Development Log Report

Course Title **: New Product Development**

Course Number **: EMGT 547/647 NPD**

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Report No.:
Type: Project Report
Note:

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Introduction

The report captures the development process that our team followed durin g the course of the New Product Development class. The layout of the report has been created aligned with the various stages that our team and the concept idea went through. We have also captured key learnings for us for the major stages where applicable.

Team Formation and Idea Generation

Our project team, "team 2" formed in class. Within a week, we had a Google group created, weekly meeting logistics decided and agreed upon. All of us agreed on meeting face-to-face at least once a week and commuicating over emails the rest of the week. We met every Friday @6 pm at the PSU Library. There were few weeks where we met on other days during the week too.

In the first week each member came up with ideas and posted on email. We had a total of 10 ideas proposed. Team used quick votes to eliminate the more complex ones keeping in mind the 10 week constraint of the class. We selected a team leader and expectations were set within the team project context. In the idea generation stage, we had 5 product ideas that the team selected for further discussion (Refer to Appendix A). We presented the same in class for Presentation I.

The team had to select one of the five ideas for development and decided to use a survey. It was decided that each of us send it to at least 2 people asking them to rank the ideas from 1 through 5 (1 being the product they like the most, or would most like to buy). The survery was created on SurveryMonkey.com and everyone took the survey themselves and sent it out to minimum 2 other persons. A minimum of 21 entries expected ranking the products from 1 to 5 with 1 being the most useful and 5 being the least. We received 24 votes and here is the result of the survery.

	Prod#1	Prod#2	Prod#3	Prod#4	Prod#5	Response Count
Really Love it (1)	39.1% (9)	17.4% (4)	21.7% (5)	0.0% (0)	21.7% (5)	23
Love it (2)	8.7% (2)	30.4% (7)	26.1% (6)	8.7% (2)	26.1% (6)	23
Like it (3)	30.4% (7)	30.4% (7)	26.1% (6)	4.3% (1)	8.7% (2)	23
Kinda Like it (4)	17.4% (4)	21.7% (5)	8.7% (2)	26.1% (6)	26.1% (6)	23
It's okay (5)	4.2%(1)	16.7% (4)	8.3% (2)	50.0% (12)	20.8% (5)	24

Project 1, the product idea to address the problem of carrying/pulling multiple suitcases when travelling in airplanes, was the top pick in the survey.

Product Planning

As the pre-project planning phase, the team decided to be the "PDX Travel Company", a company which specializes in innovative luggage design and travel accessories for domestic and international travelers. The team worked during that week's meeting to come up with the 'Mission Statement' for our product idea, identified our primary and secondary markets as captured below.

The mission of our project is to create an attachment that can connect multiple pieces of luggage into "one" for easier pulling while traveling. Our primary market is that of domestic & international travelers and our secondary market consists of students and salespeople. Given the product idea, here are some of our assumptions and identified risks.

Assumptions

- Most people who fly don't get help from family/friends for drop off
- Bags can be bundled together as needed, on top of each other, one hanging from other

Risks

- If the carts are available for free …
- If luggage manufacturers provide means to connect bags

Key Learnings

This stage of pre-project planning and going through the exercise of defining our mission helped clarify the goal of the project. It brought everyone in the team to a common understanding of what it is that we are trying to build. At the later stages of the project, we kept coming back to the mission statement to keep us on track so that we deliver what we set out to at the outset.

Identifying Customer Needs

The first step was gathering customer data. Our team used two methods to gather raw data from the customers and then noted down these statements for further analysis.

1. Customer Interviews to establish the need
2. Photographing and interviewing travelers at the airport (Appendix J)

For the first method we each interviewed at least 2 potential travelers who carry heavy luggage during their travel, based on a set of guiding questions for a total of 18 customer interviews. Appendix B captures our Customer Survey Questionnaire guide.

Customers Voices to Needs

Based on our interviews and observations we collected all the customer voices. As a team, we removed any redundant voices to get a more concise list of needs. After that, we "Affinitized" the voices – grouping similar needs together. Finally we divided the need statements into 3 categories - Functional (What the product must do?), Non-functional (How the product looks/feels?) and Product constraints (What are the limits?). Appendix C captures all. Below are few examples.

- Functional
  - "It would be nice if my carry-on hooked on to my suitcase in a way that it wouldn't fall off"
  - "Two suitcases don't fit through doors while pulling with two hands"
- Non-functional
  - "All luggages look the same, I hate it."
  - "It should not be clumsy to use or look ugly."
- Product limitations
  - "The cost of $10-$20 should be fine."

    "They don't have bellhops everywhere"

Next we converted need statements to both measurable needs and subjective needs.

"It would be nice to pull two bags with one hand - so that I can hold my ticket, boarding pass or a cup of coffee in the other hand"

- **The product allows handling of multiple bags in one hand.**

"I try to balance the laptop bag on my suitcase to pull them together and it falls off when I turn or go over a bump"

- **The product keeps the pieces of luggage together to be dragged from parking to check-in counter without falling apart.**

"Those lines are all zig zaggy and thin, so when i have two bags I'm rolling, it's hard to make 90 degree turns and the way they're zig zagging requires me to make two ninety degree turns and I end up tripping because I have to have one hand in front of the other and its weird"

- **The product helps the luggage move smoothly while taking turns.**

Establishing Target Specifications

Our team developed target specifications based on the customer needs statements. An example of the target specifications spreadsheet is found below. Appendix D shows the Needs-Matrix that our team created.

Metric No.	Need Nos.		Imp	Units
1	6	The product allows handling of multiple bags in one hand.	1	inch x inch x inch
2	1	The product keeps the pieces of luggage together to be dragged from parking to check-in counter without falling apart.	1	feet
3	9	The product helps the luggage move smoothly while taking turns.	1	degrees/lb/sec
4	16	The product takes couple of minutes to set up without special instructions	2	minutes
5	12	The product is adjustible to cover from allowed cabin bag sizes to largest checkin bags.	2	inch x inch x inch

Key Learnings

While gathering raw data from the customer we had two key learnings. First, gathering data from multiple sources (airport interviews, outside interviews, photos), provided us with a much richer set of data, including things we would not have thought of on our own. Secondly, there are diminishing returns on raw customer data, because after we got about half way through all of our raw data we did not gain many new insights – most of the needs were captured in the first half of the data set.

Converting the customer voices into needs was one of our most challenging tasks. Using the examples given in the book and in class was very helpful – but it still took us multiple meetings and email coordination to agree on this translation among the team. This is one of the most important steps of the process, because if the needs aren't correct, your entire basis for a product is wrong, so it makes sense that this would be one of the most challenging steps.

The team found the process recommended by the book helpful but it was difficult coming up with the exact specifications. More than likely this was due to team members working out of their functions. Our guess is that if this were a real product development project, team members would have a better feel for the target specifications since they would have expertise in the needed project function.

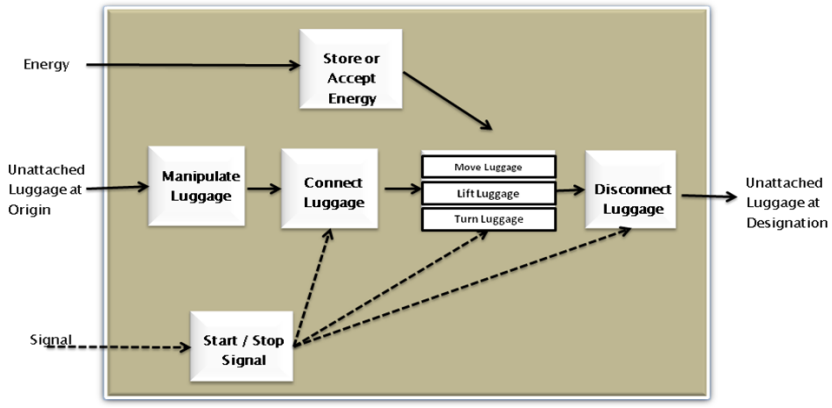
Concept Generation

The very first abstract synopsis of the new product is called product idea and a more detailed description of it is usually called product concept. Ulrich defined product concept as a description of technology, working principle and form of the product. Our product concept is based upon the customer needs and target specifications. For the team project we followed the Five Step Methodology described in the text book. For concept generation we conducted surveys, extensive brainstorming, and interviews with frequent travelers and visits to the airport to observe passengers commuting with multiple pieces of luggage. Benchmarking of the existing products and patents

searches were also conducted before concept generation. Finally six product concepts were developed and subsequently one concept was selected. (Appendix F)

Problem Clarification

After understanding the customer needs and establishing the target specifications of the product, we were able to clarify the problem. Customers needs and target specifications have already been mentioned in this development log. We developed the function diagram of the product (luggage attachment). Functional diagram is a useful tool to decompose large problems into smaller sub-problems. We think that functional diagram is highly useful tool especially for complex products. It also helps in clustering the multiple parts into chunks. Moreover functional diagram also facilitates developing a concept combination table. Though our product is really simple but for the sake of exercise we developed the function diagram. The box operating on energy (for pushing the luggage), material (luggage) and signal (to connect, maneuver and disconnect the luggage) is shown below in the function diagram. The solid lines indicate the transfer of energy and material and dotted lines indicates the control signal. In case of complex product each element of the function diagram can also be sub-functions. However since our product is very simple therefore further breakdown of function diagram is not appropriate.



