**ALY6050 Introduction to Enterprise Analytics**

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Module 6

Optimization Problems

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# INTRODUCTION

This project contains two separate analyses using non-linear programming methods to optimize a business model. In the first analysis, the goal is to optimize shipping plans for both direct and indirect shipments to minimize costs for the company. In the second, an investment portfolio will be optimized for minimizing risk across a range of investments mixes, based around the expected return of each part of the portfolio. These are demonstrations of vital analytical methods that represent essential skill sets for business analysts.

# Analysis

## Part 1 – Rockhill Shipping and Transportation Company

The first project comes from Allen, a manager from the South-Atlantic office of Rockhill Shipping and Transportation Company. Allen is negotiating a new shipping contract with Chimotoxic, an industrial chemical manufacturer. Chimotoxic wants to contract with Rockhill to pick up and remove barrels of waste products from their six plants and deliver them to three different disposal sites. There are many safety and regulatory concerns when shipping these types of materials but also, Chimotoxic is looking to minimize the cost of transportation for these barrels.

Allen has gathered data on the cost per barrel for transporting between each plant and each waste disposal site

|  |  |  |  |
| --- | --- | --- | --- |
|  | ***Waste Proposal Site*** | | |
| **Plant:** | ***Orangeburg*** | ***Florence*** | ***Macon*** |
| **Denver** | $12 | $15 | $17 |
| **Morganton** | 14 | 9 | 10 |
| **Morrisville** | 13 | 20 | 11 |
| **Pineville** | 17 | 16 | 19 |
| **Rockhill** | 7 | 14 | 12 |
| **Statesville** | 22 | 16 | 18 |

As well as the amount of waste generated by each plant per week.

|  |  |
| --- | --- |
| **Plant:** | ***Waste per Week (bbl)*** |
| **Denver** | 45 |
| **Morganton** | 26 |
| **Morrisville** | 42 |
| **Pineville** | 53 |
| **Rockhill** | 29 |
| **Statesville** | 38 |

Allen also obtained the weekly maximum amount (in barrels) that each disposal site could manage.

|  |  |
| --- | --- |
| **Waste Disposal Site** | ***Max Capacity per Week (bbl)*** |
| **Orangeburg** | 65 |
| **Florence** | 80 |
| **Macon** | 105 |

With this data gathered, a non-linear programming model can be created. The decision variables for the model are represented by the number of barrel travel from each of the six plants to each of the three disposal sites, this creates 18 different pairs. The goal of the model is to minimize the cost of moving all waste barrels from each plant to a disposal site by optimizing the mix of the different pairs. The constraints on the model are represented by the weekly waste generated by each plant and the maximum capacity of each disposal site (as shown in the tables above). In setting up the mathematic representations of these constraints, equality is applied to the waste production of each plant and inequality is used for the disposal site max capacity, specifically a less than or equal to inequality. A non-negativity constraint is also assumed. Using the Excel Solver functionality with these parameters, the following optimized table is created.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | ***Waste Disposal Site*** | | |  | | |
| **Plant:** | ***Orangeburg*** | ***Florence*** | ***Macon*** | **Total Barrels** |  | **Waste per Week (bbl)** |
| **Denver** | 41 | 1 | 3 | 45 | = | 45 |
| **Morganton** | 0 | 0 | 26 | 26 | = | 26 |
| **Morrisville** | 0 | 0 | 42 | 42 | = | 42 |
| **Pineville** | 0 | 53 | 0 | 53 | = | 53 |
| **Rockhill** | 24 | 0 | 5 | 29 | = | 29 |
| **Statesville** | 0 | 26 | 12 | 38 | = | 38 |
| **Total Barrels to** | 65 | 80 | 88 |  |  |  |
|  | ≤ | ≤ | ≤ |  |  |  |
| **Max Capacity** | 65 | 80 | 105 |  |  |  |

The optimized solution sends 65 barrels to Orangeburg, 80 to Florence, and 88 to Macon. These are all less than or equal to their maximum capacity, and all six plants have the entirety of their waste barrels removed each week. The total cost for this model is $2,988.00

Allen is also considering utilizing each of the plants and waste disposal sites as intermediate shipping sites, where barrels can be dropped off, collected, and reshipped to a final processing plant. This would allow for shorter trips and hopefully, more efficient shipping. He has provided the cost per barrel for shipping between sites to accommodate another model. Again, using the Excel Solver tool, the following optimization table has been created to fit the new transshipment model.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Denver** | **Morganton** | **Morrisville** | **Pineville** | **Rockhill** | **Statesville** | **Orangeburg** | **Florence** | **Macon** | **Total** |  |  |
| **Denver** | 0 | 0 | 0 | 0 | 0 | 45 | 0 | 0 | 0 | 45 | = | 45 |
| **Morganton** | 0 | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 26 | = | 26 |
| **Morrisville** | 0 | 0 | 0 | 42 | 0 | 0 | 0 | 0 | 0 | 42 | = | 42 |
| **Pineville** | 0 | 0 | 0 | 0 | 53 | 0 | 0 | 0 | 0 | 53 | = | 53 |
| **Rockhill** | 0 | 0 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 29 | = | 29 |
| **Statesville** | 0 | 0 | 0 | 0 | 38 | 0 | 0 | 0 | 0 | 38 | = | 38 |
| **Orangeburg** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ≤ | 65 |
| **Florence** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ≤ | 80 |
| **Macon** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | ≤ | 108 |
| **Shipped to** | 0 | 0 | 0 | 71 | 91 | 71 | 0 | 0 | 0 |  |  |  |
|  | = | = | = | = | = | = | ≤ | ≤ | ≤ |  |  |  |
|  | 45 | 26 | 42 | 53 | 29 | 38 | 65 | 80 | 105 |  |  |  |

