

Quadruple Bottom Line Evaluation of Laptop Computers
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University of British Columbia

Quadruple Bottom Line Evaluation of Laptop Computers

Sustainability Project



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ABSTRACT

This project revolves around the design of a laptop purchasing guide to help prospective laptop buyers make more informed decisions. More specifically, this project consists of a scoring system, called the Quadruple Bottom Line (QBL) evaluation, which not only takes into account the functional qualities of a laptop in relation to its cost, but also its environmental and social impacts. This scoring system is developed by integrating the traditional functional evaluation of laptops with the Triple Bottom Line (TBL) approach. By doing so, four main scoring categories are identified, namely functional, economic, environmental and social. For each category, a list of relevant criteria is enumerated and ranked according to the results of a survey. Using the concept of a weighted decision matrix, weights are assigned to each criteria and category, and an overall score is consequently calculated for the laptop unit evaluated. To demonstrate the use of the QBL evaluation, laptop units from Apple, Lenovo, HP and Dell are evaluated.

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GLOSSARY

Battery life	The maximum length of time a laptop can operate on a single charge of a rechargeable battery.
Conflict materials	Materials that are sourced from areas that have conditions of armed conflict or human rights abuses.
CPU performance	The amount of work accomplished by a computer system in relation to the time used. For this investigation, this quantity is determined by the processor speed.
Portability	The ease at which an object can be carried.
Power consumption	The electrical energy over time supplied to operate an electrical appliance.
Purchase cost	The upfront cost associated with purchasing a laptop.
RAM size	The amount of bytes allocated to the Random Access Memory (RAM) of a computer.
Recyclability	The capacity of a material or product to be recovered or diverted from the solid waste stream for the purpose of recycling.
Storage capacity	The amount of bytes allocated to the primary storage system of a computer.
Waste management	The collection, transport, processing or disposal, managing and monitoring of waste materials.
Weighted decision matrix	A quantitative technique used to compare alternatives with respect to multiple criteria of varying levels of importance.

LIST OF ABBREVIATIONS

RAM	Random Access Memory
CPU	Central Processing Unit
SSD	Solid State Drive
VESA	Video Electronics Standards Association
EPEAT	Electronic Product Environmental Assessment Tool
TCO	Tjänstemännens Centralorganisation
EICC	Edinburgh International Conference Centre
OECD	Organisation for Economic Co-operation and Development
QBL	Quadruple Bottom Line
TBL	Triple Bottom Line

1 INTRODUCTION

Needless to say, laptop computers are an integral aspect of modern post-secondary education; students and teachers alike are heavily reliant on laptops for everyday tasks. These days, however, it is no simple task to choose the right laptop brand and model. Today's selection of laptops includes everything from lightweight Ultrabooks to bulky, high-performance gaming laptops. More often than not, in selecting laptop units, students tend to only assess laptop performance and functionality in relation to the cost. This is because there is little to no information available to help in choosing laptops based on other criteria such as energy usage, life cycle, environmental impact and social responsibility.

This project seeks to develop a laptop purchasing guide, in the form of a scoring system, that takes into consideration, not only the cost and functionality of the laptop unit, but also its environmental and social implications. The outcome of this project will be of practical use to prospective laptop buyers and, at the same time, promote green and responsible product purchasing.

This project focuses on laptops that are commonly used by university students. That is, portability, durability, battery life, CPU performance, RAM size and storage capability are important functional qualities. In addition to these, the concept of Triple Bottom Line (TBL) will be used to determine the economic, environmental and social factors that need to be considered when choosing a laptop unit. To test the laptop scoring system, this project will evaluate four laptop units from different brands, namely Apple, Lenovo, HP and Dell. The resulting laptop scoring system, called the Quadruple Bottom Line Evaluation, will be comprehensive, easy-to-use and suitable to the needs of university students.

This report is divided into 3 main parts. *Section 2: Methodology* contains detailed discussions of all four categories (functional, economic, environmental and social) and their corresponding criteria. This section also contains the scoring scheme for each criteria, as well as a discussion on the Weighted Decision Matrix, which is the quantitative technique that we will use to rank each criteria and category. *Section 3: Results* demonstrates the use of the scoring system developed in section 2 by evaluating laptop units from 4 different brands and identifying the model with the highest score. *Section 4: Conclusions and Recommendations* summarizes the outcomes of this project and offers suggestions on how to further improve and expand on the results.

2 METHODOLOGY

In order to develop a laptop scoring system, it is necessary to identify a list of criteria with which to evaluate each laptop model. Traditionally, laptop buyers develop a list of criteria solely based on functionality and performance. However, since the main premise of this project is to promote green and responsible laptop purchasing, three more categories will be considered in addition to the functional category, in accordance with the Triple Bottom Line approach. These three categories are economic, environmental and social. Within each of these four categories, a list of criteria will be developed and ranked using a weighted decision matrix. The weights assigned to each criteria are determined from surveys conducted amongst UBC students and client feedback. Furthermore, each category will also be ranked and weighted according to survey results. The total score will be determined by the weighted scores from each category and from each criterion within each category.

2.1 Weighted Decision Matrix

To be able to rank the four laptops in discussion and to come up with a final recommendation, we developed a system in which we assigned a different weight for each category (functional, economic, environmental and social), coming to a total of 1, according to their importance when purchasing a new laptop. To determine the relative weights, we conducted a survey among a sample of 20 randomly chosen people, and asked them to rank the categories of concern according to their importance when purchasing a new laptop. Since economical reasons tend to be the main concern of consumers, we opted out that category and aimed to have more focus on the remaining aspects. The following figure demonstrates the results obtained from the survey:

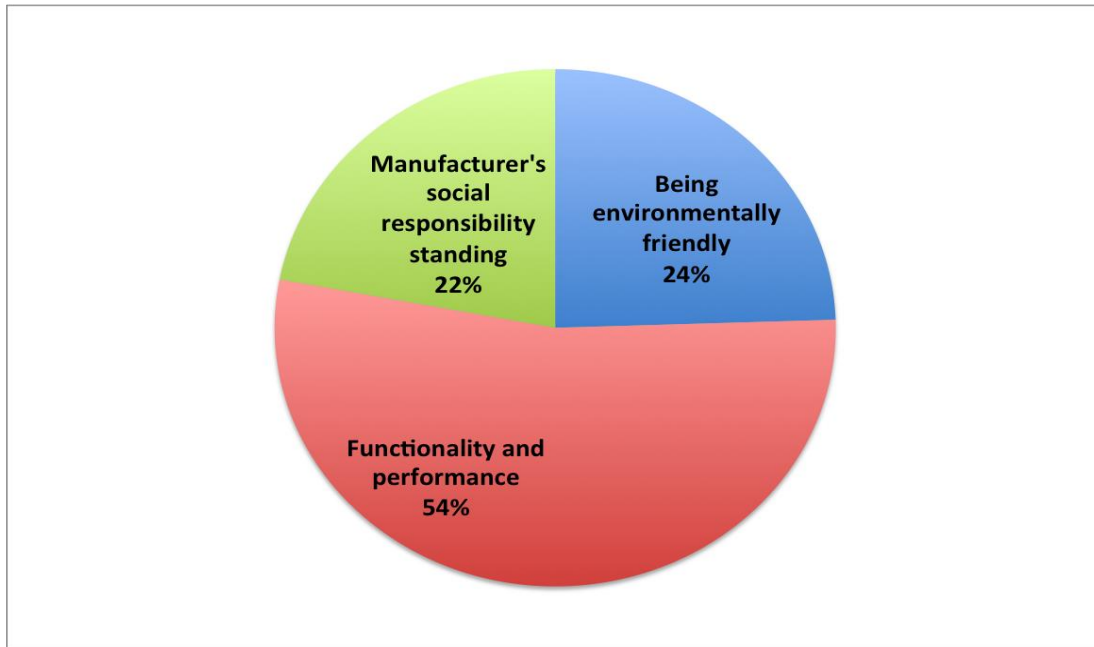


Figure 1: Survey results showing the relative importance of categories to public

After combining these results with our initially assigned 0.25 fair weight to economical category, the following relative weights were obtained for use in ranking of the laptop models investigated.

Category	Weight
Functional	0.40
Economical	0.25
Environmental	0.18
Social	0.17

Table 1: Overall weights for categories of concern

2.2 Functional Category

It is common practice for buyers to examine the technical specifications of laptops before making a purchasing decision. There is a wide variety of options for the processor, RAM, storage and other features to choose from, and the choice is dependent on the buyer's personal preference. Gamers, in general, tend to prefer high resolution graphics, fast processor speeds and large amounts of RAM. On the other hand, some students simply prefer portability and a comfortable keyboard to type up lengthy term papers on.

For the purpose of this investigation, we narrowed down the list of functional criteria to five, namely portability, battery life, CPU performance, RAM size, and storage capacity. Each criteria and their corresponding scoring schemes will be elaborated in this section.

2.2.1 Criteria 1: Portability

Portability is an important consideration to make when purchasing a laptop, especially since most university students find the need to carry their laptops with them around campus. Portability is largely determined by the weight of the laptop itself. Laptop weights range from less than 3 pounds for light-weight Ultrabooks to over 10 pounds for a typical gaming laptop. The following table shows the scoring scheme based on laptop weight.

Laptop Weight	Score (1-10)
> 11 lbs	1
10-11 lbs	2
9-10 lbs	3
8-9 lbs	4
7-8 lbs	5
6-7 lbs	6
5-6 lbs	7
4-5 lbs	8
3-4 lbs	9
<= 3 lbs	10

Table 2: Portability scoring scheme

2.2.2 Criteria 2: Battery Life

The number of hours the laptop battery can last is also another important consideration for users that do not have constant access to a power outlet. However, it is important to note that most manufacturers tend to exaggerate the battery usage hours for their laptop units. For instance, they may advertise the battery usage time for the lowest possible settings. In any case, the scoring scheme below considers the maximum possible battery life.

Battery Usage Hours	Score (1-10)
< 1 hr	1
1-2 hrs	2
2-3 hrs	3
3-4 hrs	4
4-5 hrs	5
5-6 hrs	6
6-7 hrs	7
7-8 hrs	8
9-10 hr	9
>= 10 hrs	10

Table 3: Battery life scoring scheme

2.2.3 Criteria 3: CPU Performance

The Central Processing Unit (CPU) is arguably the most important part of a computer. The CPU is responsible for running the operating system and other applications in a computer. In general, faster processors result in faster-running programs. However, there is usually a compromise between processor clock speeds and portability. Faster processor speeds tend to consume more power and require more powerful cooling systems.²⁵ As a result, laptops with faster processors are generally bulkier and heavier. In addition, such laptops tend to be more expensive as well. The table below shows a scoring scheme for CPU performance based on the processor clock speed in Hz.

Processor Clock Speed	Score (1-10)
< 1 GHz	1
1-1.25 GHz	2
1.25-1.5 GHz	3
1.5-1.75 GHz	4
1.75-2 GHz	5
2-2.2 GHz	6
2.2-2.4 GHz	7
2.4-2.6 GHz	8
2.6-2.8 GHz	9
>= 2.8 GHz	10

Table 4: CPU performance scoring scheme

2.2.4 Criteria 4: RAM Size

Random Access Memory (RAM) is a form of short-term storage for data involved in programs that are currently running. Program data that is stored in RAM can be accessed almost instantly.²² This is an important consideration because it is much faster to load data from RAM than from a hard drive. The larger the RAM size, the less often the computer has to load from the hard drive. Mid-range priced laptops tend to have about 4GB of RAM, and in most cases, 4GB is considered adequate. Laptops generally come with RAM sizes of 2GB, 4GB and 8GB. The table below shows the scoring scheme based on laptop RAM size.

RAM Size	Score (1-10)
>2 GB	2
2 GB	5
4 GB	7
8 GB	9
> 8 GB	10

Table 5: RAM size scoring scheme

2.2.5 Criteria 5: Storage Capacity

The storage capacity of a laptop is an important consideration especially for users that need to store large files, videos, music and pictures. The hard drive disk is typically the main storage system used by laptops, but recently, an increasing number of laptops have started offering solid state drives (SSD) as an alternative. The use of SSDs results in faster booting times and more portability, however, they offer significantly less storage space than traditional hard drives and are generally more expensive. The table below shows a scoring system based on the amount of GB a laptop's storage system has.

Storage Capacity	Score (1-10)
> 100 GB	1
100-125 GB	2
125-150 GB	3
150-175 GB	4
175-200 GB	5
200-250 GB	6
250-300 GB	7
300-400 GB	8
400-500 GB	9
>=500 GB GB	10

Table 6: Storage capacity scoring scheme

2.2.6 Weighted Functional Criteria

A survey was conducted amongst 20 UBC students to rank the five functional criteria according to personal preference. The outcome of the survey is summarized in Figure 2.