Function Diagram

Benchmarking and Patent Analysis

Study of the existing product having similar functionality is called benchmarking. At the time of idea generation we envisaged that of our proposed product for NPD project is based upon a unique concept and there will not be any similar product existing in the market. However after research we found out two similar products in the market - Air-Porter: Adjustable straps and Clubglove: Luggage

set. Though these products are not very similar to our product but it was useful to review these products and evaluate their strengths and weaknesses.

Ref: http://www.air-porter.com/index.html

Air Porter: Adjustable Straps

Strengths:

- Strapping system
- Adjustable (22" to 30")
- Very light weight
- Easy To Maneuver
- Convenient & easy to Use

Weakness:

- Cannot attach two suitcases /large roller bags
- Attaches with four Buckles
- Price is very high i.e. $ 75

Ref: http://www.clubglove.com/user/Train-Reaction.asp

Clubglove: West Coast Trends Inc

Strengths:

- Can handle large bags
- Luggage Set of two or three bags
- Train Reaction

Weaknesses:

- Cannot be used with other types of bags
- Customer have to buy three new bags

- Just use handle / strap to hookup the bags together
- Not securely attached and poor balancing
- Price range $ 650 - $800

Patents Search:

Patents are also a good source of information containing basic information and technical details. During research a patent similar product named as Luggage connector and Transport Aid (Patent application # 20070164067) was found. Its details are attached as Appendix E. Strengths and weaknesses of Luggage Connector and Transport Aid are:

Strengths:

- Simple product (consisting of a cylindrical rod made of plastic)
- Can connect bags of different make and sizes
- Easy to use
- Can facilitate conveying one piece of luggage with both hands free

Weaknesses:

- Not a good arrangement for two pieces of luggage
- Usefulness in case of two pieces is not clear
- Not a tested product

Concept Combination Table

After we created the functional diagram which shows the product system, we divided this system into a set of sub-systems as follows - Store or accept energy, Manipulate luggage, Connect luggage, Move luggage, Disconnect luggage and Start/ stop move signal. The team decided to brainstorm what possible ideas could fit in each sub-system even if they were imaginary but at least possible.

Based on the function diagram modules, the team created the concept combination table as shown in Appendix H. After we created brainstorming table, we had to connect the logical combination that would help us to figure out how our product would look. We removed the obvious and absurd combinations which seemed impractical and infeasible within the 10 weeks. This exercise helped us in coming up with various concept ideas.

Concept Selection

We used “Multivoting” along with “Decision matrix” method to choose a single concept for final production. As suggested in the textbook, we followed a two stage concept selection methodology – concept screening and concept scoring.

Initial Concept Screening

We had six concepts during the concept generation process. We picked 11 criteria selected from the top customer needs. There is no product available in the market that could have been compared directly feature by feature with our concepts, so for simplification purposes and we chose one of our concepts to be the reference concept. All seven of our team members rated five other concepts against the reference concepts on each listed criterion. A score of +1 meant the concept being rated does better on the given criterion when compared to the reference concept. A score of 0 would mean no difference and a score of -1 would mean worse off. All criteria is assumed to have equal weight. Due to the discrete scoring method the scores can not be averaged so the score with a majority was taken. After collating the results we discarded 1 concept as it was scored very low (Concept D). We decided to combine two concepts (Concepts C and E) as they received the same score during the process. So we moved with 4 concepts (A, B, CE and F) to the next phase of concept selection. Appendix P shows the concept screening spreadsheet data.

Concept Scoring

In concept screening stage all the customer needs that are used as selection criteria are assumed to have equal weight. In this stage customer need priorities are given weights. In this stage instead of discrete scoring a continuous scoring of 1 to 5 us used where 3 is the reference score, 5 is the best and 1 is the worst. In this step different concepts can be selected to serve as reference concepts for different criterion. Once a reference concept is chosen for a given criterion other concepts are scored accordingly. After collecting votes from all six members an weighted average was taken and two concepts were scored really close. We decided to keep both concepts and make a decision by doing another round of survey and comparing ease of manufacturing parameters. Appendix P shows the concept scoring data.

Concept Testing

The concept scoring table showed that the slide lock concept scored the highest number (3.09) and Spider wrap came in the second rank and scored 2.925. Because these two numbers were the highest and so close compared to the other concepts we were a little confused about which concept we should go with. As a team we decided to conduct a survey for both of the concepts to remove the ambiguity in the selection of the product. Conducting a survey would give us a clearer picture of what customers would like. This was a very important aspect to us because, at the end, they would be the consumers of our product.

Team took 2 concepts for survey - Concept 1(Sliding Lock) and Concept 2(Spider Wrap), with product offerings being - Allows for one-hand maneuvering, Ease of use, Portability and Cost. First of all, we conducted a survey at Portland Airport because we thought it would be where people really need this kind of product. However, we got and insufficient amount respondents to make the final judgment. Next, we decided to conduct another survey in our class and with some other friends.

Team decided to defer picking one concept over the other to a later stage – based on cost and ease of manufacturing. Appendix G shows the concept test survey that the team created for the products.

Results of survey for concept 1:

Sample size ~ 16

Most probably would buy = 9

Definitely would buy = 0

Results of survey for concept 2:

Sample size ~ 8

Most probably would buy = 2

Definitely would buy = 2

Results

Let, Q = Quantity of product expected to be sold during a time period

N = Number of Potential Customers expected to make a purchase

A = Fraction of this customer base for which product is available and customer is aware

P = Probability that the product is purchased if available and awareness is there

P = Cdefinitely X Fdefinitely + Cprobably X Fprobably

(We assumed Cdefinitely = 0.4, Cprobably=0.2 from book example)

P (Concept 1) = 0.4 x (0/16) + 0.2 x (9/16) = 0.1125

P (Concept 2) = 0.4 x (2/8) + 0.2 x (2/8) = 0.15

Number of air travellers inside US (as of June 2007) = 640~660M (million)

[Source: http://www.transtats.bts.gov/]

About 75% seem to travel light or carry less than 2 bags and dont want to spend extra bucks for any attachment.

Our potential customer base N = 25% of 640 M = 160 M

Q = N * A * P

Assuming 10% of travell accessory sales happen through SkyMall or airport travel shops, A = 0.1

Q (Concept 1)= 160M * 0.1 * 0.1125 = 1.8M units/yr

Q (Concept 2)= 160M * 0.1 * 0.15 = 2.4M units/yr

Key Learnings

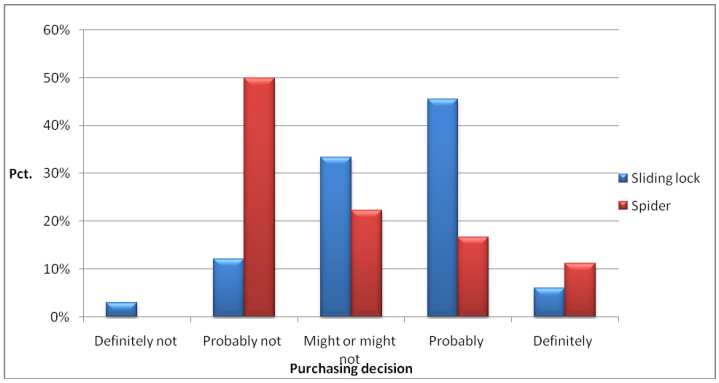
Concept screening method provided a structured way of picking good concepts. Our observation was that if open voting/scoring was allowed, late respondents seems to be get biased by previous respondents. Also individuals seem to have prejudiced view at some point of time as the criteria were not objective all the time.

The concept scoring method can help designers identify the strengths and weaknesses of alternative designs; and, by combining of the advantages of different designs, a designer can achieve an improved design. Concept scoring method relies heavily on biased personal judgements in both weighting and scoring. The concept scoring method is easier to use, because it is easy to determine the advantages and disadvantages of designs in achieving the design requirements.

We also observed that a concept can be top ranked in the concept screening method while it can be raked high in the concept scoring method. In our case, the 'Sliding Lock' concept was ranked 3rd in screening matrix but ranked 1st in concept scoring matrix.

Product Architecture

To zero-in on one concept, the team surveyed the class. The information obtained from the survey was helpful and allowed us to narrow down our selection. The chart below shows the complete survey results for the final two concepts from both the general survey and the class survey.



Survey Summary

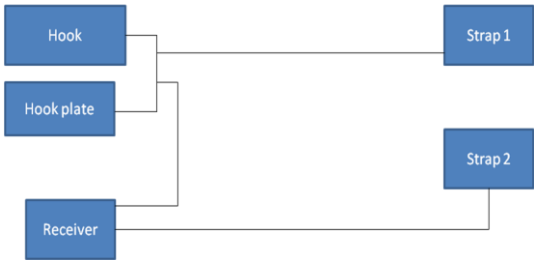
In addition to the survey, we performed a side by side cursory manufacturability comparison, found in the chart shown in Appendix O, for the final two concepts. This along with the survey

results allowed us to make our final selection, the sliding lock. We also searched for a complementary product. The straps shown below are the ones we selected.

Dongguan Chenglian Gifts & Arts Co., Ltd.
http://www.made-in-china.com/showroom/dgchenglian/product-detaildqPQYnfVgLWw/China-Luggage-Belt-CL-044-.html

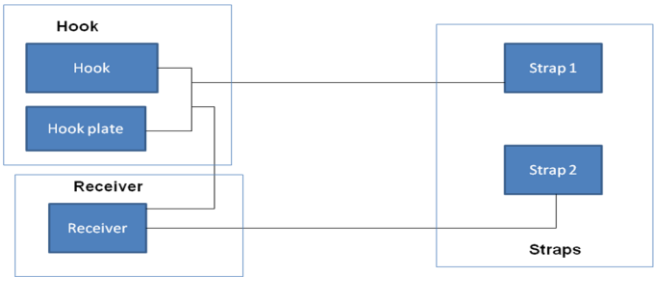
Establishing the Architecture

We created the product architecture schematic shown in the figure below and found that the tool was not the most useful for such as simple product. If the product had been more complex, then we feel the tool would have been very beneficial.