This new model contains the same constraints from before but now considers the cost of shipment between both the first and potentially second plant before final shipment to the disposal site. This model maintains the same equality and inequality metrics as the original to ensure all barrels are removed from the plants and that no disposal site receives more than their maximum capacity per week. The addition of the intermediate shipping sites has dramatically lowered the cost of waste removal, down from $2,988.00 in the original model to $960.00 in the second.

## Part 2 – Investment Allocation

For the second analysis, an investor has chosen a list of investment types and has presented an expected return on each type, based on historical performance.

|  |  |
| --- | --- |
|  | **Expected Returns** |
| **Bonds** | **7%** |
| **High tech stocks** | **12%** |
| **Foreign stocks** | **11%** |
| **Call options** | **14%** |
| **Put options** | **14%** |
| **Gold** | **9%** |

A covariance table of each assets’ returns has also been created. The variances, highlighted in gray, were provided and the remaining covariances were manually calculated.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Bonds** | **High tech stocks** | **Foreign stocks** | **Call options** | **Put options** | **Gold** |
|  |
| **Bonds** | **0.001** | **0.0003** | **0.0003** | **0.00035** | **-0.00035** | **0.0004** |
| **High tech stocks** | **0.0003** | **0.009** | **0.0004** | **0.0016** | **-0.0016** | **0.0006** |
| **Foreign stocks** | **0.0003** | **0.0004** | **0.008** | **0.0015** | **-0.0055** | **-0.0007** |
| **Call options** | **0.00035** | **0.0016** | **0.0015** | **0.012** | **-0.0005** | **0.0008** |
| **Put options** | **-0.00035** | **-0.0016** | **-0.0055** | **-0.0005** | **0.012** | **-0.0008** |
| **Gold** | **0.0004** | **0.0006** | **-0.0007** | **0.0008** | **-0.0008** | **0.005** |

This is a classic example of quadratic programing modeling as the investor is looking to minimize risk while maintaining a desired return. In the first scenario, the investor wishes to invest $10,000 with a minimum return of 11%.

The following table is the result of using the Excel Solver tool to minimize risk in the portfolio while maintain the 11% return on investment.

|  |  |  |  |
| --- | --- | --- | --- |
| **Investment Type** | **Investment $** | **Investment %** |  |
| **Bonds** | 1,763.67 | 0.18 |  |
| **High tech stocks** | 1,116.15 | 0.11 |  |
| **Foreign stocks** | 2,646.77 | 0.26 |  |
| **Call options** | 459.42 | 0.05 |  |
| **Put options** | 2,517.65 | 0.25 |  |
| **Gold** | 1,496.34 | 0.15 |  |
| **Total** | 10000 | 1 |  |
|  |  | Actual Return | 0.11 |
|  |  | Variance | 0.000794 |

To maintain the desired performance of the portfolio, the optimized solution invests heavily in foreign stocks (26%) and put options (25%), these two categories represent $5,164.42 of the entire $10,000 investment. The variance of this portfolio, the measurement of risk is 0.0794%.

In the second scenario, the investor wants to explore the relationship between expected returns on the entire portfolio and risk. Therefore, the Solver equation is run several times to create the following table.

|  |  |
| --- | --- |
| Target Return (e) | Minimized Risk (r) |
| 10.0% | 0.0610% |
| 10.5% | 0.0684% |
| 11.0% | 0.0794% |
| 11.5% | 0.0942% |
| 12.0% | 0.1130% |
| 12.5% | 0.1463% |
| 13.0% | 0.2098% |
| 13.5% | 0.3496% |

Which is also graphically represented here

From this representation it is clear that there is quadratic relationship between risk and return. There is not a sizeable risk difference between an investment mix with expected returns of 10% or 11.5% but that relationship levels off but beyond that, the increase in risk grows quickly.

# Conclusion

These types of optimization problems represent vital analytical skills for business analysts. In the case of Rockhill Shipping and Transportation Company, the ability to minimize cost of shipping for their clint represents a competitive advantage by being able to offer a competitive price for their services while ensuring core business needs are met for both parties. In the investment portfolio study, understanding the interplay of risk and return in an investment portfolio is fundamental for good investment strategy and portfolio management.

# References

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