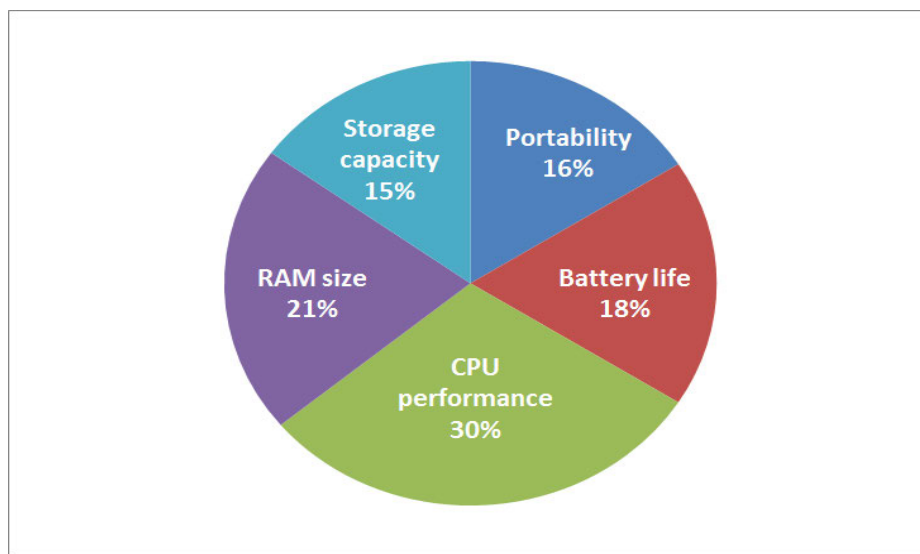


Figure 2: Functional criteria survey result

The resulting weights for each criteria of the functional category are summarized below:

Criteria	Weight
Portability	0.16
Battery life	0.18
CPU performance	0.30
RAM size	0.21
Storage capacity	0.15

Table 7: Relative weights of functional criteria

2.3 Economic Category

To some extent, economics is one of the traditional categories considered by laptop buyers. Economics includes initial purchase price of a laptop, its power consumption, repair costs, and expected lifetime. Economics is a very important category as cost is often a defining feature when choosing a laptop model. This category should also help factor into account lifetime costs instead of merely purchasing costs. The two categories of this focused upon here are purchase price and power consumption. Repair costs were not considered as most repair services looked at had standard rates not attached to brands or specific laptops. Life expectancy was not factored into ratings as most information on lifetimes for newer models are customer reviews. Such sources are not reputable. An overall economic rating for a laptop is formed through a weighted average based on purchasing cost and power consumption. Information on laptop pricing obtained directly from manufacturer websites while power consumption data was obtained from Penn Information Systems and Computing.²

2.3.1 Criteria 1: Purchase Cost

Pricing of a laptop is intrinsically linked to its performance. Due to this, it would be inappropriate to rate laptops based on their cost as a lower priced laptop would likely have worse performance and less features. Therefore, rating a laptop's purchase cost is done in comparison to other laptops with similar specifications.

The first step in creating a rating was to find other similar laptops. This can be done manually or by using a laptop search function from a website such as CNET. Such searches may not be as specific as needed so after the initial search one must manually filter out any dissimilar models. Once an accurate list has been created the highest and lowest prices on this list are found. With a highest price of *max*, a lowest price of *min*, and the price of the model being rated as *x*, the score of the model in the purchase cost section is:

$$\text{Score} = 10 \times (1 - ((x - \text{min}) \div (\text{max} - \text{min})))$$

This equation produces a score out of 10 with the cheapest laptop on the list receiving 10 and the most expensive receiving 0. When calculating a final score in the economics category a weighted average will be used. In this weighted average purchase cost will receive a weight of 0.75.

2.3.2 Criteria 2: Power Consumption

An often overlooked economic aspect of purchasing a laptop is power consumption. This is one of the factors in the lifetime cost of a laptop. A ranking for power consumption is created using an equation similar to that for purchasing cost except that instead of using prices, the equation uses power consumption in Watts. When finding minimum and maximum values for power consumption to be inserted into the equation it is not necessary to only take into account laptops similar to the one being rated. One reason for this is that power consumption figures are not as readily available as prices so very few similar laptops may be found with figures available. Furthermore, power usage is not necessarily tied to performance. A portable Ultrabook may use very little power compared a larger laptop with a less powerful processor. Power consumption receives a score of 0.25 when calculating a weighted average.

2.4 Environmental Category

Enterprises, governments and societies are always tackling environmental issues whereas over the years, the use of IT has exploded in improving our lives, work and offering convenience along with several other benefits. However, IT has been contributing to environmental problems which most people do not realize. Computers and other IT infrastructure consume significant amounts of electricity. Additionally, IT hardware disposal also poses severe environmental problems. For example, this report focuses on using the triple bottom line (quadruple bottom line in our case) to evaluate and consider several environmental aspects when buying laptops and other IT products. This study not only helps us when selecting IT products also helps us in designing, manufacturing, using and disposing them as a future engineer. Adopting the TBL offers both businesses and individuals financial and other benefits, and researchers found that reducing power consumption and lowering costs are the major reasons for using eco-responsible practices, followed by a lower environmental impact and improved system as shown in Figure 1.

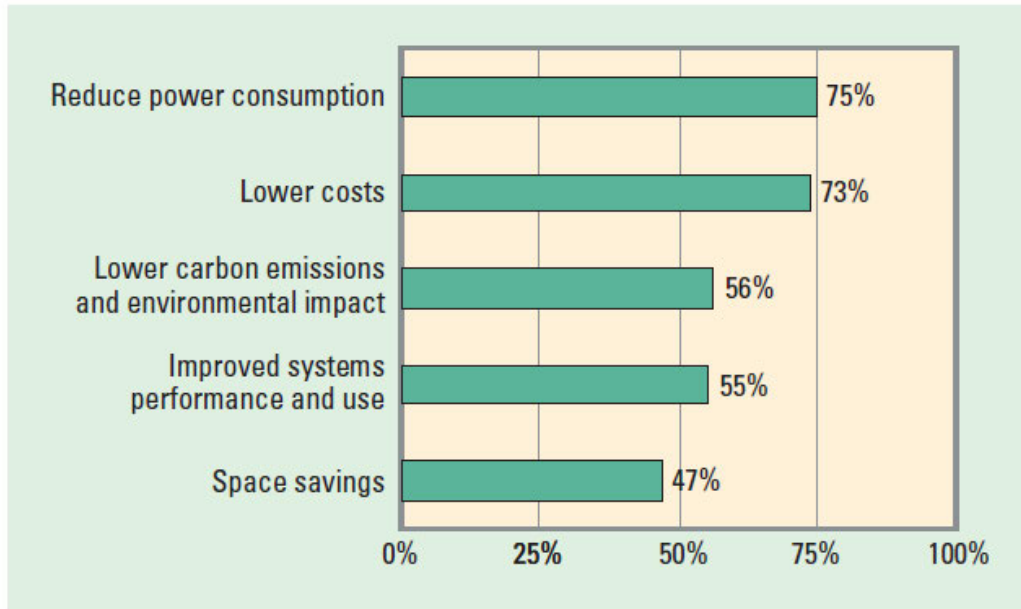


Figure 3: Reasons and benefits for environmental evaluation

Narrowing down the evaluation of environmental sustainability we found a number of focus areas including:

- design for environmental sustainability;
- energy-efficient computing;
- power management;
- data center design, layout, and location;
- responsible disposal and recycling;
- regulatory compliance;
- green metrics, assessment tools, and methodology;
- environment-related risk mitigation;
- use of renewable energy sources; and
- eco-labeling of IT products.