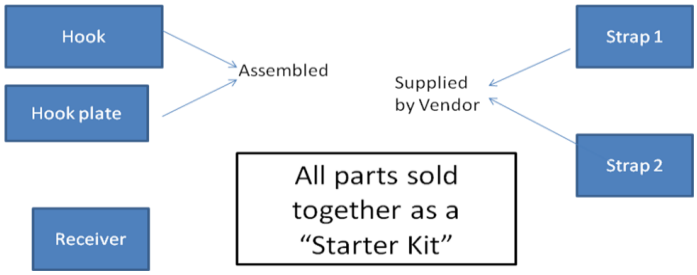
Product Architecture Schematic

We used the product architecture schematic to separate the functions into “chunks” or clusters. The “chunks” were identified as the hook, receiver, and straps. This figure is shown below. Again, the tool was not the most useful.



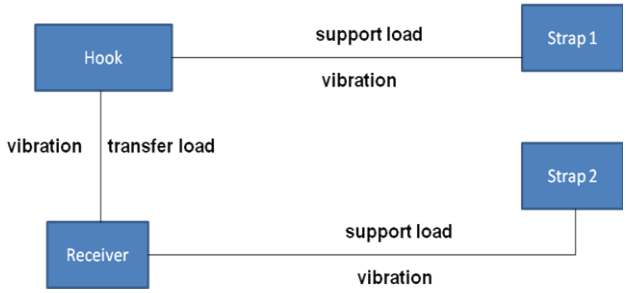
Product Architecture “Chunks” Schematic

After the chunks were identified, we concluded that the design is slot modular since the pieces fit tigether in one particular way (see the figure below). The Hook and Hook Plate can be assembled together and the straps will be supplied by an outside vendor. We will design the Hook and Receiver to be compatible with the majority of straps on the market.



Slot Modularity

Interactions were generated for the product design. These can be seen in the figure below. This tool was very useful in defining the support and transfer loads as well as highlighting the vibration in the system. We will have these interactions in mind as we further define the product.



Interactions

Platform Planning

For platform planning, the team decided to keep the following usage patterns in mind:

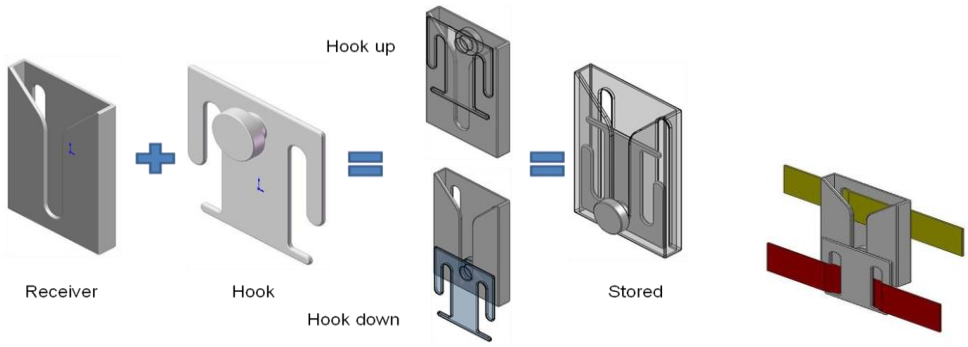
1. Multiple attachments – use outside of airports.
2. Variety of hooks to handle hand carried, compact size and shape of luggage. E.g., Computer bag, contact lens pouch, toiletry bag etc.
3. Variety of products/attachments going with the strap.

Technical Analysis

Geometric Layout

We constructed a geometric layout of the design as seen in the figure below. As stated in the product schematic section, we will be manufacturing the product in three pieces: the hook plate, the

knob, and the receiver plate. The knob and the hook plate will be assembled together. When in use, the hook plate will slide into the receiver plate and straps will be interwoven into the arms of the hook plate and receiver plate. The geometric layout was helpful in the product design process.



Appendix K shows the control drawings for the various components of the product.

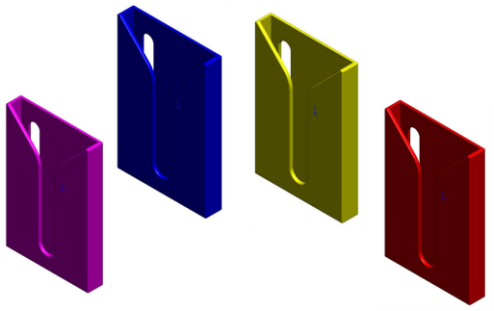
Engineering Trade-offs

It was a difficult decision for the team to decide which of the target needs to implement and which ones to drop, given the time and resource constraint. We had to decide on the engineering trade-offs that we needed to do. One of the requirements was for the product to be light-weight and compact so that it can be carried in a carry-on luggage on an airplane without adding extra weight and without taking up a lot of space. Another requirement was for the attachment to be strong so that it does not break while wheeling the attached luggages. Both of these needs will dictate the kind of material we choose to build the attachment, which resulted in a trade-off for the product – strong and stable versus light weight and compact. Appendix N captures the team's assessment on technical and manufacturing needs based on selected material.

Assess the Need for Industrial Design and its Impact

There are a few areas in which industrial design impacts our product. The most important aspects of this for our product are ease of use, usefulness, safety, compliance to TSA standards, and aesthetics. Ease of use is particularly important since it was one of our customer needs – this product is used in high stress and time sensitive situations, so if it is difficult to use it will not be a useful product. In addition, since it is attached to people's luggage, it is important that it be attractive in both shape and color, and safe to avoid injury. Obviously, since the product will be used in airports it must be TSA compliant.

Needs	Level of Importance (High, Medium, Low)
Ease of Use	High
Usefulness	High
Compactness of Product	Medium
Durability	Medium
Safety (secure connection)	High
Compliance to TSA standards	High
Product Aesthetics (product should not look clumsy)	High



Design Refinements

During the concept testing, many customers gave valuable feedback to refine our product. Customer also raised some important concerns related to our product during the concept testing. Some important customers' feedback / concerns and action taken by us are summarized below:

- The product should be compact (reduce the size / volume of the product)
- Product should be light weight (based upon this primary requirement it was decided that finally the product will be made of plastic material).
- Product should be able to bear weight of two heavy bags (Finite Element Analysis (FEA) was conducted to observe stress at the critical points and later on due to higher strength ABS plastic material has been selected).
- Both pieces of the luggage should be balanced properly (based upon this primary requirement and initial testing of the physical prototype, design was modified and two steel balls were used to ensure better stability and balancing as shown in the physical prototype).

Some other important customer inputs that resulted in product design refinement are mentioned in Appendix R.

Key learnings

Product architecture represents both functional and physical elements of the product. It helps to divide the product into "chunks" or clusters and facilitates deciding about other issues like product modularity and part standardization. Although our product is very simple but still we are able to identify three chunks i.e. the hook, receiver, and straps. Creating product architecture was important because due the following reasons:

- Drawing the schematics of the products indicating functional and physical elements as well as follow of energy, material and signals.
- Defining interactions and their impact on design.
- Clustering the elements into "chunks"
- Decompose problem into smaller sub-problems and developed schematic of sub-systems of the product.
- Product platform development which allows us to subsequently launch a variety of products
- Customer inputs and prototype testing facilitates the designers to refine the product

Importance of Industrial Design:

It was not easy based on the information in our textbook how best to accomplish the industrial design for our product. Based on the feedback of our third presentation we decided to revisit this idea and do an additional assessment of our product's industrial design – including how well we met our key industrial design goals, such as ease of use, aesthetics, and safety. We also took a closer look at the types of straps we want to sell with our product, since the industrial design of the straps will affect the way our product is perceived when sold as a package.

Importance of Engineering Trade-offs:

FAA and TSA Compliance and material selection

Design for Manufacturing

The group researched and studied two different materials and the manufacturing processes associated with it. The two materials selected were metal (Aluminum 6061) and plastic (High impact ABS). We compared the parameters between the two materials with the products functionality and customer needs in mind. Some of the data can be seen on the engineering trade-off table. The manufacturing process for metal and plastic was laid out (Appendix S) and cost of manufacturing was calculated using the formula:

$$\text{Total unit cost} = \frac{\text{Set-up cost} + \text{Tooling cost}}{\text{Volume}} + \text{Variable cost}$$

Estimating Manufacturing Costs

Appendix T shows the cost of manufacturing for Aluminium and for ABS Plastic. After calculating the unit cost, plastic material was found to cost less to manufacture than metal. It also allowed us to integrate the hook with the hook plate thereby eliminating the need for assembly. Since

there is trade-off in material strength, the group initiated a test to verify strength of the plastic material. Appendix U captures the bill of materials for our product.

Prototyping

Since we did not have the physical proto-type on hand, the group decided to test a virtual proto-type utilizing finite element analysis (FEA) method to test the two parts, the receiver and the hook. The study showed the yield strength of the chosen plastic material as well as the shear points. Using a load 4 times the required load (lifting capacity); the FEA (Appendix V) showed that plastic material is sufficient enough to handle the load. These were the basis for our selection of the ABS plastic. Our team is also planning to submit a provisional patent application form.

