# Introduction

There are many different types of models that can represent a prediction of the future given a data-set. This, however, becomes extremely difficult when there are high dimensional/high volumes of data entries. Thus, we introduce the *Monte Carlo* simulation. We will be discussing and analyzing a specific scenario: Kim's budget plan for post-grad using a Monte Carlo simulation because it is the adult thing to do. We will use the Monte Carlo simulation to improve an unsophisticated estimate process. The budget plan involves allocating a percentage of savings towards a new goal. This sample modeling problem of budgeting can be applied to many different scenarios, especially at a larger scale. Some of which are figuring out realistic commission rates for individual employee at a company where we can then draw conclusions to decide if it is a reasonable rate, how much of an impact it has on the overall company, if there should be budget cuts, or decision to lay employees off, etc. This problem is interesting because Kim does not know how to save money nor is she responsible with her money.

# 1 Situation

Below is a table of a sample budgeting plan based on a $65,000 salary; however, her job is based on projects where some months she would be paid more than others depending on the company's workload and time of the year. Each category has a target saving and an actual saving. Kim has a profound love for traveling but she has not been allocating any of her earnings towards a traveling fund. Because her monthly paycheck fluctuates from month to month, it is hard to predict how much percentage to allocate to this new traveling fund.

Monthly Budget

| Category | Target Saving | Actual Saving | Percentage to Plan | Percentage to allocate | Amount Allocated |
|---|---|---|---|---|---|
| Rent/utilities | $2,500.00 | $2,700.00 | 108% | 7% | $189.00 |
| Transportation | $150.00 | $145.00 | 97% | 2% | $2.90 |
| Food | $130.00 | $200.00 | 154% | 14% | $28.00 |
| Daily leisure | $300.00 | $190.00 | 63% | 0% | $0.00 |
| Student loans | $500.00 | $465.00 | 93% | 0% | $0.00 |
| Household/Personal care | $150.00 | $160.00 | 107% | 2% | $3.20 |
| Stocks | $200.00 | $250.00 | 125% | 7% | $17.50 |
| | | | | | |
| Total | $3,930.00 | $4,110.00 | | | $240.60 |

Table 1

The *Amount Allocated* is calculated by taking the *Percentage to allocate* of *Actual saving*. The *Percentage to allocate* is based on the following *Percentage to Plan* table:

| Rate Schedule | |
|---|---|
| 0-93% | 0% |
| 94-99% | 2% |
| 100-125% | 7% |
| >=126% | 14% |

# 2 Basic idea

Before we begin, let's look at similar plans without a rate schedule and fluctuation in *Actual Savings* where we create the *Percentage to allocate* by hand.

Monthly Budget

| Category | Target Saving | Actual Saving | Percentage to Plan | Percentage to allocate | Amount Allocated |
|---|---|---|---|---|---|
| Rent/utilities | $2,500.00 | $2,700.00 | 108% | 6% | $162.00 |
| Transportation | $150.00 | $135.00 | 90% | 6% | $8.10 |
| Food | $130.00 | $165.00 | 127% | 6% | $9.90 |
| Daily leisure | $300.00 | $200.00 | 67% | 6% | $12.00 |
| Student loans | $500.00 | $520.00 | 104% | 6% | $31.20 |
| Household/Personal care | $150.00 | $185.00 | 123% | 6% | $11.10 |
| Stocks | $200.00 | $300.00 | 150% | 6% | $18.00 |
| | | | | | |
| Total | $3,930.00 | $4,205.00 | | | $252.30 |

Table 2.1

Monthly Budget

| Category | Target Saving | Actual Saving | Percentage to Plan | Percentage to allocate | Amount Allocated |
|---|---|---|---|---|---|
| Rent/utilities | $2,500.00 | $2,650.00 | 106% | 3% | $79.50 |
| Transportation | $150.00 | $145.00 | 97% | 0% | $0.00 |
| Food | $130.00 | $175.00 | 135% | 12% | $21.00 |
| Daily leisure | $300.00 | $195.00 | 65% | 0% | $0.00 |
| Student loans | $500.00 | $350.00 | 70% | 5% | $17.50 |
| Household/Personal care | $150.00 | $125.00 | 83% | 18% | $22.50 |
| Stocks | $200.00 | $135.00 | 68% | 24% | $32.40 |
| | | | | | |
| Total | $3,930.00 | $3,775.00 | | | $172.90 |