A growing number of computer vendors and users are moving toward green products and thereby assisting in building a green society and economy. Furthermore by narrowing down these points we created a survey and collected data from randomly chosen groups and weighted aspects of material recyclability, durability and replaceable components, environmental standards and waste management by manufactures. Material recyclability focuses on environmental material handling, toxic components as well as using renewable energy sources. Durability focuses on build quality and life cycle of each model with higher upgradability laptops can be more endure. Environmental standards focus on design for environmental sustainability and environment-related risk mitigation as well as eco-labeling. Finally, waste management by manufactures focuses on disposal and recycling E-wastes by vendors. According to the weigh in from the survey we generated a scoring scheme that evaluates laptop models from Apple, Dell, HP, and Lenovo, and furthermore recommend a model that not only help consumer to select their laptops, also building a trend for laptop

vendors and manufactures. From the results of our survey, we found that durability outweighs other three aspects for consumers, followed by environmental standards, material recyclability, and waste management is comes end which is understandable that it is hard for consumer and even for toxics coalition to track. Figure 2 shows the pie chart of environmental section of our survey. A demonstration of the scoring system is shown in section 4.

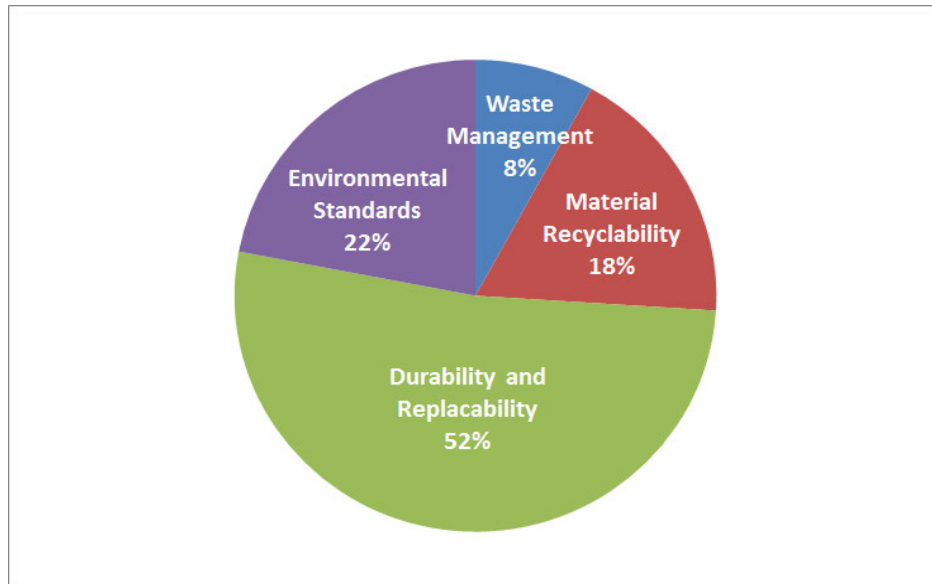


Figure 4: Environmental survey results

2.5 Social Category

Even if it is not one of the main aspects consumers consider when purchasing a new laptop, social impacts of manufacturers are becoming more important with improving technology and increased availability of information and materials from overseas. People do not only take roles as consumers but also as a part of production and delivery; that is why both sides should be paid attention to and treated fairly. It is important for manufacturers to have an overall positive impact on the society and to promote ethical behaviour along with the improvement of employees', local communities' and the society's quality of life. As was suggested by The World Business Council for Sustainable Development, with the increasing focus on people, companies are better off when they take social responsibilities as an integral part of their business and can benefit from it in the long term.¹¹ Analyzing implementation of social responsibilities is an essential part of the TBL approach; thus we will be investigating each manufacturers' actions under the criteria explained below.

2.5.1 Criteria 1: Worker Health and Safety

In this criteria, the main focus was on the training of employees on their rights, provision of a safe and healthy work environment and whether excessive hours of work were

required or not. When analyzing the manufacturers under this criteria, we took into account whether they provide skills training and education on their rights to their employees, the programs' quality, and the compliance of their suppliers with their maximum weekly work hour policy. The scoring was based on weekly work hours and was adjusted according to the quality and promotion of their employee training programs.

Property	Score
80+ work hours per week	1-2
70-79 work hours per week	3-4
60-69 work hours per week	5-6
50-59 work hours per week	7-8
50- work hours per week	9-10

Table 8: Worker health and safety scoring scheme

2.5.2 Criteria 2: Employment Ethics

In this section, we focused on whether all the employees involved in the production and distribution of the product were paid a livable wage and the employment of underage workers. Since this remains to be a main topic of discussion, many well-known firms seem to provide enough information on their employment ethics. As these manufacturers have a long chain of suppliers overseas, we found it reasonable that there were occurrences where these conditions were not met. In these cases, the manufacturers response and following actions were taken into account. The scoring was based on the availability of information and promotion of ethical employment, and was adjusted according to the their responses to cases that revealed the circumstances where their published codes were not met.

Property	Score
Not enough information provided	1-3
Available information and sufficient back-up provision	4-6
Available information and promotion of using conflict free materials	7+

Table 9: Employment ethics scoring scheme

2.5.3 Criteria 3: Auditing and Disclosure of Practices

For this criteria, we investigated whether the manufacturers have external or internal audits to validate their practices, and whether they fully disclose and publish them. Having external audits was seen as more reliable and the manufacturers that internally audit their practices were assigned a relatively lower score. Sufficiency of information provided was scored relatively to other manufacturers.

Property	Score
Self auditing and not enough information provided	1-3
External auditing and not enough information provided	3-5
Self auditing and sufficient publicly available information	6-8
External auditing and sufficient publicly available information	8-10

Table 10: Auditing and disclosure of practices scoring scheme

2.5.4 Criteria 4: Use of Conflict Free Materials

Use of conflict materials has been a main subject of discussion, as it affects people that live in conditions of armed conflict and human right abuses. We believe that it is manufacturers' responsibility to use conflict free materials and also promote its usage. For this criteria, the following scoring scheme was used:

Property	Score
Not enough information provided	1-3
Available information and provision of sufficient back-up	4-6
Available information and promotion of using conflict free materials	7+

Table 11: Use of conflict free materials scoring scheme

2.5.5 Weighted Social Criteria

In order to get a relative weight for each criteria, we did a survey on a randomly chosen group of 20 people, and asked them which one of the previously mentioned criteria they thought was the most important when purchasing a new laptop. The following figure shows the results obtained:

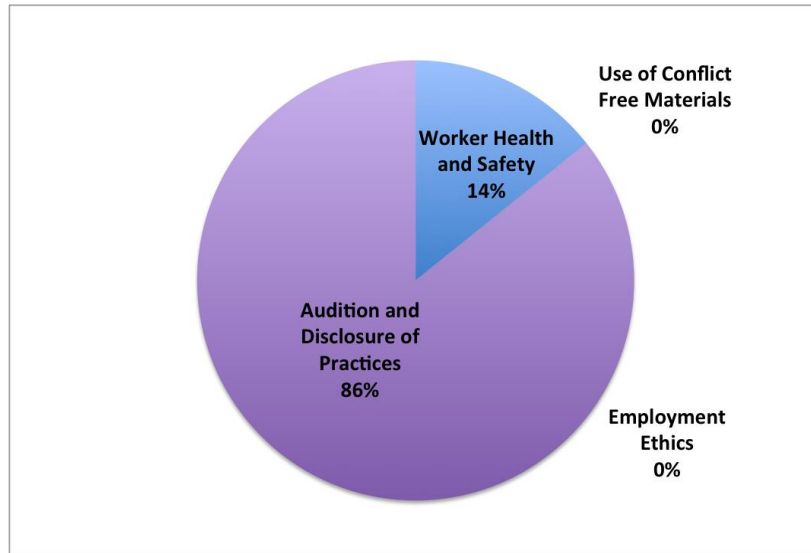


Figure 5: Survey results for weighting social component of our evaluation

We also asked for our client’s input regarding the relative ranks of these criteria. The following figure demonstrates our client’s suggestion on the matter:



Figure 6: Client feedback for weighting of social component criteria

By averaging the two sets of results, we came to the following conclusion for the relative weights of criteria considered in the social portion of our investigation:

Criteria	Weight
Worker health and safety	0.22
Employment Ethics	0.10
Use of Conflict Free Materials	0.10
Audits and Disclosure of Practices	0.58

Table 12: Overall Weighting Results for Social Category

3 RESULTS

When purchasing laptops, students generally look at the functionality and performance specs of a laptop unit. This traditional approach to laptop purchasing is reflected in the online article, “Best Laptops 2014” by Avram Piltch.²⁴ This article identifies laptop units that are the “best”, so to speak, in different categories such as battery life, hybrid performance and affordability. It also identifies the best laptop overall, based only on functionality and performance.

- **Best laptop overall: MacBook Pro 13-inch With Retina Display**
- **Longest battery life laptop: Lenovo ThinkPad X240**
- **Best hybrid laptop: Dell XPS 12**
- **Best budget laptop: HP TouchSmart 11z**

In order to compare the outcome of the traditional laptop purchasing approach with Quadruple Bottom Line method, the same four laptop units will be evaluated in this section. For the social evaluation sections, the manufacturers will be evaluated.

3.1 MacBook Pro 13-inch with Retina Display

3.1.1 Functional Evaluation

Criteria	Laptop Specifications	Score (1-10)	Weighted Score
Portability	Weight: 3.56 lbs	9	1.44
Battery life	Maximum battery run time: 7:00	8	1.44
CPU performance	Processor speed: 2.5 GHz	8	2.40
RAM size	Memory size: 8 GB	9	1.89
Storage capacity	Storage size: 128 GB	3	0.45
Functional score			7.62

3.1.2 Economic Evaluation

Criteria	Description	Score	Weighted Score
Purchase Cost	\$1349	3.6	2.70
Power Consumption	53 Watts	1.8	0.45
Economic score	-	-	3.15

3.1.3 Environmental Evaluation

Criteria	Description	Score (1-10)	Weighted score
Material and Recyclability	<ul style="list-style-type: none"> • Apple uses single block of Aluminum produces the lid,back, and main enclosure. Aluminum is lightweight, high strength to weight ratio ($S_y=500$ Mpa, 2.70 g/cm³).¹⁴ • Apple is all about brand image- focusing on being green and on illegal labor performed on products. • manufactured from recyclable glass and aluminum parts can be rescued and 100% recyclable. • shipped in packaging 34%-41% smaller than before and other vendors. This leads to saving more trees and less transportation required with more systems on fewer planes.¹⁴ 	10	1.8
Durability	<ul style="list-style-type: none"> • excellent build quality and great customer service with many retail stores available • irreplaceable components increases cost in repairing and lack of upgradability • Mac OS does a better job at managing the speed, and temperature than Windows • Good battery life with varies selection of specs 	8	4.3
Environmental standards	<ul style="list-style-type: none"> • no harmful toxins used in the Macbook • The manufacturing process apple uses accounts for 38% of apples CO2 emissions.¹⁴ 	9	1.9
Waste management by manufactures	<ul style="list-style-type: none"> • used equipment is disassembled, and key components that can be reused are removed. Glass and metal can be reprocessed for use in new products. A majority of the plastics can be pelletized into a raw secondary material. With materials reprocessing and component reuse, Apple often achieves a 90 percent recovery rate by weight of the original product. 	7	0.6

	<ul style="list-style-type: none"> • However e-waste management is not transparent and hard to track. Many Companies export hazardous e-waste to developing countries whereas apple refuse to sign the commitment that promises not to do so.¹⁵ 		
Overall	Due to weighted score, Durability out weights other aspects.		8.6

3.1.4 Social Evaluation

Criteria	Description	Score (1-10)	Weighted Score
Worker Health and Safety	<ul style="list-style-type: none"> • Apple Inc. provided a free education and development program to more than 280,000 of its employees in 2013, and promotes training of employees on their rights.¹ • The company has an Apple Supplier EHS(Environment, Health and Safety) Academy which provides an 18 month long formal training. They also claim to have a maximum of 60 hour work week with a 95% supplier compliance.¹ 	9	1.98
Employment Ethics	<ul style="list-style-type: none"> • The company promotes fair treatment of all workers, including migrants and students interns that are at risk.¹ • After an audit of Guangdong Real Faith Pingzhou Electronics, China in January 2012 revealed employment of 74 underage workers, Apple terminated their contract and stopped working with this particular supplier.^{3 6} 	7	0.70
Use of Conflict Free Materials	<ul style="list-style-type: none"> • The company highly promotes the use of conflict free materials and had a third party auditor to confirm the situation of the tantalum supplied.¹ • The company is an Electronics Industry Citizenship Coalition(EICC) member.⁷ • The Enough Project, a non-profit organization that aims to end the use of conflict minerals based in Congo, ranked Apple 6th and listed the manufacturer as top-tier.¹⁶ The score assigned is mainly based on the manufacturer's relative ranking here. 	6	0.60
Auditing and Disclosure of	<ul style="list-style-type: none"> • Apple does most of its auditing internally and publishes an annual 	7	4.06

Practices	<p>report that is available online.¹</p> <ul style="list-style-type: none"> • Apple also uses external auditors (Ernst & Young LLP as independent auditor) to validate their practices and highly promotes transparency.^{1,23} • Apple lacks transparency on GHG emission reporting.⁷ • In 2011, Apple became a first at mapping and publishing its suppliers.⁷ 		
Social score	-	-	7.34

3.2 Lenovo ThinkPad X240

3.2.1 Functional Evaluation

Criteria	Laptop Specifications	Score (1-10)	Weighted Score
Portability	Weight: 3 lbs	9	1.44
Battery life	Maximum battery run time: 6:23	7	1.26
CPU performance	Processor speed: 1.6 GHz	4	1.2
RAM size	Standard memory: 8 GB	9	1.89
Storage capacity	Storage size: 256 GB	7	1.05
Functional score	-	-	6.84