Economic Analysis

An economic analysis was performed using the example spreadsheet from the textbook. NPV was calculated using a MARR value of 10%. A sensitivity analysis was performed where Unit Sale, Unit Price and Product Cost were varied along with a trade-off comparison between the two selected materials: aluminum and ABS plastic. The NPV for ABS plastic showed a higher NPV even though the initial tooling costs were higher. The full spreadsheet can be seen in Appendix Q.

Conclusion

During this exercise, what our team found out was that theory differs from practice. We were not able to apply all the book's methods to a real new product development process. A key learning was that "Everything is based on customer needs". The team must ask the customer what they want. Sometimes they do NOT want the same thing you think they want. So it is important to ask. Also, it's very important to remain open-minded. If the team gets stuck on a solution, it misses opportunities! There is a high value in having a "cross functional" team.

What worked for us?

- Survey to determine initial concept
- Gathering customer data with interviews & pictures
- Creating the function diagram to brainstorm concept ideas
- Concept Screening Matrix
- Concept Selection Matrix
- 2nd Airport visit for concept surveys

- NPV Spreadsheet
- Bill of Materials Example

What did not?

- Unable to find a good way to evaluate engineering trade-offs
- Unable to find a good way to examine industrial design needs
- Had trouble identifying units for target specs and ways to measure all product needs
- Some people got very attached to their concepts ;)

Appendix A – NPD Product Ideas

Prod#1: An attachment that can connect two roller suitcases into "one" for easier pulling while traveling. Imagine yourself at airport logging two heavy bags in both hands - this attachment will help you use just one hand.

Prod#2: A soda/water cup holder attachment for trays to avoid spilling. Particularly useful in cafeterias with flat trays, since balancing a full cup on one of those trays is not easy. ;) - Just think of not being forced to walk in baby steps while balancing the soda.

Prod#3: "Book Arms" - a holder for your book so when you're lying on a bed or couch you don't have to use your hands. Imagine reading a novel and pages keep flipping and hand gets tired after a while - what if you just need to use your hand only to flip a page when needed.

Prod#4: A multiple remote holder/caddy of some sort, that can be carried around and stored easily (for users who are not ready for a complex universal remote yet). May be hang them together on a wall when not in use.

Prod#5: Comfortable neck and head rest for use on an airplane that can be part of the seat or removable. Imagine waking up without any neck pain and not falling on to your neighbor during a long flight when you tried to catch some sleep.

Appendix B – Customer Survey Questionnaire Guide

Questionnaire rule - Open ended questions

1. Find out the demographic of the customers
    a. How frequently do you travel?
    b. Do they travel internationally, domestically
    c. Do they fly alone, family, with kids etc
    d. Do they fly economy, first class etc
    e. Do you face any difficulty with carrying any bags?
        i. How do you solve it today?
2. How do they get to the airport?
    a. MAX, cabs, own car
3. Do they have any problems collecting their bags from the baggage claim area?
4. Ask the Airport Transporation Authority on to the weight, size of the individual bags.
5. Any other complaints about your luggage

Appendix C – Customer Voices to Target Needs to Metrics

#	Assigned	Voice of the Customer	Customer Need statement
1	Tony	"I try to balance the laptop bag on my suitcase to pull them together and it falls off when I turn or go over a bump"	The product securely connects items together.
2	Tony	"It all falls over when I stop"	The product balances the luggage.
3		"They don't stand up on their own"	
4		"It would be nice if my carry-on hooked on to my suitcase in a way that it wouldn't fall off"	
5	Tony	"When I have two suitcases on long trips it's impossible to pull them both, especially on and off the max, and they crash into each other and fall over"	The product will bundle the luggage into one piece securely.
6		"Its really hard to wheel two things at a time, I'm usually tripping all over myself"	
7		"I don't have a third hand, so sometimes when I have a third bag, I have to stack a bag on the other bag that rolls and I can only move like two inches at a time without it falling off"	
8		"It would be nice if my carryon could securely latch on the suitcase"	
9		"It takes me multiple trips from the elevator to the check-in"	
10	Muhammed	"Two suitcases don't fit through doors side by side"	The product minimizes the luggage bundle.
11		It should work in the MAX bus and train stop and elevator doors.	
12		"My luggage never fits through the aisle of the plane and gets caught on the seats"	
13	Muhammed	"Two suitcases don't fit through doors side by side"	The product minimizes the luggage bundle.
14		It should work in the MAX bus and train stop and elevator doors.	
15		"My luggage never fits through the aisle of the plane and gets caught on the seats"	
17	Muhammed	"They came with straps to connect them but those broke off long ago"	The product is durable and rugged.
18		It should be durable and rugged (withstands wear and tear)	
19	?	It should facilitate handling of two bags with one hand (so that I can hold my ticket, boarding pass or a cup of coffee in the other hand)	The product allows handling of multiple bags in one hand.
20	Muhammed	"It's awkward when having my hands full of bags and I'm going through security, trying to get my ticket out"	The product allows hands free operation.
21	Dash	"I would prefer to be totally hands-free and not have to carry the carry-on"	
22	Dash	"I like wheels, I hate carrying things"	The product facilitates utilization of wheels.
23	Dash	"Those lines are all zig zaggy and thin, so when i have two bags I'm rolling, it's hard to make 90 degree turns and the way they're zig zagging requires me to make two ninety degree turns and I end up tripping because I have to have one hand in front of the other and its weird"	The product allows easy manuevering,
24	Mitali	"It sucks to lug it all up and down stairs"	The product allows easy manuerving in escalators and stairs.
25		"I had a little mishap on the escalator because my bags didn't roll off right"	

26	Mitali	"I'm often in a hurry to get in and out of the airport, and all my bags slow me down"	The product allows easy movement.
27 28	Mitali	"I bring different combinations of bags depending on the length/type of the trip" Not everyone travels with suitcases, may be soft bags.	The product works with different shapes, sizes and types.
29 30	Nayef	It should be small enough to take it in your carry-on. It should stay with the check in bag	The product is compact/portable.
31 32	Nayef	It should be extensible to latch more bags. Should allow attachment of a toy or 3rd soft bag or winter jacket.	The product allows to bundle multiple bags.
33	Nayef	It should take care of the weight.	The product works with light and heavy bags.
34	Robin	User friendly - easy to use - attaching and detaching should be easy.	The product is easy to setup.
35	Robin	Should be able to access contents of the bag even when attached.	The product allows easy access to the contents.

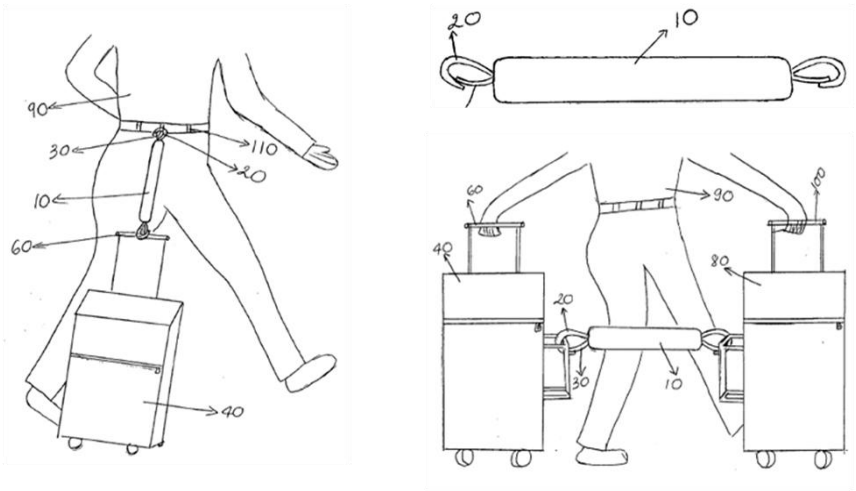
36	Robin	"I hate that my luggage clicks when going over cracks in the floor"	The product minimizes noise.
37	Erin	All luggages look the same, I hate it.	The product is distinguishable.
38	Erin	Tying a rope can be clumsy and does not look good.	The product is elegant and neat.
39		It should not be clumsy to use or look ugly.	
40	Erin	I don't care what material it is made of – it should just work.	The product is functional.
41	Mitali	"My arms hurt from pulling the suitcase"	The product is light and ergonomic.
42	Dash	The cost of $10-$20 should be fine.	The product is reasonably priced.
43		Air port officials should not object on the material.	The product material should be airport compliant.

