Design 3 Cost Memo

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1 Introduction

The purpose of the project's cost memo is to create a detailed breakdown of the costs to produce, calibrate, transport, and maintain the knee-brace. One of the most important factors to consider is the real cost of the components for the brace, as expensive components will make the project not feasible. Broken down in the cost memo is a detailed list of the components required for the project, quantities of each per brace, and the unit cost for each of these components.

Materials and the physical components, however, are only part of the production costs. Manufacturing expenses, utilities, office supplies, shipping and handling, and insurance are just some of the costs that will be incurred in addition to the components of the brace. To account for these, several assumptions have been stated in the cost memo to give a general idea on how these will affect profitability.

Finally, a series of economic feasibility analyses will be conducted to demonstrate the financial robustness of the design. The results will be summaries, evaluated, and potential modifications to improve the profitability of the project will be summarized.

2 Problem Statement for Calculations

Cost is imperative to the success of the design. Financial analyses such as payback period, initial cost analysis, and life cycle maintenance will be fundamental in the verification and justification behind design decisions. Countless factors such as manufacturing costs, quality, materials, durability, expenses, and proximity to clients contributed to the decisions made for the creation of the knee-brace. The results of this cost memo have demonstrated that the design is not only economically feasible, but likely to succeed in the proposed target market of professional and higher-level athletes.

3 Economic Cost Analysis

3.1 Cost Information Gathered

Current knee braces provide users with additional support and compression to prevent acute and chronic injuries [8]. Such braces used within athletic settings range between the price range of $20 - $150 based on length and level of compression [9]. These braces only provide the user with support without any additional information. Knee braces in general are used to minimize needs for physiotherapy, chiropractors, and possibly the need for surgery. With average sports having a season last 4-6 months, physiotherapy is recommended to ensure athletes are playing at peak performance levels, with physiotherapy visits about every 2 weeks for 6 months with the initial fee of $110, and $55 for each session after [10]. This leads to physiotherapy costs per season to average $660 before tax without including any additional physiotherapy appointments resulting from injuries sustained during games. When a player sustains an injury to the ACL needing reconstructive surgery the overall cost is between $20,000 to $50,000 [11]. With the need for surgery comes the additional need for physiotherapy.
The current design of this knee brace is based on the standard compressive knee brace while integrating sensors to provide accurate readings of lower leg movement. This assessment provides results of injury to the ACL for when physiotherapy appointments are necessary right after an injury. This physiotherapy can be tailored based on athletes needs rather than on a 2 week basis which in the end will be cost effective and more beneficial to the athlete. At the moment there are no similar designs on the market, but this design will help minimize costs athletes currently have.

3.2 Bill of Materials

Part Number	Name	Quantity	Cost	Description
1	Knitted Fabric	0.3m x 0.6m	$1.4	Material the knee brace will be made out of
2	Flex Sensor	2	$0.35	Calculates how much weight is applied
3	Force Sensor	2	$0.35	Calculates the angles of the foot
4	Accelerometer	1	$0.50	Calculates the X, Y and Z coordinates
5	ESP 8266	2	$0.50	WIFI Communication between boards
6	ATMega 8266	1	$1	Computes results using algorithm
7	Battery	1	$1	Supplies power to the PCB board
8	Design Casing	2	$2	Encases the PCB Board
9	Power Supply Chip	2	$0.5	Supplies the right amount of voltage

Table 1: Bill of Materials

3.3 Assumptions

The assumptions made are based on current prices around the GTA. Individual parts are estimated bases on individual cost fees. These prices are subject to change based on location and time of production. For these purposes the following assumptions were made to provide a base cost for production and manufacturing.

1. Manufacturing will be based within the GTA
2. Average monthly electricity usage is 10,000 kWh costing $1500 [1]
3. Required space for manufacturing and office space will be 10,000 ft^2. Rent approximately costs $\$1/ft^2$ [4]
4. Paying employees will cost $10,000 monthly
5. $500 is required for Office Supplies monthly
6. $15,000 is required for Machine Maintenance annually
7. Insurance costs are $2000 monthly
8. A Minimum Acceptable Rate of Return will be equal to an average personal savings account rate of 2%.
9. The cost per unit, for shipping and handling is equal to $14.10 [5]
10. The cost per unit, of Manufacturing the product is equal to $35
11. Buying the necessary machinery for manufacturing will cost $7500 upfront.
12. The materials cost of the cloth sleeve, wiring, and anything else not related to the PCB is equal to $5.

