Production Analysis for Reducing Operating and Labor Costs

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1. Introduction and Background

The motivation for this analysis is to provide some recommendations to the company's executive board to help reduce operating and labor costs for the manufacturing firm. The strategy under consideration is reallocation of lot sizes to some optimal efficiency range. We are assuming that lot size is directly proportional to the number of production equipment deployed in that respective operational setting.

Preliminary analysis reports inefficiencies in the current operational state. We define efficiency as optimizing the time it takes to manufacture one production unit in a typical factory setting. Manufacturing one production unit requires the deployment of resources collectively such as labor workforce, production equipment, lot size and costs associated in running an open facility (gas, water, electrical, etc.). This study aims to demonstrate the company can further reduce time spent per production unit by deploying an optimal lot size.

2. Data

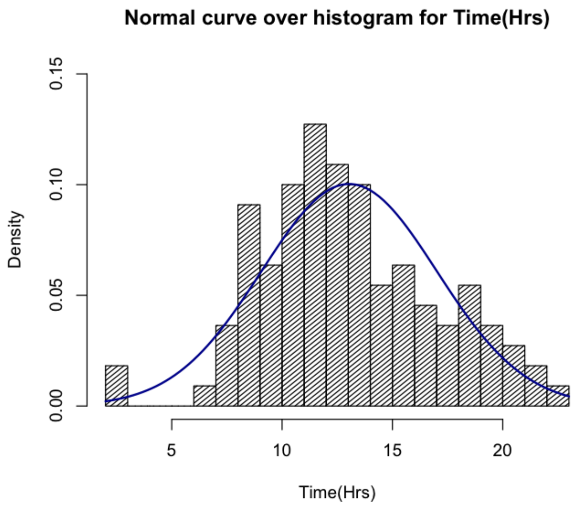
The head of production provided a bivariate data set "production time". Total number of observations collected was n=111. Each observation contained 2 variables: Time (measured in hours) and Lot size. In order to proceed with data analysis, it was also necessary to standardize the collected observations by introducing a third variable, Time per Lot size (TPL).

TPL was calculated to be the ratio of Time per Lot size per observation. TPL measures the operational setting observed at Y_i. One can think of TPL as the ratio of staff to equipment. We assume that time differences between employees in the amount of time it takes to output one production unit given all other variables fixed, is very small and negligible in the analysis. For completeness, the following descriptive statistics is provided below to gain some preliminary insight to the range of data values for each variable.

Variable 1: Time

Time is measured in hours. Each observation measures the total time spent per production unit under its respective setting.

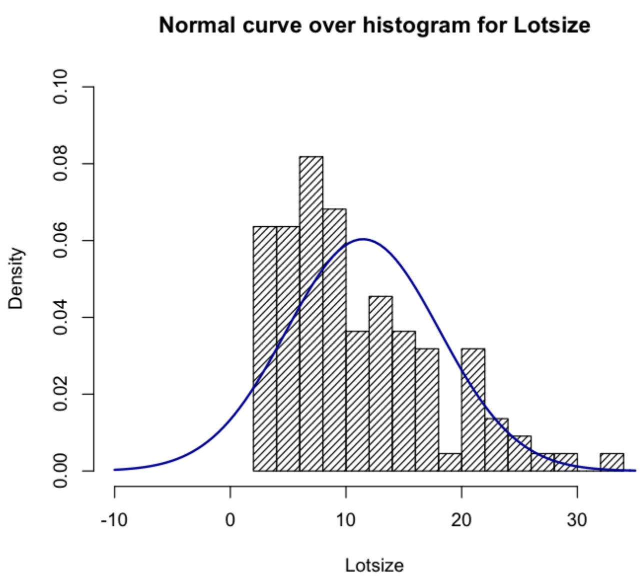
Figure 1.




```
summary(prod$Time)
 Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 2.53   10.64   12.47   13.04   15.74   22.35
```

Variable 2: Lot size
Each time measurement is coupled with a second variable, Lot size, which measures the size of the lot in the corresponding observational setting. The plot below suggests that lot size varies considerably from one setting to another in a non-normally distributed fashion.