Functional

#	Importance	Customer Need statement	Metric	Units
1	1	The product securely connects items together..	Force gauges to meausure secure connection	lbs
2	1	The product balances the luggage.	Perform a stability test	
3	1	The product will bundle the luggage into one piece securely.	Force gauges to meausure secure connection	lbs
4	3	The product minimizes the luggage bundle.	Volume measurement	$inches^3$
5	1	The product is durable.	stress test - number of cycles to failure	# of cycles
6	5	The product is rugged.	stress test - number of cycles to failure	# of cycles
7	3	The product allows handling of multiple bags in one hand.	Test for handling of multiple bags with one hand	Binary
8	5	The product allows hands free operation.	Test for hands free operation	Binary
9	3	The product facilitates utilization of wheels.	Test for use of wheels	Binary
10	1	The product allows easy manuevering,	Measure tunring radius	inches
11	2	The product allows easy handling on escalators	Test movement up & down stairs	distance
12	4	The product allows easy handling of bags up & down stairs.	Test movement up & down stairs	# of ateps
13	1	The product allows easy movement in a stright line	Deviation from a straight line	inches
14	3	The product works with different shapes	luggage shapes	duffle bag laptop, suitcases purse small carryon
15	3	The product works with different sizes	luggage sizes	duffle bag laptop, suitcases purse small carryon
16	3	The product works with different weights	Weight measurement	lbs
17	3	The product works with different types.	soft & hard luggage	duffle bag laptop, suitcases
18	1	The product is compact	Volume measurement	$inches^3$
19	1	The product is portable.	Meaurements of size & weight	inches & lbs
20	1	The product is easy to setup.	The time required to assemble/disassemble	seconds
21	5	The product allows easy access to the contents.	The time required to access bag contents	seconds
Non-functional				
22	5	The product minimizes noise.	sound level meter test	dB
23	5	The product is distinguishable.	appearance or color	subj
24	3	The product is elegant and neat.	coolness factor	subj
Product Limitations				
25	3	The product is light	total weight of the product	lbs
26	2	The product is ergonomic.	force gauges to meausure safety and health factors	ft-lbs
27	1	The product is reasonably priced.	Unit cost to manyfacturer	$
28	1	Air port officials should not object on the material.	TSA restrictions	Binary
Additional ones				
29	3	Product works at different terrain	road test for stability, vibration, wear	ft

Appendix D – Needs Metric Matrix

Appendix E – Luggage Connector and Transport Aid - US Patent Application Publication



Ref: United States Patent Application 20070164067,
http://www.freepatentsonline.com/y2007/0164067.html

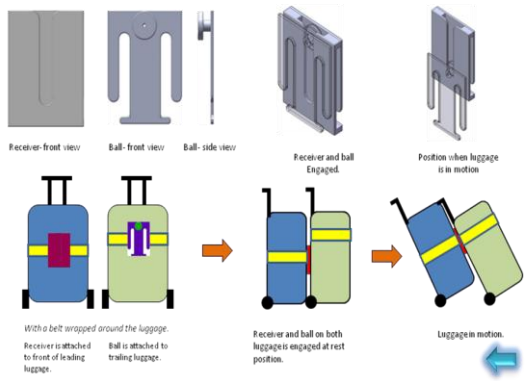
Patent: Luggage Connector and Transport Aid

Invented a connector

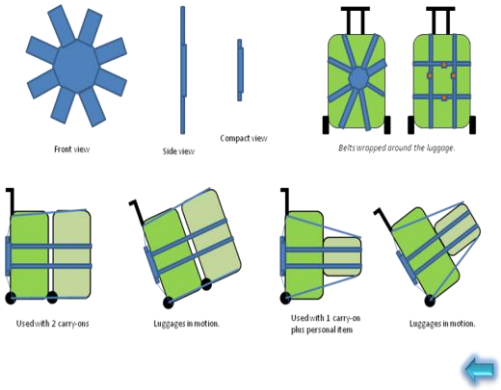
- Solid plastic cylindrical rod with hooks and latches
- To connect 2 pieces of wheeled, carry-on luggage
- To convey one piece luggage with both hands free
  - Other side connecting to the clothing of a passenger
- Good arrangement for one piece
- Not clear its usefulness in case of two bags
- Price not available

Appendix F – Concept Ideas

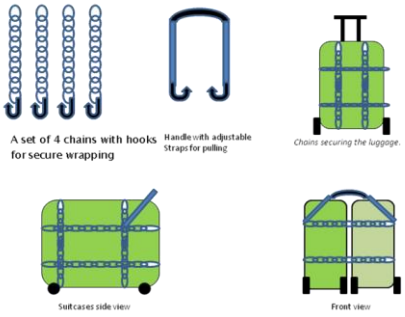
Concept A: Sliding Lock



Concept B – Spider Wrap

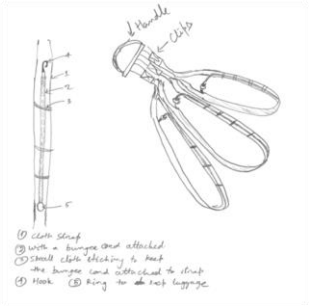


Concept C – Chain-Hook with Handle

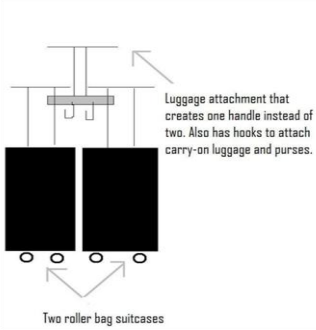


Concept D – Netting with Handle

Concept E – Bungee Cord Strap with Handle



Concept F – Snap-on Attachment with Hooks



- Plastic molded attachment snaps two handles together (gray box in diagram)
- Connecter has one handle for easy pulling
- Connector has two plastic hooks that allow the attachment of carry-on bags and/or purses.
- Assumptions: Two pieces of luggage with pull-out handles and wheels are used with at most two carry-ons.

Appendix G – Concept Test Surveys

Concept test survey – Attachment to bundle multiple luggage together

I am gathering information for an attachment to combine multiple luggages together to allow easy maneuvering of all combined luggage. I am hoping that you would be willing to share your opinions with me.

Do you travel frequently? _____

Do you carry multiple luggages when you travel? _____

How do currently move multiple luggages when traveling? _____

Do you travel with your family? _____

Product description:

<Concept Photo>

The spider-wrap is light-weight and compact so that it can be carried with your luggage. It connects two or more bags securely so that they can be pulled using one hand. The spider-wrap is easy to use: it has belts which extend to wrap around the luggages and has snap-on clips at the end of the belts which securely connects.

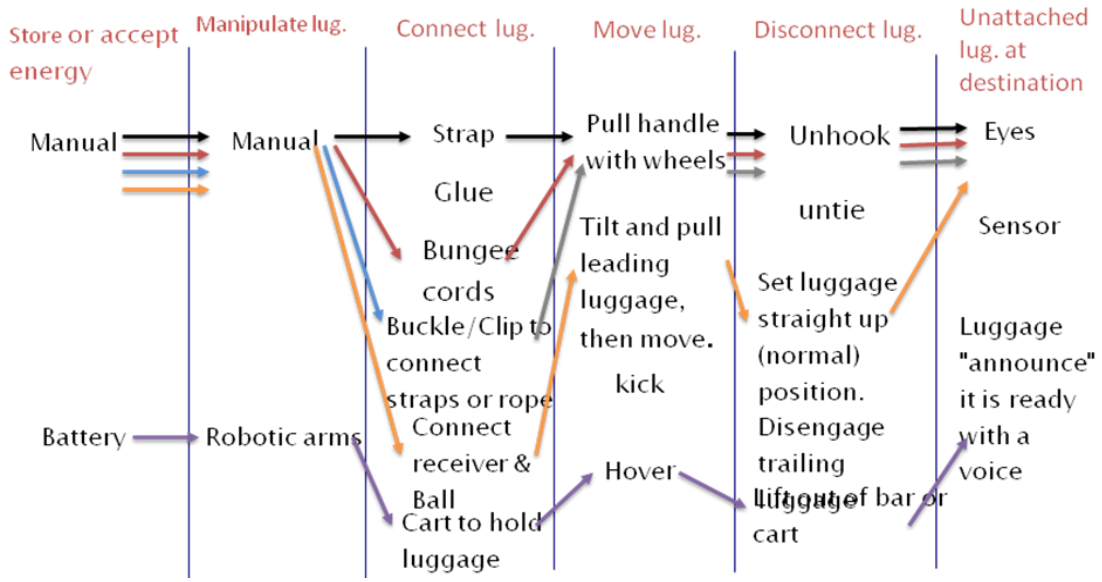
If the product were reasonably priced and is available in the market would, how likely would you purchase the luggage attachment within the next year?

I would **definitely not purchase** the attachment.	I would **probably not purchase** the attachment.	I **might or might not purchase** the attachment.	I would **probably purchase** the attachment.	I would **definitely purchase** the attachment.

What concerns do you have about this product concept?

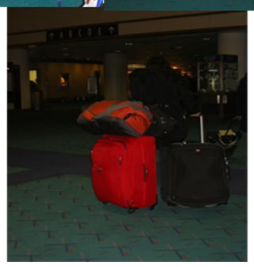
How might the product be improved?