4 Capital Costs of Design

Because of the ongoing nature of the business, there will be a lot of recurring costs, in fact, most of the costs of operating a manufacturing system will be recurring. This minimizes the capital costs, as costs that happen periodically do not count as capital costs.

However, the one important capital cost is in the purchasing of manufacturing equipment. Machines needed to create the fabric sleeve will be needed, as well as to integrate the sensors, PCBs and wires to the brace. This will be the most important, and only capital cost, valued as $7500.

Also, initially, the first month of payroll and materials will be counted as a capital cost. The first month's pay will be $10000 and the first month's worth of materials (assuming approximately 250 units are made in the first month to break even) will cost $4250, but after the first month, the cash flows will happen according with revenues from sales as well, and ten they can be treated as a periodic cost.

4.1 Lifetime Maintenance and Operation Costs

Contrasting to the small amount of capital costs, there are many ongoing costs for maintenance and operation. These include rent, electricity, employee payroll, office supplies, machine maintenance, shipping and handling of the finished product, a manufacturing cost per product, a cost for each printed circuit board, an insurance for the business. Details for each operation cost will be expanded upon below.

Renting an industrial property will be necessary for the production of goods. Because it is assumed that the manufacturing will happen in the Greater Toronto Area, renting a property in Toronto will be investigated. It was found that to rent an industrial property in Toronto, it approximately costs $\$1/\text{ft}^2$ **??**. It was also assumed that for the business requirements, approximately 10,000 ft^2 will be required for manufacturing and for office space, and as a result, $10,000 was allocated for rent each month.

A similar argument can be made for electricity costs from Hydro One. Based on the property size and location, the cost per month of electricity was found to be $1492.13 [1]. Without electricity, the business will have no hope of being productive, and as such, electricity is a necessary expense.

Another necessary expense is the payment of employees, as if the endeavour does not have people putting in effort to produce product, there will be no production. It is assumed that for all the employees in the manufacturing process and business, $10,000 will be paid out monthly.

Office supplies are another cost that has been accounted for. This can include computers, phones, paper, pens, and the phone bill and the internet bill. As it is tough to quantify a precise amount for everything, $500 monthly is assumed to be the total cost of office supplies needed.

Another monthly cost of business is insurance, to ensure that any potential damages, if they happen, can be mitigated and mediated. As it is another tough number to quantify, it is assumed that insurance costs will be $2000 monthly.

The final group of cash flows that happen periodically are all the costs and revenues that happen as a per unit basis during manufacturing. For each knee brace manufactured, the materials needed to produce the brace will cost money. It was found that materials will cost $5 per unit. Furthermore, as manufacturing printed circuit boards will need to be outsourced, that cost is not in control of the manufacturing process. However, the cost of manufacturing a printed circuit board is variable from the provider that was selected [12]. Calculations for the price per circuit board can be found in the appendix. Another cost associated with each unit is the manufacturing cost of each unit made. It was assumed that the cost of each unit's manufacturing will be $35. Finally, the revenue made from each unit will need to be found. It was found

that the cost per unit to break even was $358.75, including sales tax.

5 Economic Feasibility Analysis

Based on the Break Even analysis in subsection A.2, the cost of one brace will be $171.55 to break even, and 146 units will need to be sold monthly to break even. Based on the target market of semi-professional and university athletes, this is a margin that is completely attainable. The target market are athletes at this level, playing Volleyball, Basketball, and Football. Taking into account the University of Guelph's varsity rosters as a typical size for university team sizes, information can be gathered about the size of the target market for the brace. There are 105 players on the Men's Football roster, 16 on the Men's Basketball, 19 on the Men's Volleyball, and likewise 16 on the Women's Basketball and 18 on the Women's Volleyball. In total, 180 players are in the target market at the University of Guelph, for a total of 360 potential units to be sold (1 for each knee). This size is completely attainable to sell to, as many players of these sports wear knee braces as a precaution, rather than a necessity for their health. To expand on the target market, it is very easy to market to sports of lesser risk, such as Soccer of Field Hockey. Doing so would sell more units, earning higer revenues.

Furthermore, the price of each brace is certainly reasonable for the alternatives that are available for purchase. Many high-end knee braces can cost upwards of a few hundred dollars, and may range to one thousand, so a break even cost of $171.55 is easily attainable, even with a hefty markup. Adding a markup only increases profits.