3.2.2 Economic Evaluation

Criteria	Description	Score	Weighted Score
Purchase Cost	\$979	8.0	6.00
Power Consumption	48 Watts	3.0	0.75
Economic score	-	-	6.75

3.2.3 Environmental Evaluation

Criteria	Description	Score (1-10)	weighted score
Material and Recyclability	<ul style="list-style-type: none"> • 3-pound carbon-fiber chassis • 10-65% of post consumer recycled content or PCC plastics resulting in a double win for our environment. 	9	1.7
Durability	<ul style="list-style-type: none"> • Excellent build quality • Exceptional performance and amazing battery life • easy to disassemble and fix with 	9	5

	varieties of upgradable components		
Environmental standards	<ul style="list-style-type: none"> • Full lineup Energy Star 5.0 • VESA with mercury free low halogen monitor¹⁸ • EPEAT Gold rated commercial monitors¹⁸ • TCO certified with zero virgin plastics¹⁸ • GREENGUARD¹⁸ • NORDIC ECOLABEL¹⁸ 	10	2.2
Waste management by manufactures	<ul style="list-style-type: none"> • Plastic is diverted from landfills and resources and energy that would have gone into the manufacture of new plastics is conserved.¹⁸ • However e-waste management is not transparent and hard to track. Many Companies export hazardous e-waste to developing countries whereas Lenovo refuses to sign the commitment that promises not to do so.¹⁵ 	8	0.6
Environmental Score	Due to weighted score, Durability out weights other aspects.		9.5

3.2.4 Social Evaluation

Criteria	Description	Score (1-10)	Weighted Score
Worker Health and Safety	<ul style="list-style-type: none"> • There is no available information regarding the number of weekly work hours. • Lenovo provides training programs for employees. • The Lenovo Code of Conduct provides a list of guidelines that protects the privacy of its employees and upholds their health, safety and security.²¹ 	6	1.32
Employment Ethics	<ul style="list-style-type: none"> • The Lenovo Code of Conduct provides a list of ethical guidelines that promote fair treatment and discourages acts of harassment and discrimination.²¹ • Lenovo does not actively promote the use of conflict-free materials. 	6	0.60
Use of Conflict Free Materials	<ul style="list-style-type: none"> • Lenovo has a conflict mineral policy which states the actions the company is taking to inform its suppliers about conflict minerals.²² 	4	0.40

	<ul style="list-style-type: none"> • Lenovo is active in the EICC smelter audit process.¹⁰ • Lenovo has no internal policy on conflict minerals. • Lenovo has not publicly committed to implement the OECD due diligence guidelines.¹⁰ • The Enough Project ranked Lenovo 19th for their efforts towards reducing the use of conflict materials and listed the manufacturer as middle-tier.¹⁶ The score assigned is mainly based on the manufacturer's relative ranking here. 		
Auditing and Disclosure of Practices	<ul style="list-style-type: none"> • Lenovo does most of its auditing internally and publishes an annual report that is available online.¹⁷ • An external, independent audit is also conducted and is published in the annual report. 	9	4.06
Social Score	-	-	6.38

3.3 HP TouchSmart 11z

3.3.1 Functional Evaluation

Criteria	Laptop Specifications	Score (1-10)	Weighted Score
Portability	Weight: 3.3 lbs	9	1.44
Battery life	Maximum battery run time: 5:06	6	1.08
CPU performance	Processor speed: 1.0 GHz	2	0.6
RAM size	Standard memory: 4 GB	7	1.47
Storage capacity	Storage size: 500 GB	10	1.5
Functional score			6.09

3.3.2 Economic Evaluation

Criteria	Description	Score	Weighted Score
Purchase Cost	\$429	7.7	5.78
Power Consumption	21 Watts	9.3	2.33
Economic score			8.11

3.3.3 Environmental Evaluation

Criteria	Description	Score (1-10)	Weighted Score
Material and Recyclability	<ul style="list-style-type: none"> HP's DfE program drives us to reduce the amount of product materials and increase energy efficiency, and ensures that our suppliers meet our high standards. Efficient operations can save energy and reduce waste. 	9	1.6
Durability	<ul style="list-style-type: none"> mid range specs for budget consumers durable build with long lasting battery life Solid touch-screen that suits for windows 8 	5.5	2.5
Environmental standards	<ul style="list-style-type: none"> HP's Power Management Technology can reduce PC energy use by up to 45% HP estimates that in 2008 the total energy saved by HP Power Management Technology in consumer PC products alone was 350,000,000 kg of CO₂—equivalent to removing 76,000 cars from the road for one year. ENERGY STAR qualified 	9	2
Waste management by manufactures	<ul style="list-style-type: none"> HP Consumer Buyback and Planet Partners Recycling Program reduces the amount of electronics in landfills by refurbishing technology for further use or safely recycling it. HP offers U.S. customers a variety of convenient product reuse and responsible end-of-life programs. However e-waste management is not transparent and hard to track. Many Companies export hazardous e-waste to developing countries whereas hp refuse to sign the commitment that promises not to do so. 	7	0.6
Environmental score	Due to weighted score, Durability out weights other aspects.		6.7

3.3.4 Social Evaluation

Criteria	Description	Score (1-10)	Weighted Score
Worker Health and	<ul style="list-style-type: none"> HP actively promotes human rights, 	7	1.98

Safety	<p>implements policies of United Nations Declaration of Human Rights in its own code of conduct.¹⁹</p> <ul style="list-style-type: none"> HP has employee training programs for its management teams, yet does not offer an enhanced and high quality training to the rest of the workforce.²⁰ 		
Employment Ethics	<ul style="list-style-type: none"> HP actively works for ending employment of underage workers in its Chinese suppliers.¹⁹ The company promotes fair treatment of all workers, including migrants and students interns that are at risk.¹ 	7	0.70
Use of Conflict Free Materials	<ul style="list-style-type: none"> HP actively engages in EICC's conflict-free smelter program.⁹ The Enough Project ranked HP 2nd for their efforts towards reducing the use of conflict materials and listed the manufacturer as top-tier.¹⁶ The score assigned is mainly based on the manufacturer's relative ranking here. 	9	0.90
Auditing and Disclosure of Practices	<ul style="list-style-type: none"> HP has auditing of its practices done externally and was ranked as top for publishing and management of its suppliers.⁹ 	9	5.22
Social score	-	-	8.80

3.4 Dell XPS 12

3.4.1 Functional Evaluation

Criteria	Laptop Specifications	Score (1-10)	Weighted Score
Portability	Weight: 3.4 lbs	9	1.44
Battery life	Maximum battery run time: 6:49	7	1.26
CPU performance	Processor speed: 1.5 GHz	4	1.2
RAM size	Standard memory: 4 GB	7	1.47
Storage capacity	Storage size: 128 GB	3	0.45
Functional score	-	-	5.82