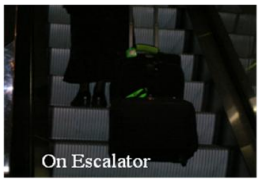
Appendix H – Concept Combinations



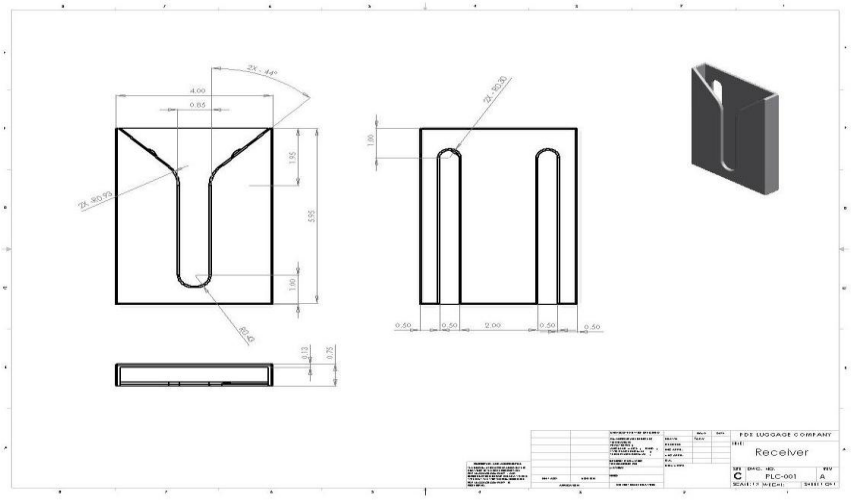
	Store or Accept Energy	Manipulate Luggage	Connect Luggage	Move Luggage	Disconnect Luggage	Start/Stop Move Signal
2						
3	Battery	Manual (hands)	strap	pull handle with wheels (seems like this is two separate problems?) The wheels and the pulling mechanism?	rip apart	Eyes (when is it connected
4	manual	robotic arms	duct tape	belt attachment	unsnap	Sensor
5			glue	push bundle	cut	Fits correctly into some kind of mold?
6			gum	push button (automatic)	untie	Luggage "announces" it is ready with a voice
7			rope	Hover	unhook	
8			big rubber band	kick	Lift out of bag or cart	
9			netting of some kind	drag with rope		
10			large bag to put everything in		Push button	
11			Velcro			
12			Bungee cords			
13			Cart to hold baggage			
14						
15			Buckle / Clip to connect the straps or rope		Lift the latch of the buckle to untie the straps / rope	
16			chains			Based upon personal judgment
17						
18		An absurd idea but luggages are programmed to get aligned and oriented themselves ;-) (intelligent luggages - iLuggage :))	magnetic buttons or patch on luggages by which they align and stay connected	Wheels of existing luggage	Separate the magetic alignments	Visual indication that all luggages are connected/disconnected
19			Indicator/Display that luggage is balanced. Is this a part of Connect Luggage or separate subsystem?	Additional wheels for luggages which do not have wheels	Take the rubber band apart	Click sound (audio indication) which notifies that luggages are connected/disconnected
20			A rod or board (plastic/wooden/metal) to which luggages get attached	Pivot-like part (to enable pushing or pulling the luggage in any direction)		
21			Voice-activated commands	Movable push handle to enable pushing in different directions	Voice-activated commands	
22				Voice-activated commands		
24	Manual	Manually (by hands)	Connect receiver and ball (not necessarily a ball). Receiver on leading luggage and ball on trailing luggage.	Tilt and pull leading luggage, then move.	Set luggage straight up (normal) position. Disengage trailing luggage.	

Appendix J – Airport Photographs

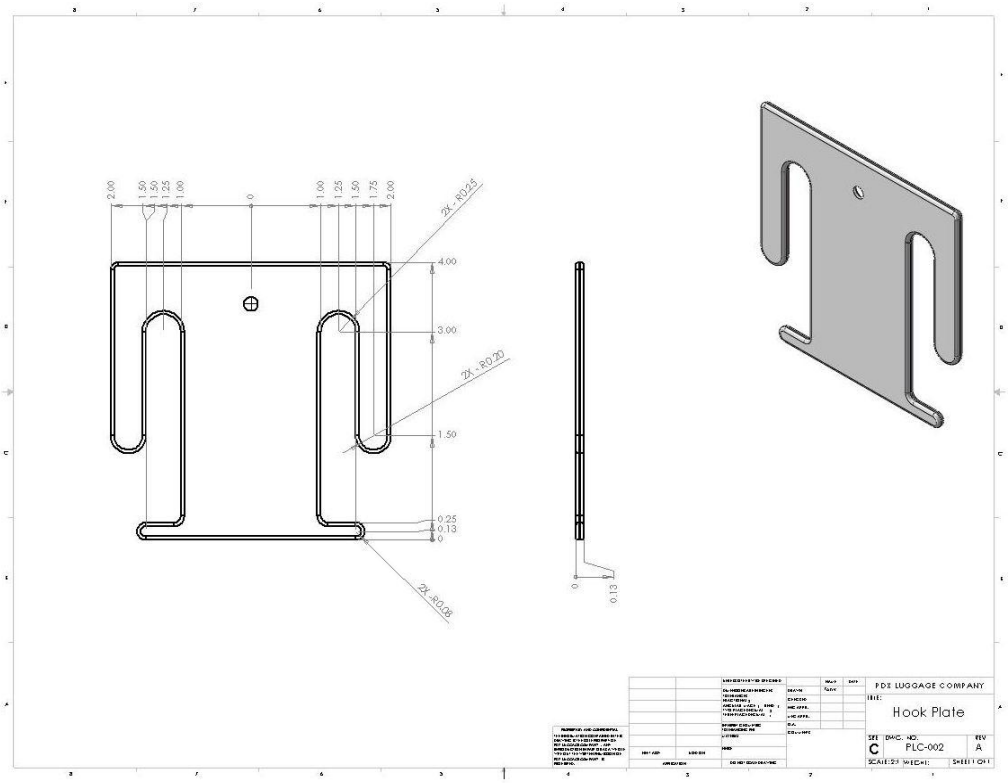




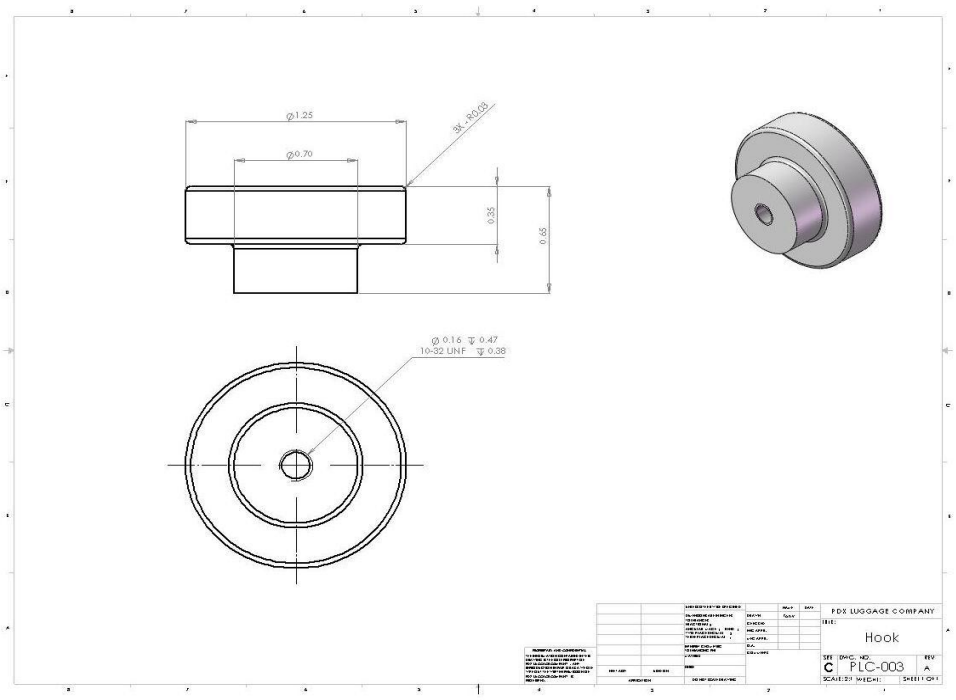
Appendix K – Control Drawings



Control Drawing-Receiver



Control Drawing-Hook Plate



Control Drawing – Hook

Appendix L – Customer Voices translated to Needs

Customer input	Translation	Addressed by
}"I am concerned about the stability - if it will hold the luggage together well."	Strength	Material
}"Product seems like a great idea"		
}"I am careful about the budget"	Cost	Material and manufacturing cost (COGS)
}"What kind of material will it be - will it hold for heavy luggage -	Strength	Material selection
}What about wear and tear and storage?"	Strength	Material selection
}"Would it damage my suitcase?"		Material selection
}"Is the mechanism removed after checking in the baggage - compatible }enough for storage?"	Portability	Design
}"Hang mounting fixture for bag on a handle - hence does not require }extra storage"	Portability	Design
}"The fixture might slide out under shock - add a firm lock device"	Function	Design
}"The receiver should be longer, so it would not disconnect while moving baggage"	Function	Design
}"How would you align two pieces of luggage. It depends on position of the strap. Have a release button to make hooking easier"	Design	Design
}"Other shaped devices can't be carried – do not use metal"	material	Material selection
}"It should be portable and light weight"	Portability	Material selection
}"How well the straps stay in place. Will the latch work when place vertically as well when pulling/angled or is adjustment required?"	Function	Design
}"Do I have to lift one case up to slide it in? How is it is to move to insert or remove?"	Function	Design
}"How secure is the belt"	Function	Design
}"Seems difficult to attach"	Function	Design

Appendix M – Airline Checked Baggage Allowances

Destinations	Free Baggage Acceptance	Baggage Requirements
50 United States, Puerto Rico, U.S. Virgin Islands - **Economy Class** **For customers who purchased tickets on or after April 9, 2008 through July 30, 2008**	1 checked bag	Maximum 50 lbs (23 kg) and 62 linear inches (157 cm) (total length + width + height)
50 United States, Puerto Rico, U.S. Virgin Islands - **Economy Class** **For customers who purchased tickets prior to April 9, 2008**	2 checked bags	Each bag at a maximum 50 lbs (23 kg) and 62 linear inches (157 cm) (total length + width + height)
Latin America (South America, Central America, the Caribbean, Bahamas, and Mexico), the Middle East, Africa, Europe, and Canada - **Economy Class**	2 checked bags	Each bag at a maximum 50 lbs (23 kg) and 62 linear inches (157 cm) (total length + width + height)
Tickets purchased in Brazil or purchased in Japan for travel to/from Brazil - **Economy Class**	2 checked bags	Each bag at a maximum 70 lbs (32 kg) and 62 linear inches (157 cm) (total length + width + height)
First Class, Business First, and International Business Class (on Delta and Delta Connection® flights only)	3 checked bags	Each bag at a maximum 70lbs (32 kg) and 62 linear inches (157 cm) (total length + width + height) Ticket must reflect confirmed seat for segment in which customer is checking in