6 Economic Analysis Results

6.1 Future Goals

The future goals for this product would be to do a revised version after the first batch has been used through their life cycle, as in any product issues will arise over its life cycle. The expected issues range from the knitted fiber cloth losing its elastic properties over time, as well all flex sensors losing accuracy over time due to repetitive motion. Although these issues have be identified as possible issues in the life cycle of the product, the raw materials that we have selected for this product are supposed to protect against this issues. But this product has not been put through real life testing and as such they could behave unpredictably, as such a float fund should be created in case these raw products do not preform as expected. As these issues are identified through real life testing the product through its life cycle, reviewing and revising this product as well as looking for better alternatives are on the top of the priority list for the revision process moving forward.

6.2 Update Plan

In 5 years time the revision will be needed as the first products are finishing their life cycles, expected updates are to improve the weight and communication system power consumption and by extent decreasing the battery size. At this point marketing the product to higher end as well as more expensive markets with professional money behind them, may become a viable option to increase the products market. If this becomes reality the improved number of products in use will help to refine the product even further.

In 10 years another revision will be implemented, this revision will be focused on improving the accuracy and dependability of the system. Sensors have improved greatly in accuracy and longevity in recent years as well as decreasing in costs in 10 years this may lead to new sensors that could greatly improve the overall system. By allowing for revision to implement these new sensors will also allow the product to keep up with market demands. By this time the ability to cooperate with other companies may lead to working with high

end athletic footwear companies and allow the embedding of sensors into footwear making the system more inclusive and less of an add on product. Making the product smaller and more efficient will allow the system to be more compact and make the sensors more secure.

By 15 years time the product will have underwent 2 revisions and after such a rebuild with added features may be needed to keep the product competitive in the market place. Expected features to be added range from a mechanical system to respond and physically intervene to dangerous movements, to using lighter products and materials to try and reduce the impact on the athletes performance. This complete rebuild may also allow for re-banding or diversifying allowing for a lower end and cheaper product for athlete's in those markets.

In 20 years if computer power continues to progress at the rate it is now then a completely new computation system may be a better option. Advancements in motion tracking may lead to it being an option as tracking multiple athletes during play is currently very demanding. But as this computational power is becoming cheaper this may be an option moving forward, another option when brainstorming may be to develop a sublimity system to support the ankle joint as while as the knee. If that were to happen a specialized system to sports may be an option such as a neck sensory system in football or an elbow system for tennis.

7 Conclusion and Recommendations

This cost memo demonstrates all of the initial overhead costs that will allow this business to function. With comparing supplier costs, bulk products can be bought for less which will minimize material costs. With increased demand of the product, production costs can then in turn also be minimized. Some costs that have not been accounted for are the liability costs that can be occurred if in fact it has been proven an athlete was injured due to this product. Currently the assumption was made no athletes would be harmed from this device and therefore liability costs will be negligible. Future recommendations for this device is to ensure this device is feasible for the future, along will creating a need for the device to ensure success.

References

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[11] *ACL reconstruction cost* CostHelper, 2019

[12] *Instant Quote for PCBs* PCB Way, 2019. https://www.pcbway.com/

Appendix A Calculations

A.1 Present Worth of Costs and Revenues

To find the present worth of the initial cost of Machinery, financial ratios were used to calculate the annual worth of an indefinite annuity. Taxes were included, and the values for taxes were found from the Government of Canada [6]. The present worth of the first cost is the cost of the Machinery, all that is needed is to multiply by CTF, where P is the first cost, t is the tax rate, d is the depreciation rate defined by the government, and i is the interest rate [7].

$PW(Machinery) = P(CTF)$
$PW(Machinery) = P(1 - \frac{td(1+0.5i)}{i+t})$
$PW(Machinery) = -\$7500(1 - \frac{(0.1)(0.02)(1+0.01)}{0.02+0.2)(1+0.02)})$
$PW(Machinery) = -\$6824.25$

A similar method was used to calculate the cost of the periodic payments, of Rent, Payroll, Electricity bills, Office Supplies, and Insurance for the business. All of these are monthly periodic payments, so the form of the equation is the same for all of them, and the prices, tax rates, and present worth values will be listed below the equation. Each of the monthly payments needs to be converted to a present worth so it can be made an indefinite annuity. The variable A represents the monthly annuity amount.

