As stated in the concept generation, the formal and finalized trimming processes will include these two methods. The final report will include a detailed model involving these two methods that were generated conceptually and scored against other competing methods

# 4. CONCEPT DESIGN OUTCOME

In the concept design outcome, the engineering design team eight has subdivided this section in: Summary of Problem, Conclusion, which is listed below in further detail.

## 4.1. SUMMARY OF PROBLEM

To reiterate EMTEQ has tasked us with developing a tool that is low-cost, with a greater degree of accuracy than the existing process in anticipation of an increase in current production. The existing manual panel trim procedure, EMTEQ has encountered quality issues in maintaining thickness uniformity during the trimming process. The resulting design should provide a hand cutting fixture that doesn't rely on large equipment with long set-up times which will help facilitate their anticipated increase in production. EMTEQ has emphasized that in addition to the resulting concept being low-cost it should utilize a hand held cutting operation. All the details of the design must be illustrated and justified. The concept design must be strong enough that EMTEQ can use for implementation without having to fill any major gaps. The concept must be able to be adapted to a wide range of panel shapes ranging in size from 1x2 feet to 14x3 feet. Equipment and process design make up the bulk of this project.

## 4.2. CONCLUSION

In conclusion, the Engineering design team eight deemed that the final design will be subdivided into two sections:

- Trim Process.
- Restraint Method.

The concepts developed in Concept Analysis, were weighted against each other using: Screening and Scoring, Quality function deployment. These methods were weighted against criteria modeled after the customer's needs.  The resulting final design concept for the trimming process for a composite panel required by EMTEQ was a vacuum table which is used for the second subdivision of the process, which is Restraint Method and with the incorporation of the slide guide to the vacuum table, which will suffice the first subdivision of the trimming process which is Trim Process. In theory, the panels would be held down by using the vacuum table and trimmed with the current tool the operator uses, but attached to the slide guide, which is incorporated to the vacuum table. The final report will have a detailed model that involves a vacuum table and slide guide.

# 5. REFERENCES

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