[Source: Delta airlines]

Appendix N – Technical and Manufacturing trade-offs based on selected material

			Material comparison		Scoring Result	
Criteria	Metrics	Spec	Plastic	Metal	Plastic	Metal
Technical						
Towing capacity	Weight	400 lbs (min)	>400 lbs	>400 lbs	0	0
Lifting capacity	Weight	600 lbs (min)	>600 lbs	>600 lbs	0	0
*Yield strength	Force	1000 psi	6240 psi	8000 ksi	-1	1
Durability (failure rate)	**MTBF	> 20,000 hrs	> 20,000hrs	> 20,000hrs	0	0
Portability	Size	6" x 6" max	6" x 4"	6" x 4"	0	0
Weight	lbs	1 lb. max	0.367 lbs	0.706 lbs	1	-1
Aesthetics (color variety)	N/A	Multi	Multi	Multi	0	0
Integrated design capable	N/A	Yes	Yes	**No	1	-1
Modular design capable	N/A	Yes	Yes	Yes	0	0
***TSA approved	N/A	Yes	Yes	Not sure	1	0
Manufacturing						
Cost to manufacture	Range					
Initial		Low	Low	High	1	-1
Long term		Low	High	Low	-1	1
Cost to assemble	Range					
Initial		Low	Very low	Low	1	-1
Long term		Low	Low	Medium	1	-1
					4	-3

*Source: Matweb material technical data.

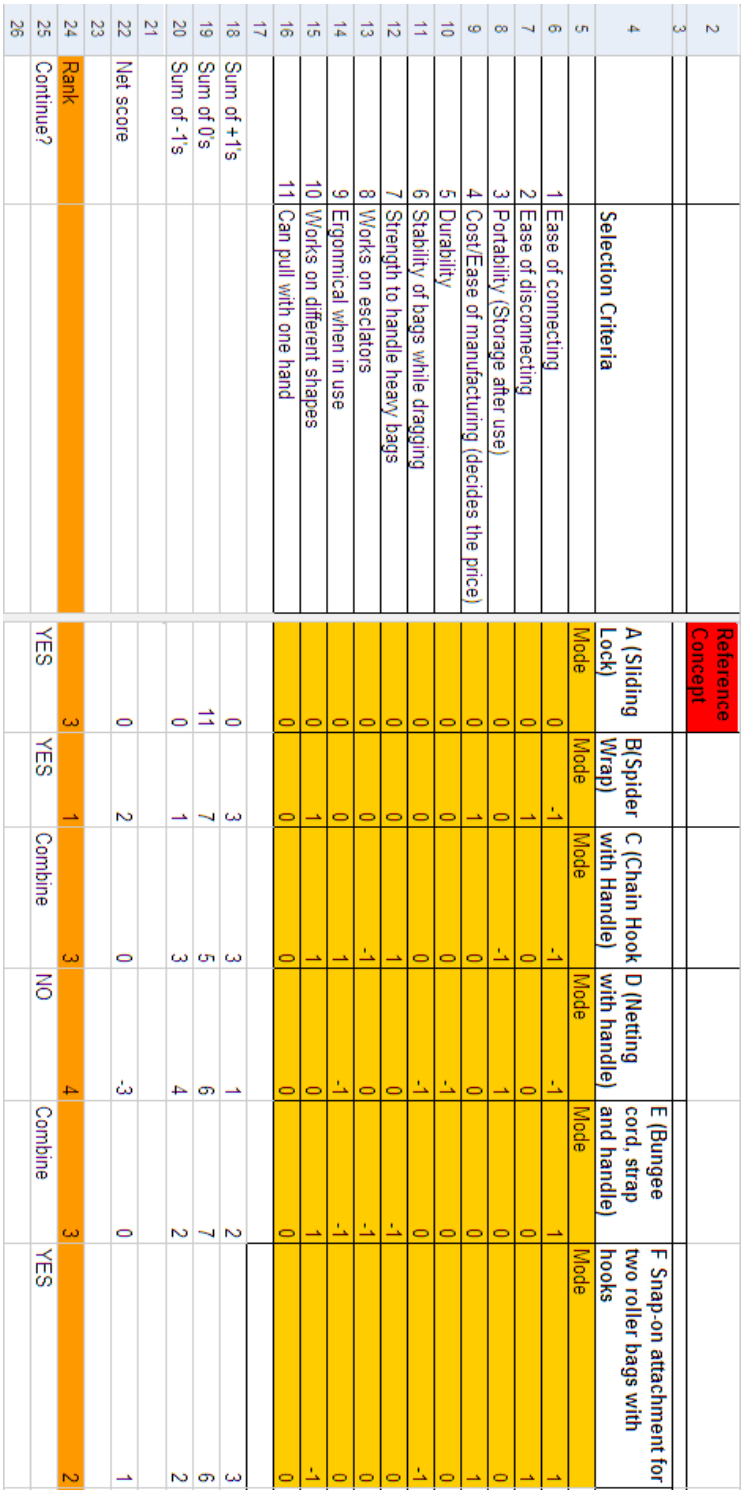
** Mean Time Before Failure.

***TSA website. http://www.tsa.gov/travelers/airtravel/prohibited/permitted-prohibited-items.shtm

Appendix O –Manufacturability comparion between concepts

Criteria	Sliding Lock	Spider Wrap
Use of Modular Parts	Nil	Standard Straps / buckles can be used
Use of Customized Parts	Customized Sliding lock arrangement	Nil
Requirement of Die / Mould	Required for the sliding lock assembly	Nil
No of components used (BOM)	Sliding Lock Assembly (02 Modules comprising of 03 Parts)	08 Belts 04 buckles Spider assembly (connecting the all belts together)
Additional standard accessories required to use the product	02 belts for each piece of luggage	Nil
Manufacturing Cost	Less in case of mass production	Less in case of low production volume
Assembly Time / Cost	Less	More

Appendix P – Concept Screening and Scoring



	Selection Criteria	Reference Concept	A (Sliding Lock)	B(Spider Wrap)	C (Chain Hook with Handle)	D (Netting with handle)	E (Bungee cord, strap and handle)	F Snap-on attachment for two roller bags with hooks
			Mode	Mode	Mode	Mode	Mode	Mode
1	Ease of connecting		0	-1	-1	-1	1	1
2	Ease of disconnecting		0	1	0	0	0	1
3	Portability (Storage after use)		0	0	-1	1	0	0
4	Cost/Ease of manufacturing (decides the price)		0	1	0	0	0	1
5	Durability		0	0	0	-1	0	0
6	Stability of bags while dragging		0	0	0	-1	0	-1
7	Strength to handle heavy bags		0	0	1	0	-1	0
8	Works on esclators		0	0	-1	0	-1	0
9	Ergonmical when in use		0	0	1	-1	-1	0
10	Works on different shapes		0	1	1	0	1	-1
11	Can pull with one hand		0	0	0	0	0	0
	Sum of +1's		0	3	3	1	2	3
	Sum of 0's		11	7	5	6	7	6
	Sum of -1's		0	1	3	4	2	2
	Net score		0	2	0	-3	0	1
	Rank		3	1	3	4	3	2
	Continue?		YES	YES	Combine	NO	Combine	YES

		The reference concepts are already rated to be 3 so no one is allowed to vote for them		A (Sliding Lock)		B(Spider Wrap)		CE (Chain, Bungee cord, Strap and handle combo)		attachment for two roller bags with hooks	
	Selection Criteria		Weight	Rating	Weight Score	Rating	Weight Score	Rating	Weighte Score	Rating	Weighted Score
		Reference model									
1	Ease of connecting	CE (Chain, Bungee cord, Strap and handle combo)	15%	3.666666	0.55	4	0.6	3	0.45	3.83333333333	0.575
2	Ease of disconnecting	F Snap-on attachment for two roller bags with hooks	15%	2.5	0.375	2.5	0.375	2	0.3	3	0.45
3	Portability (Storage after use)	A (Sliding Lock)	10%	3	0.3	2.33333333333	0.23333	2	0.2	2.66666666666	0.2666666
4	Cost/Ease of manufacturing (decides the price)	B(Spider Wrap)	10%	3.333333	0.33333	3	0.3	2.66666666666667	0.266666	3.33333333333	0.3333333
5	Durability	A (Sliding Lock)	10%	3	0.3	2.83333333333	0.28333	2.16666666666667	0.216666	2	0.2
6	Stability of bags while dragging	A (Sliding Lock)	10%	3	0.3	2.83333333333	0.28333	3.16666666666667	0.316666	2.5	0.25
7	Strength to handle heavy bags	CE (Chain, Bungee cord, Strap and handle combo)	10%	2.833333	0.28333	2.16666666666	0.21666	3	0.3	1.83333333333	0.1833333
8	Works on esclators	CE (Chain, Bungee cord, Strap and handle combo)	5%	2.833333	0.14166	2.66666666666	0.13333	3	0.15	1.66666666666	0.0833333
9	Ergonmical when in use	CE (Chain, Bungee cord, Strap and handle combo)	5%	3.666666	0.18333	2.33333333333	0.11666	3	0.15	3.33333333333	0.1666666
10	Works on different shapes	F Snap-on attachment for two roller bags with hooks	5%	3	0.15	4.66666666666	0.23333	3.66666666666667	0.183333	3	0.15
11	Can pull with one hand	F Snap-on attachment for two roller bags with hooks	5%	3.5	0.175	3	0.15	2.33333333333333	0.116666	3	0.15
			Total Score		3.09166		2.925		2.65		2.8083333
			Rank		1		2		4		3
	Continue?										