$PW = A(F|A, i, 12)(P|F, i, 1)(1 - t)$

Table 2: Monthly Cost, Tax Rate, and Present Worth including Taxes

Monthly Item	Monthly Annuity	Tax Rate	Present Worth
Rent	-$10,000	10%	-$95,177.05
Electricity	-$1492.13	Included	$15,779.61
Payroll	-$10,000	Included	-$105,752.28
Office Supplies	-$500	20%	-$4230
Insurance	-$2000	Included	-$21,150.46

The annual annuity calculation is easier. For the annually Maintenance of Machines, the calculation is below.
$PW(Maintenance) = A(P|A, i, 1)(1 - t)$
$PW(Maintenance) = -\$15,000(0.98039)(1 - 0)$
$PW(Maintenance) = -\$14,705.85$

The Manufacturing, Shipping, PCB, and Materials costs are a little more challenging. For the purposes of a Break-Even analysis, the number of products is unknown. But the number of items sold is so that the present worth will be equal to $0. In the following calculation, p is the unit cost of a PCP (the manufacturer chosen has variable cost, so the cost will need to be calculated), and n is the total number of products being sold to break even.

$PW(Unitcost) = (p - \$35 - \$14.10 - \$12 - \$5)n(F|A, i, 12)(P|F, i12)$
$PW(Unitcost) = (p - \$66.10)n(13.412)(0.78849)$
$PW(Unitcost) = (p - \$66.10)n(10.5752)$
The total price of the PCBs were found by asking the producer to give prices of different numbers of PCBs to see what the change in cost would be. The data for that is below.

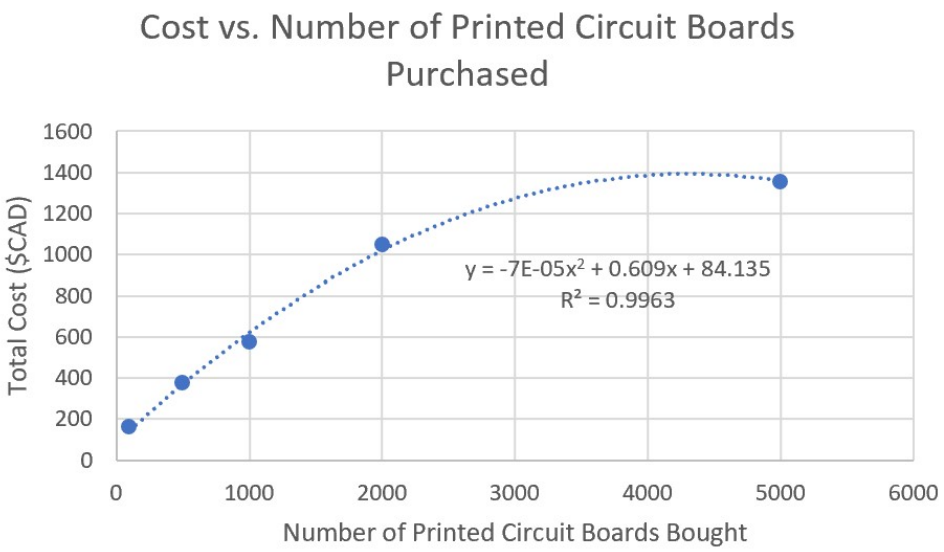

Figure 1: Total Price of PCB vs Number bought

The quadratic correlation gives the total price of PCBs with the equation:

$$p = -7x10^{-5}n^2 + 0.609n + 84.135 \tag{1}$$

Where p is the unit cost of a Printed Circuit Board multiplied by the number of circuit boards bought.

A.2 Break Even Analysis

To determine the break even value, the number of units to be sold at a particular price is needed to be found. This can be found when the Present Worth is equal to zero. Substituting in the values found from subsection A.1, the break even calculation can be found below.

$\sum_{i=1}^{n} PW(i) = 0$
$-\$95177.05 - \$15779.61 - \$105752.28 - \$4230 - \$14705.85 - \$6824.25 - \$21150.46 + (p - \$66.10)n(10.5752) = 0$
$\frac{\$263619.50}{10.5752} = np - 66.10n$

Substituting in Equation 1,
$0 = -7 * 10^{-5}n^3 + 0.609n^2 + 84.135n - 24928.09$
Solving the equation using MATLAB, and disregarding values that do not make sense physically, the minimum number of units sold to break even on investment is 146.

Substituting the number for n into Equation 1, the price that each unit needs to be sold to earn back the principal investment is $171.55.