3.4.2 Economic Evaluation

Criteria	Description	Score	Weighted Score
Purchase Cost	\$1200	8.1	6.08
Power Consumption	41 Watts	4.5	1.13
Economic score			7.21

3.4.3 Environmental Evaluation

Criteria	Description	Score (1-10)	Weighted Score
Material and Recyclability	<ul style="list-style-type: none"> • Dell's industry-leading packaging solutions focus on reducing packaging volume, increasing the use of sustainable content.²⁶ • 3Cs – “cube, content and curb” – to accomplish a number of goals: reduce the size of all packaging by more than 12 percent; increase the amount of recycled and renewable content by up to 40 percent; and increase the ratio of materials ready for curbside recycling to 75 percent.¹⁵ 	9	1.6
Durability	<ul style="list-style-type: none"> • Excellent build quality with seamless table experience • software issues • lack of ports (no media card reader) • lack of space for upgrade • high cost in fixing • battery life is normal • touch-screen that suits for windows 8 	5	2.3
Environmental standards	<ul style="list-style-type: none"> • EPEAT-registered • Doubled the number of facilities that use 100 percent renewable energy²⁶ 	8	1.7
Waste management by manufactures	<ul style="list-style-type: none"> • Around the globe, dell offers easy, responsible recycling options for businesses and free options for consumers, which help keep more electronic equipment out of landfills²⁶ • However e-waste management is not transparent and hard to track. Many Companies export hazardous e-waste to developing countries whereas apple refuse to sign the commitment that promises not to do so.¹⁵ 	7	0.6
Overall	Due to weighted score, Durability outweighs other aspects.		5.8

3.4.4 Social Evaluation

Criteria	Description	Score (1-10)	Weighted Score
Worker Health and Safety	<ul style="list-style-type: none"> Dell suppliers in China have been found to work for up to 74 hours amid health risks.¹² Dell is allegedly in the process of auditing the suppliers mentioned in the report.¹² 	4	0.88
Employment Ethics	<ul style="list-style-type: none"> According to Dell's Code of Conduct, Dell promotes fairness, respect and the avoidance of harassment in the workplace.⁴ Dell's Code of Conduct promotes compliance with US trade regulations and reports information regarding the place of manufacture and cost of imported products.⁴ 	9	0.9
Use of Conflict Free Materials	<ul style="list-style-type: none"> Dell launched a conflict-free smelter assessment program in 2011 to ensure that they are using responsibly sourced materials.¹² The Enough Project ranked Dell 8th for their efforts towards reducing the use of conflict materials and listed the manufacturer as top-tier.¹⁶ The score assigned is mainly based on the manufacturer's relative ranking here. 	8	0.8
Auditing and Disclosure of Practices	<ul style="list-style-type: none"> An internal audit committee conducts audits and publishes reports that are available for the public.⁵ 	7	4.06
Social score	-	-	6.64

3.5 Overall Scores

A summary of all the categorical scores for each laptop is shown in the table below. Note that, if we were to simply compare the functional scores of the four laptop brands, MacBook Pro 13-inch would emerge as the clear winner. However, taking the economic, environmental and social categories into consideration, Lenovo ThinkPad X240 ended up with the highest overall score.

Laptop Unit	Functional Score	Economic Score	Environmental Score	Social Score
MacBook Pro 13-inch With Retina Display	7.62	3.15	8.60	7.34
Lenovo ThinkPad X240	6.84	6.75	9.50	6.38
Dell XPS 12	5.82	8.11	5.80	6.64
HP TouchSmart 11z	6.09	7.21	6.70	8.80

Table 13: Summary of categorical scores for all laptop units

Laptop Unit	Weighted Functional Score	Weighted Economic Score	Weighted Environmental Score	Weighted Social Score	Overall Score
MacBook Pro 13-inch With Retina Display	3.05	0.79	1.55	1.25	6.63
Lenovo ThinkPad X240	2.74	1.69	1.71	1.08	7.22
Dell XPS 12	2.33	2.03	1.04	1.13	6.53
HP TouchSmart 11z	2.44	1.80	1.21	1.50	6.94

Table 14: Summary of overall scores

5 CONCLUSION

This investigation resulted in a systematic and comprehensive scoring system that can evaluate laptop brands based on functional, economic, environmental and social criteria. This scoring system, called the Quadruple Bottom Line (QBL) evaluation, was developed by integrating the traditional approach to evaluating laptops with the the Triple Bottom Line concept. Using survey results, as well as findings from our own research, we were able to develop and assign weights to different criteria for each of the four categories. By assigning weights to the categories themselves, we were able to calculate the overall scores for each laptop unit. According to the QBL approach, Lenovo ThinkPad X240 is the best laptop out of the four units considered in this investigation. Interestingly, this was a different result from the evaluation made by Avram Piltch in his online article which preferred MacBook Pro 13-inch with Retina Display. It is important to note that, in Piltch's article, the only category that was under consideration was functionality.

Although the outcome of this investigation met the objectives that were initially set out, there is still plenty of room for improvement. There is a wide array of other criteria that can also be considered for each category. We opted for at most five criteria for each category in this investigation for the purpose of simplicity and to demonstrate the use of the weighted decision matrix. As well, since we only managed to include 20 people in the survey, a smaller number of criteria to be ranked would certainly produce more meaningful results. Other criteria that may be investigated for future studies are listed below:

- Functional Category
 - Display and backlight technology
 - Graphics
- Economic Category
 - Life expectancy associated with the cost
 - Repair costs
- Environmental Category
 - Efficiency of the manufacturing process
 - Type of battery that is used
- Social Category
 - Contract terms and expectancies of manufacturers from their suppliers
 - Employee evaluations of the manufacturers

The QBL approach developed in this project can serve as a guide for prospective laptop purchasers. However, the weights assigned to each criteria for every category were determined from a survey of only 20 students. Therefore, the results may not be representative of the personal preferences of a typical university student. Ultimately, it should be up to the user to decide on the weights to assign to each category and criteria. A template on the Appendix shows how the QBL evaluation can be used, but with user-defined criteria and weights.