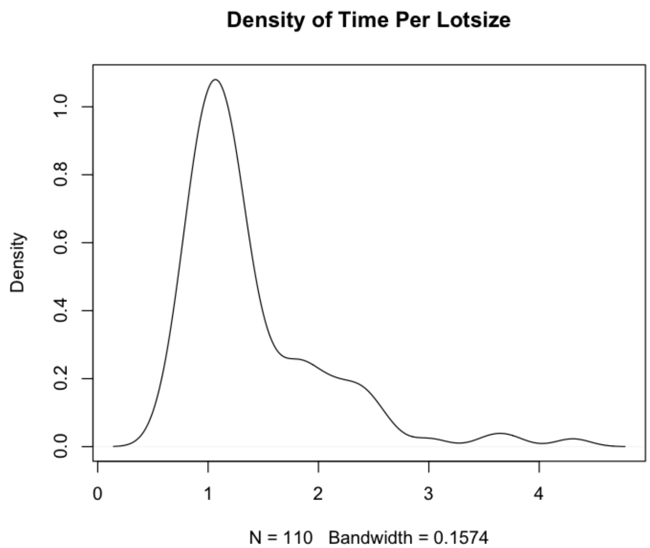
Figure 2.




```
summary(prod$Time)
 Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 2.53   10.64   12.47   13.04   15.74   22.35
```

Variable 3: Time per Lot Size (TPL):
Because observation #101 had a lot size value equal to 0, the record was censored from the data analysis, reducing the sample size by 1 to n=110. Observations with TPL values > 2.0 suggest operational inefficiencies because it takes at least twice as long to manufacture a production unit than those with TPL values <= 1.0.

Figure 3.



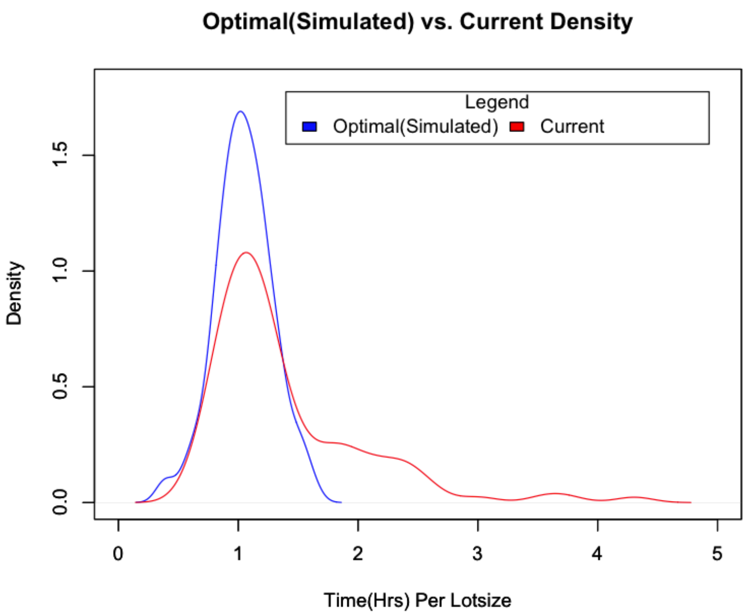
3. Methodology

The methodology assumes the company does not want to give up its *total* resources such as employees or lot size (equipment). Instead, the company wishes to maximize how these resources are deployed under a typical production setting.

In order to derive the optimal lot size, we first plot the density curve for TPL (the current state of operations) against some Optimal-TPL, a simulated normal density curve. The idea here is the company has already demonstrated some realizations having efficient settings at TPL values concentrated around the peak at TPL ≈ 1 (peak of red curve), but just needs to be consistent in implementing these optimal settings consistently. The goal is to adjust the lot sizes given an observed total time, particularly those observations having TPL values >= 2 (represented in the right-skewed red curve). The simulation resulted in 110 realizations of TPL values ranging in (0.3783, 1.6290). Simulations were done using R function: *rnorm* by setting the standard deviation parameter equal to 0.2264171. This value was chosen due to the fact that a normally distributed data set will have a probability coverage approximately equal to 95% ranging in values at approximately 2 standard deviations from both sides of its mean. (1.067834 – 0.615)/2 = 0.2264 is the difference of the TPL value at the peak of red curve and the minimum value to the left of the peak, which is taken to be approximately 1 standard deviation from 1.067834. This range was chosen because the curve visually resembles the left half of what appears to be a normally distributed curve.

```
> summary(opt.tpl)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.3783  0.9082  1.0440  1.0470  1.2010  1.6290
>
> summary(tpl)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.6150  0.9792  1.2060  1.3920  1.5790  4.3050
```

Figure 4.



The blue curve in figure 4 represents the *potential* distribution of a semi-optimal range of TPL values and red representing the current inefficiencies as evident in its right-skewed distribution. Remember, the analysis assumes the firm already deploys some efficient settings represented to the left of the red peak, but just needs to address the inefficiencies to the right of the red peak (TPLs > 1.6 for example).