Appendix Q – Economic Analysis

Period	1	2	3	4	5	6	7	8	9	10
Development	-40	-40	0	0	0	0	0	0	0	0
Testing	-25	-25	0	0	0	0	0	0	0	0
Tooling and Ramp-Up Costs	0	-60	-60	0	0	0	0	0	0	0
Market Introduction	0	-127	-127	0	0	0	0	0	0	0
Ongoing Marketing Costs	0	0	-127	-127	-127	-127	-127	-127	-127	-127
Production Cost	0	0	-806	-806	-806	-806	-806	-806	-806	-806
Product Revenues (wholesal	0	0	9000	9000	9000	9000	9000	9000	9000	9000
Unit Sales	0	0	450000	450000	450000	450000	450000	450000	450000	450000
Unit Price	0	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Unit Production Cost	0	0	-0.00179	-0.00179	-0.00179	-0.00179	-0.0018	-0.00179	-0.0018	-0.0018
Period Cash Flow	-65	-252	7881	8068	8068	8068	8068	8068	8068	8068
PV Time Period 0	-63	-240	7318	7309	7130	6957	6787	6621	6460	6302
Cumul. Disc. Cash Flow	-63	-303	7015	14323	21454	28410	35197	41819	48279	54581

PROJECT NPV $ **128,261**

Base NPV
128,261

Changes from Base NPV

% of NPV	$ change
0.0%	0

MODEL VALUES

	first	last	base burn rate	adjusted burn rate	%Δ from base value	$Δ from base value
Development	1	2	-40	-40	0.0%	0
Testing	1	2	-25	-25	0.0%	0
Tooling and Ramp-Up Costs	2	3	-60	-60	0.0%	0
Market Introduction	2	3	-127	-127	0.0%	0
Ongoing Marketing Costs	3	24	-127	-127	0.0%	0
Unit Sales	3	24	450000	450000	0.0%	0
Unit Price	3	24	0.020	0.020	0.0%	0.00
Unit Production Cost	3	24	-0.002	-0.002	0.0%	0.00
Discount Rate (per time period)	2.50%					

Set input values in shaded cells.

Appendix R – User Comments from Concept Testing

I am concerned about more than 2 luggages attached together.
I do not take that much luggage but I think it is a good design. Does it work on turnstiles?
Good idea !!
I travel light but could be usable when I go to the Far east with my girlfriend.
I am concerned about how much weight it can carry.
I do not carry more than one bag when I travel. Is it TSA approved?
Makes a lot of sense.
How much weight can it carry?
Hmmm…Got to go.
Mostly I travel alone but with family it could be useful.

This looks simpler to use than the spider wrap. $25 is a good price.
The working of the system look complicated. $25 is a good price. I should be able to store it in carry on.

This looks simple and very good idea. I don't travel with much luggage but can see the usefulness for others who travel with lot of luggage. Something less than $50 looks like a good price.

Under $25 looks like a good price. Most of time I get friend's help but product looks useful. Can use as a backup if friend does not show up.

Currently manage with carabiner sort of arrangement. A price of $10-$20 sounds good. The material should be good to hold heavy luggages, should tolerate wear and tear, fits in to a pocket or carry on.

Should not be more than $20. Two heavy bags might make it unstable. A big and small bag might work well. Flat sided on top of each other will be more stable.

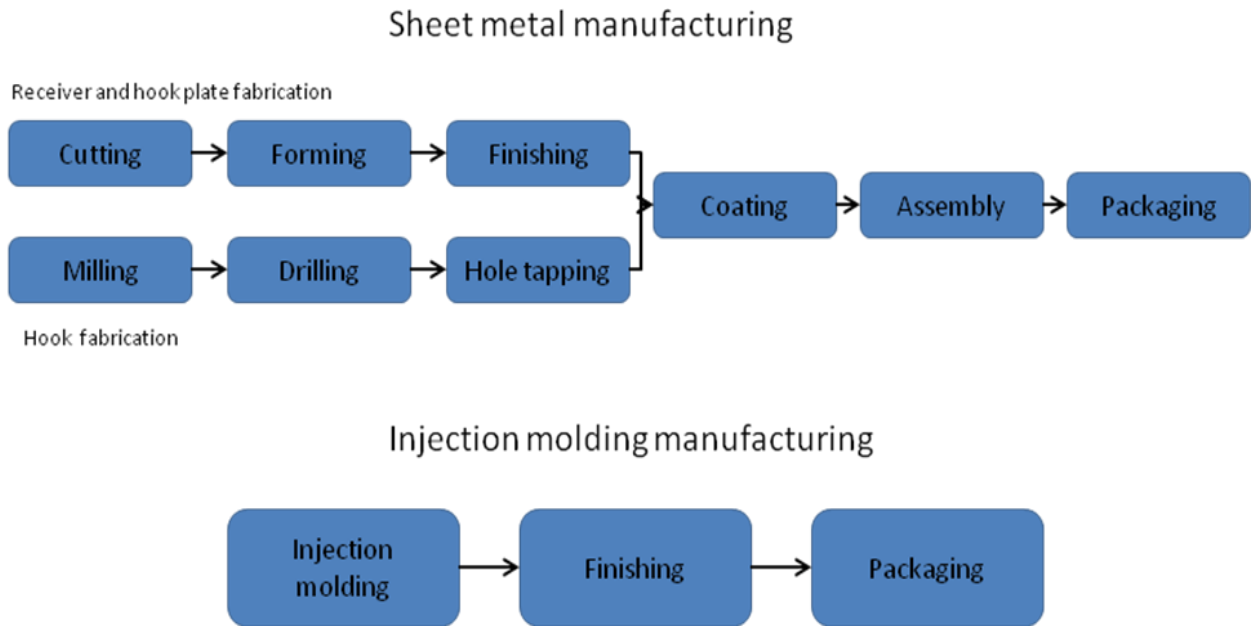
$20 to $30 sounds like a good price. Though I am okay with carrying my luggages with 2 hands there are stupid people around to pay for such things. A lot of people might buy it.

It looks easy to use. $20 sounds like a good price. Center of gravity concern - should be stable.

Moderately interesting. $10-$15 sounds like a good price. Concerned about stability and holding bags together tightly.

Should not be more than $20. I might not buy as I don't carry more luggages but people who carry more luggage may want to buy.

Appendix S – Manufacturing Process



Appendix T – Cost of Manufacturing (Aluminium and ABS Plastic)

Component	Fixed cost		Variable cost		Volume	Total unit cost
	Set-up		Material	$1.27/lb Stock: 0.209 lbs of 6061 aluminum $0.26	10K 100K 1M	$4.26 $3.36 $3.27
	Tooling	$10,000	Processing	20 units/hr at $60/hr $3.00		
	Set-up		Material	$1.27/lb Stock: 0.141 of 6061 aluminum $0.18	10K 100K 1M	$3.18 $2.28 $2.19
	Tooling	$10,000	Processing	20 units/hr at $60/hr $2.00		
	Set-up	0.75hr at $60/hr $45	Material	$1.27/lb Stock: 0.052 lbs of 6061 aluminum $0.07	10K 100K 1M	$3.07 $2.17 $2.08
	Tooling	$10,000	Processing	30 units/hr at $60/hr $2.00		

Metal (Aluminium 6061)

Component	Fixed cost		Variable cost		Volume	Total unit cost
	Set-up		Material	$1.43/lb 0.194 lbs of ABS plastic $0.14	10K 100K 1M	$3.64 $0.94 $0.67
	Tooling	$30,000 4 cavities	Processing	120/hr at $60/hr $0.50		
	Set-up		Material	$1.43/lb 0.067 lbs of ABS plastic $0.05	10K 100K 1M	$3.55 $0.85 $0.58
	Tooling	$30,000 4 cavities	Processing	120/hr at $60/hr $0.50		

ABS Plastic

Appendix U – Bill of Materials

Material: Metal (Aluminum 6061)

Component	Purchased Material	Processing (Machine + labor)	Assembly (labor)	Total Unit variable	Tooling and other NRE, KS	Tooling lifetime, K units	Total unit Fixed cost	Total cost
Receiver plate	$0.26	$3.00	$0.00	$3.26	$10,000	100000	$0.10	$3.36
Hook plate	$0.18	$2.00	$0.00	$2.18	$10,000	100000	$0.10	$2.28
Hook	$0.07	$2.00	$0.00	$2.07	$10,000	100000	$0.10	$2.17
Screw	$0.03	$0.00	$1.00	$1.03				$1.03
Total direct Costs	$0.54	$7.00	$1.00	$8.54	$30,000.00		$0.30	$8.84
Overhead Charges								
Total cost								$8.84

Component	Purchased Material	Processing (Machine + labor)	Assembly (labor)	Total Unit variable	Tooling and other NRE, KS	Tooling lifetime, K units	Total unit Fixed cost	Total cost
Receiver plate	$0.14	$0.50	0	$0.64	$30,000	100000	$0.30	$0.94
Hook plate	$0.05	$0.50	0	$0.55	$30,000	100000	$0.30	$0.85
Total direct Costs	$0.19	$1.00	$0.00	$1.19	$60,000.00		$0.60	$1.79
Overhead Charges								
Total cost								$1.79

Appendix V – Digital Prototype (Finite Element Aanalysis)