Table 2.2

Monthly Budget

| Category | Target Saving | Actual Saving | Percentage to Plan | Percentage to allocate | Amount Allocated |
|---|---|---|---|---|---|
| Rent/utilities | $2,500.00 | $2,800.00 | 112% | 5% | $140.00 |
| Transportation | $150.00 | $165.00 | 110% | 0% | $0.00 |
| Food | $130.00 | $120.00 | 92% | 23% | $27.60 |
| Daily leisure | $300.00 | $310.00 | 103% | 0% | $0.00 |
| Student loans | $500.00 | $300.00 | 60% | 5% | $15.00 |
| Household/Personal care | $150.00 | $160.00 | 107% | 8% | $12.80 |
| Stocks | $200.00 | $215.00 | 108% | 11% | $23.65 |
| | | | | | |
| Total | $3,930.00 | $4,110.00 | | | $219.05 |

Table 2.3

The range of the *Percentage to allocate* and *Actual Savings* are useful. However, we chose each of the entries based on intuition. In a bigger situation, say a business, we would need to be able to choose these entries for over 500 categories. Section 2 represents a simple approach that illustrates the Monte Carlo simulation where the *Actual saving* were randomized as well as *Percentage to Allocate*. By this point, we can tell that it is extremely tedious and impractical to manually input the entries. Thus, we will use a Monte Carlo simulation using Python to make make this approach much faster and efficient.

# 3 Monte Carlo Model

There are two main components to a Monte Carlo simulation:

1. an equation to evaluate
2. random variables

**Overview:** For the sake of this project, we will be focusing on *Percentage to Plan* by randomly drawing samples from a predefined normal distribution. With those random samples, we will be able to calculate the potential *Actual Savings* by taking the (randomly picked) *Percentage to Plan* of the *Target Saving*. We will then iterate the random sampling 1500 times to create an ensemble of potential tables where we will be able to draw further conclusions.

**Defining variables:** To begin, we set the target performance centered around a mean of 100% and a standard deviation of 10%. This means that we will meet the target savings with a range of 0.1. We declare the number of iterations as 1500.

**Monte Carlo simulation:** In every iteration, we generate a random *Percentage to Plan* given the constraints that we defined. Then, we need to calculate the *Actual Savings*, *Percentage to Allocate* (using the Rate Schedule above), and *Target Savings*. In practice, taking the new calculations, we sum each categories and then divide it by the number of iterations. Below we see a sample table:

| | Pct_To_Target | Target_Savings | Actual_Savings | Percentage to Allocate | Amount Allocated |
|---|---|---|---|---|---|
| **0** | 0.83 | 2500 | 2075.0 | 0.00 | 0.000 |
| **1** | 0.91 | 150 | 136.5 | 0.00 | 0.000 |
| **2** | 0.99 | 130 | 128.7 | 0.02 | 2.574 |
| **3** | 0.98 | 300 | 294.0 | 0.02 | 5.880 |
| **4** | 1.02 | 500 | 510.0 | 0.07 | 35.700 |
| **5** | 0.97 | 150 | 145.5 | 0.02 | 2.910 |
| **6** | 1.20 | 200 | 240.0 | 0.07 | 16.800 |

Table 3.1

Lastly, we are interested in tracking the sum of each category and store it in a new dataframe in order to draw conclusions.

# 4 Conclusions

Using the new dataframe results, we can calculate the mean and standard deviations, as well as other measures.

| | Actual Savings | Amount Allocated | Target_Savings |
|---|---|---|---|
| **count** | 1,500.0 | 1,500.0 | 1,500.0 |
| **mean** | 3,930.0 | 172.0 | 3,930.0 |
| **std** | 255.0 | 91.0 | 0.0 |
| **min** | 3,161.0 | 5.0 | 3,930.0 |
| **25%** | 3,761.0 | 88.0 | 3,930.0 |
| **50%** | 3,936.0 | 205.0 | 3,930.0 |
| **75%** | 4,095.0 | 251.0 | 3,930.0 |
| **max** | 4,848.0 | 543.0 | 3,930.0 |