The Optimization method:
The next step in the analysis was to manually fiddle with the actual observed Lot sizes. An excel spreadsheet was used to track which observations will gain and lose some lot size. Adjustments were done for each observation until the resulting TPL values fell between the range of 0.75 to 1.25 subject to the constraint, total Lot size =1262. The variable Time was left untouched for each observation.

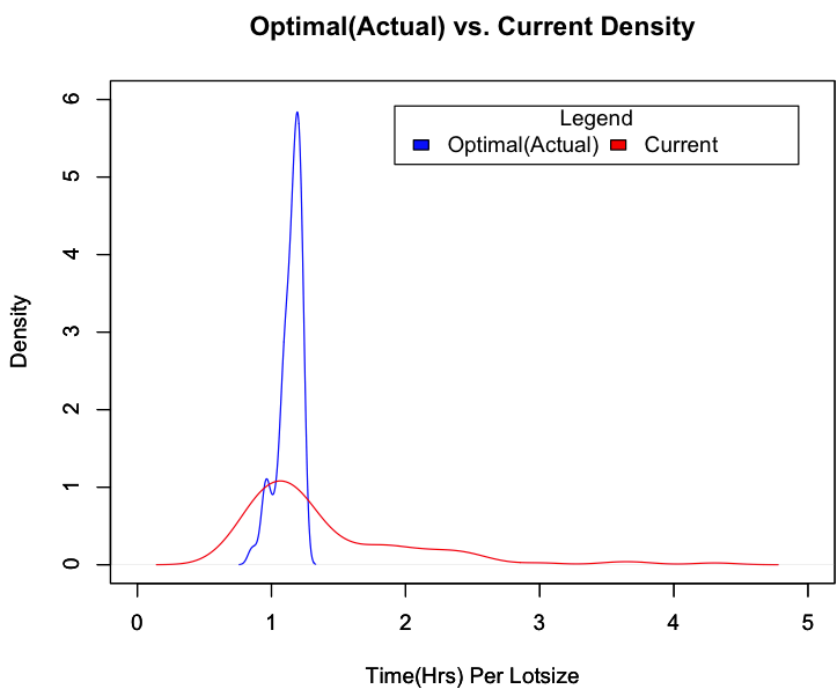
The Intuition behind the Optimization method:
For observations having high TPL values, we want to increase Lot size to decrease TPL. Such observations represent settings where equipment could be lacking due to limited availability of lots. Increasing lot size translates to having more equipment, therefore improving production throughput, thereby reducing labor cost by minimizing having to pay workers overtime to meet inventory goals. Another benefit is reducing production cost by mitigating unnecessary costs associated in keeping the facility open and functional during the extended hours.

For observations having low TPL values, we want to decrease lot size to increase TPL. Such observations represent settings where equipment is abundant (over-resourced setting) because of the large availability of lots to house the equipment. Decreasing lot size could help minimize workers being under-utilized in that there is just the right amount of equipment per worker to operate. One benefit is reduced labor cost in that the company is not "overpaying" under-utilized workers. Another benefit is reduced production cost by minimizing lost potential gains. In other words, the company would be maximizing equipment usage to its potential throughput.

4. Results

After several iterations using the Optimization method, the resulting TPL values were concentrated around 1.1931, which is identified to be the optimal value for TPL (see figure 5). The blue curve in Figure 5 appears more peaked than the simulated blue curve in Figure 4. This is due to the overall effects of reallocating more Lot sizes to those observations having relatively lower TPL values to begin with. The variance of TPL also decreased from 0.4283 to 0.0077 suggesting that factory settings to be more stabilized in the long run. Long-term stability is needed in sustaining an efficient production system.

Figure 5.



5. Conclusion and Discussion

TPL values were calculated for each observation by taking the ratio between Time and Lot size. The analysis describes how the Optimization method was able to demonstrate potential improvements in reducing operating and labor costs.

The Optimization method involves taking each observation, assessing its Lot size variable and determining whether to make any adjustments to yield a modified TPL values ranging in (0.75, 1.25). This range were determined to be the optimal range concentrated around 1.1931 hours per lot size with a variance of 0.0077 (variance before fiddling was 0.4283). Decreasing the variance by a factor of nearly 55 suggests that factory settings can potentially operate under more stable conditions in the long run subject to the current total resource constraints.