6 REFERENCES

1. Apple - Supplier Responsibility. (n.d.). *Apple - Supplier Responsibility*. Retrieved February 11, 2014, from <http://www.apple.com/supplier-responsibility/>
2. *Computer Power Usage*. Penn Information Systems & Computing, n.d. Web. Retrieved March 14, 2014.
3. Campbell, M. (2013, January 24). Apple terminates contract with supplier after audit finds underage labor violations. *Apple terminates contract with supplier after audit finds underage labor violations*. Retrieved March 21, 2014, from <http://appleinsider.com/articles/13/01/25/apple-severs-ties-with-chinese-supplier-after-audit-finds-74-cases-of-underage-worker-violations>
4. Dell - Code of Conduct External. (2012). *Dell Code of Conduct*. Retrieved March 22, 2014, from <http://i.dell.com/sites/doccontent/corporate/corp-comm/en/Documents/Dell-Code-of-Conduct-External.pdf>
5. Dell DEF 14A. (2008, June 2). *Dell - Report of the Audit Committee*. Retrieved March 21, 2014, from http://www.wikinvest.com/stock/Dell_%28DELL%29/Report_Audit_Committee
6. Frost, S., & Burnett, M. (2007). Case study: the Apple iPod in China. *Corporate Social Responsibility and Environmental Management*, 14(2), 103-113.
7. Greenpeace - Guide to greener electronics: Apple. (n.d.) *Greenpeace guide to greener electronics: Apple*. Retrieved February 16, 2014, from <http://www.greenpeace.org/international/Global/international/publications/climate/2012/GuideGreenerElectronics/Apple.pdf>
8. Greenpeace - Guide to greener electronics: Dell. (n.d.) *Greenpeace guide to greener electronics: Dell*. Retrieved February 16, 2014, from <http://www.greenpeace.org/international/Global/international/publications/climate/2012/GuideGreenerElectronics/Dell.pdf>
9. Greenpeace - Guide to greener electronics: HP. (n.d.) *Greenpeace guide to greener electronics: HP*. Retrieved February 16, 2014, from <http://www.greenpeace.org/international/Global/international/publications/climate/2012/GuideGreenerElectronics/HP.pdf>
10. Greenpeace - Guide to greener electronics: Lenovo. (n.d.) *Greenpeace guide to greener electronics: Lenovo*. Retrieved February 16, 2014, from <http://www.greenpeace.org/international/Global/international/publications/climate>

/2012/GuideGreenerElectronics/LENOVO.pdf

11. Holme, R., & Watts, P. (2000). *Corporate social responsibility: making good business sense*. Conches-Geneva, Switzerland: World Business Council for Sustainable Development.
12. Hern, A. (2013, November 6). Dell suppliers accused of human rights violations in China. *The Guardian*. Retrieved March 21, 2014, from <http://www.theguardian.com/technology/2013/nov/06/dell-suppliers-accused-of-human-rights-violations>
13. *HP helps you "Go Green"*. (2011). Retrieved from <http://h71036.www7.hp.com/hho/cache/573579-0-0-225-121.html>
<http://i.dell.com/sites/doccontent/corporate/corp-comm/en/Documents/Dell-Code-of-Conduct-External.pdf>
http://www.lenovo.com/ww/lenovo/pdf/report/E_099220130531d.pdf
14. Jeremy Crouse, Andrew Gudmundsen,, Alex Robb, & John Uhl (n.d.). *How It's Made: Macbook Pro Unibody*. Retrieved from <http://mfg.eng.rpi.edu/gmp/SProjectsPwrpt/s10/Macbook%20Pro%20Presentation.pdf>
15. Jeff Bertolucci, Macworld. (2009, August 21). *How green is Apple: Where does the e-waste go? | Macworld*. Retrieved from <http://www.macworld.com/article/1140122/greenapple3.html>
16. Lezhnev, S., & Hellmuth, A. (2012, August 16). Taking Conflict Out of Consumer Gadgets: Company Rankings on Conflict Minerals 2012. *Enough*. Retrieved March 30, 2014, from <http://www.enoughproject.org/publications/taking-conflict-out-consumer-gadgets-company-rankings-conflict-minerals-2012>
17. Lenovo - Transforming Lenovo for the PC+ Era. (n.d.). *Lenovo- 2012/13 Annual Report Lenovo Group Limited*. Retrieved February 16, 2014, from http://www.lenovo.com/ww/lenovo/pdf/report/E_099220130531d.pdf
18. *Lenovo - Green*. (2011). Retrieved from http://shop.lenovo.com/ISS_Static/WW/EMEA/merchandising/sitelets/Lenovo-Green/en/uk/
19. Living Progress. (n.d.). *Global Citizenship: Human rights*. Retrieved February 12, 2014, from <http://www8.hp.com/us/en/hp-information/global-citizenship/society/humanrights.html>
20. Learning and development. (n.d.). *HP Global Citizenship Report: Employee learning and development*. Retrieved February 15, 2014, from

<http://www.hp.com/hpinfo/globalcitizenship/08gcreport/employees/learning.html>

21. Lenovo - Code of Business Conduct. (n.d.). *Lenovo - Code of Business Conduct*. Retrieved February 11, 2014, from https://www.lenovo.com/social_responsibility/us/en/2011_Lenovo_CodeofBusinessConduct_EN.pdf
22. Lenovo - Conflict minerals statement. (n.d.). *Lenovo - Conflict minerals statement*. Retrieved February 16, 2014, from https://www.lenovo.com/social_responsibility/us/en/Conflict_minerals_statement.pdf
23. MacDailyNews. (2009, February 27). *Apple hires Ernst & Young to replace KPMG as independent accounting firm* -. Retrieved March 21, 2014, from <http://macdailynews.com/2009/02/27/apple>
24. Piltch, A. (n.d.). Best Laptops 2014. *Best Laptop 2014*. Retrieved February 15, 2014, from <http://www.laptopmag.com/best-laptops.aspx>
25. Smith, M. (2011). *Laptop buying guide 2011*. Retrieved from http://manuals.makeuseof.com.s3.amazonaws.com/for-mobile/MakeUseOf.com_-_Laptop_Guide_2011.pdf
26. Tracey Schelmetic. (2013, January 15). Dell Turns To Nature for Green Packaging Initiative | Industry Market Trends. Retrieved from <http://news.thomasnet.com/IMT/2013/01/15/dell-turns-to-nature-for-packaging-initiative/>

7 APPENDIX

The orange highlighted cells indicate user-defined parameters. The blue highlighted cells indicate calculated parameters.

Category						
Functional	Category Weight	Category Score (1-10)				Category Weighted Score
		Criteria	Criteria Weight	Criteria Score (1-10)	Criteria Weighted Score	
		Criteria 1				
		Criteria 2				
		Criteria 3				
		Criteria 4				
		Criteria 5				
		Functional score				
Economical	Category Weight	Category Score (1-10)				Category Weighted Score
		Criteria	Criteria Weight	Criteria Score (1-10)	Criteria Weighted Score	
		Criteria 1				
		Criteria 2				
		Criteria 3				
		Criteria 4				
		Criteria 5				
		Economical score				
Environmental	Category Weight	Category Score (1-10)				Category Weighted Score
		Criteria	Criteria Weight	Criteria Score (1-10)	Criteria Weighted Score	
		Criteria 1				
		Criteria 2				
		Criteria 3				
		Criteria 4				
		Criteria 5				
		Environmental Score				

Social	Category Weight	Category Score (1-10)				Category Weighted Score
		Criteria	Criteria Weight	Criteria Score (1-10)	Criteria Weighted Score	
	Criteria 1					
	Criteria 2					
	Criteria 3					
	Criteria 4					
	Criteria 5					
	Social score					
Overall Score						