Table 4.1

This table makes sense because the *Target Savings* should be constant as we are not changing the goals for that column. We can see that the average *Actual Savings* is $3,930 and the average *Amount Allocated* is $172. This helps solve our original problem because despite the unpredictable fluctuation in paycheck that dispenses into *Actual Savings*, we can expect to have an average of $172 allocated to Kim's travel funds. These findings are important because we are able to say with confidence that it is not very likely allocate $500 or more towards her travel funds. To visualize this, we can create histogram graphs of the *Actual Savings* and *Amount Allocated*.

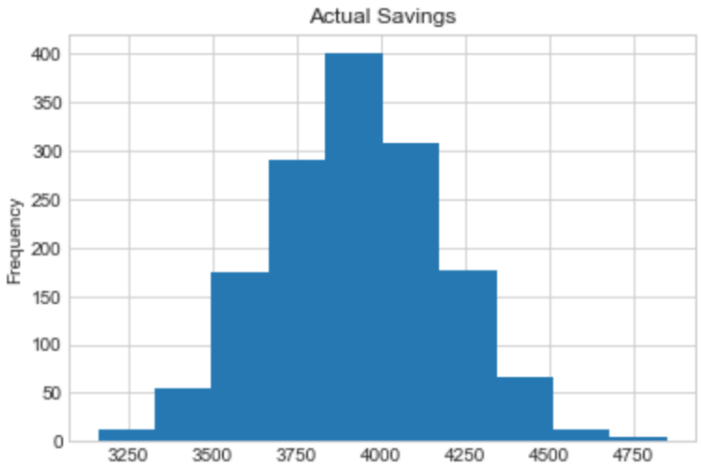


Table 4.2

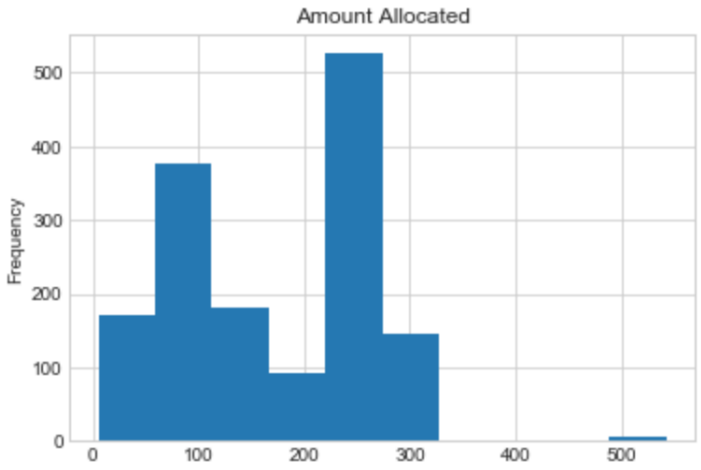


Table 4.3

We see that Table 4.2 is a normal distribution which is exactly what we expected. Table 4.3 represents the frequency of *Amount Allocated*. I'm actually unsure if that should be a normal distribution or not.

# 5 Comments

In hindsight, I think that this is a really nice way to figure out budgeting plans; however, if I had more resources and time, I would add a couple of constraints. I would like to give priority to each categories. Realistically, Rent/utilities, Transportation, Food, Household/Personal Care would have priority 3, meaning the rate of allocation will be a lot lower despite the percentage to plan is high. This is due to obvious reasons. These categories either have to be

paid on time in full (rent/utilities) or are essential to complete daily goals like going to work or eating. Student loans and stocks would have a priority 2 as they are important to me but there is some leeway room for budget cuts. Daily leisure would have priority 1 as they are activities like buying coffee, going out to bars, online shopping, etc. These activities can be easily cut with no consequences.

There are also many different things you can do with this model. We can add more categories, change the standard deviation to a higher amount, modify target distributions, etc. In the future, to take this model even further, I would like to explore the *Rate Schedule*. I think it would cool to apply the Monte Carlo simulation and try to draw conclusions altering the *Percentage to Allocate*, instead of having fixed rates.