Executive Summary

In this thesis, real options are used to identify the optimal model (in terms of cost and risk) for the reverse logistics process of a technology company in the circuit board business. The motivation of this thesis is to demonstrate how real options can be applied to logistics problems, as more and more of these logistics problems have uncertain factors, such as globalization and high product life cycle. This thesis also shows how different methodologies can be applied in a complementary manner to solve a logistics problem. Specifically, the news vendor approach, Monte Carlo simulations, discounted cash flow analysis, and real options analysis go hand in hand to evaluate different operational models.

The current reverse logistics process model is that customers return defective boards and then the company repairs the boards and sends them back. This can be called the repair model. Now that the new product cost is falling below the level of the repair cost, the company is considering an alternative operational model, which is to scrap the returned boards and swap them with new products. This is called the swap model. Another possibility is to use the repair model as the main process and the swap model as an option or vice versa.
What makes it difficult to determine the optimal model is uncertainty in product cost and return volume. As the product cost declines, it is also widely fluctuating (see Figure 1). Because of this fluctuation, neither of the models is always optimal. Additionally, there are economies of scale in the repair model due to its high fixed costs. This makes it even more complicated to determine the optimal model.

Figure 1.

Figure 2.
Taking these uncertainties into consideration, the research questions are identified as follows:

- What is the optimal model, considering the trend and volatility of the repair cost, the new product cost, and the volume?
- What are the cost savings and risks associated with different models over the next few years?
- What is the value of using the switching option between the repair and new product swap models?
  How much should be paid to obtain this option?
- How robust is the optimal model when the variables deviate from the forecasts and assumptions?

The steps for analysis in this thesis is as follows (see Figure 3):

**Figure 3.**

1. **News Vendor Approach**
   - News vendor approach for multi-product families.
   - The optimal order quantity for new products swap volume.

2. **Discounted Cash Flow Analysis**
   - Optimal swap volume from the news vendor approach.
   - Sensitivity Analysis to identify key drivers of the project.

3. **Monte Carlo Simulation**
   - Simulation is within discounted cash flow analysis
   - Probability distribution of the key drivers identified in sensitivity analysis
   - Identify volatility of each model.

4. **Real Options Analysis**
   - Volatility from Monte Carlo simulation
   - Present value of each operational model with switching option
   - Sensitivity analysis to evaluate robustness.

The inventory of new product (to be replaced with return products) is determined at the beginning of the new product release. In order to identify optimal order quantity, the news vendor approach is used. The approach is applied for multi-product families because during the life cycle of a product family, another product family is released. After optimal order quantity is determined for each product, the
quantity across product families is aggregated. Then, the new product swap volume becomes an input to the discounted cash flow analysis.

Discounted cash flow analysis is performed to obtain the present value of total costs over the next three years for the repair model and the swap model respectively (the growth assumptions in the next three years are made for volume, product unit cost, and repair unit cost). The hybrid model of repair and swap is evaluated through DCF analysis and the result shows that both the repair everything model and the swap everything model are more cost effective than the hybrid model because of the economies of scale in the repair everything model and the advantage of no fixed costs in the swap everything model. Sensitivity analysis is conducted and the key drivers for the reverse logistics process are identified as volume, product unit cost, and repair unit cost.

Probability distribution of the key drivers is assigned so that a Monte Carlo simulation can be performed. The purpose of the simulation is to identify the volatility of the repair and swap models. This volatility shows how difficult it is to forecast the growth in costs of each model in the next three years. Volatility is the standard deviation of the growth of the present value. To put it simply, volatility represents “risk.”

Volatility is the key input for real options analysis. The analysis identifies the present value for the repair model with a swap option and for the swap model with a repair option. Therefore, the analysis quantifies the value of option (e.g., the present value of the repair everything model minus the present value of the repair model with a switching option to swap). The value can be taken as the maximum investment to obtain such options. It is always good to keep options, but you will never know how much you should invest to obtain options if you do not know the value.
As a result of real options analysis, the swap model with the switching option to repair is determined to be optimal and has only modest risk (see Table 1). Specifically, the costs would be reduced by $1.3 million (of which $0.9 million is the option value) and by 18% compared to the costs under the current model, and the volatility will moderately increase from 8% to 11%.

Table 1.

*all in $’000*

<table>
<thead>
<tr>
<th>Result Summary</th>
<th>PV</th>
<th>Volatility</th>
<th>Best case</th>
<th>Worst case</th>
<th>Option value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair everything model</td>
<td>$7,083</td>
<td>8%</td>
<td>$4,383</td>
<td>$11,447</td>
<td>NA</td>
</tr>
<tr>
<td>Repair model with option to swap</td>
<td>$6,094</td>
<td>10%</td>
<td>$2,669</td>
<td>$11,447</td>
<td>$989</td>
</tr>
<tr>
<td>Swap everything model</td>
<td>$6,710</td>
<td>16%</td>
<td>$2,569</td>
<td>$17,524</td>
<td>NA</td>
</tr>
<tr>
<td>Swap model with repair option to repair</td>
<td>$5,807</td>
<td>11%</td>
<td>$2,569</td>
<td>$11,547</td>
<td>$903</td>
</tr>
</tbody>
</table>

Key sensitivities are the switching cost and volatility that can change the optimal model to the repair model with a swap option. Therefore, it is important to monitor these sensitivities. Additionally, other sensitivities related to volume and unit cost also change the present value of each model, as well as the option value. In many cases, the repair model with an option to swap can be optimal.

Practically, switching options can be fully exploited only when both quality data to identify an optimal model and incentive systems to exercise options are available. Thus, it is important to establish such flexibility in the reverse logistics process operations.

Finally, the weaknesses of real options are as follows: assuming no-arbitrage is not reasonable in a real asset project, the maturity period is often hard to identify, and real options analysis does not address the timing of exercising options. The refinement of real options should be an area for further research.