AN EMPLOYEE ASSIGNMENT OPTIMIZATION MODEL EXPLORING CROSS-TRAINING AND SPECIALIZATION THROUGH MULTIPLE MANAGEMENT STRATEGIES

by

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ABSTRACT

Company managers continually face challenges in the market, such as increased demand for their services and variability in the types of service requested. In addition, managers may face internal challenges during periods of adjustment such as moving the company forward through a hiring freeze. In these situations, a manager must be able to allocate their scarce resources in a way to continue to perform. For employees, this could mean specializing in tasks or increasing cross-training to improve work schedule flexibility. The objective of this research is to determine the optimal allocation of employees to tasks, given resource constraints and the need for staff flexibility, to satisfy alternative management strategies. The setting is the service industry, in particular a laboratory setting providing testing and consulting services.

An optimization model was developed to incorporate key aspects of a company's operation, and determine labor allocation among tasks, and for how many hours, to satisfy the manager's objective. The model estimates the optimal allocation of labor and how much production and net revenues would be generated, with more specialized employees. A sensitivity analysis was employed to determine the impact of cross-training current staff. Results indicate that cross-training affords flexibility; however, the impact on overall production varies depending on the employee trained. The highest benefit is derived from training a lower-producing employee into a high value task at a high productivity rate. Specialization can help

improve productivity in net returns for higher valued tasks, but may limit flexibility, as employees cannot switch between tasks as readily.

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CHAPTER I: INTRODUCTION

1.1 Problem Statement

Theodore Roosevelt once said: “Do what you can, with what you have, where you are (ThinkExist 2014).” His advice is quite relevant in today’s tough economic environment. The economic downturn that began in 2008 has forced companies to lay off staff, implement hiring freezes, and in some cases, leave vacant positions unfilled. Despite a stagnant or reduced workforce, a company must maintain, if not increase, their productivity to remain competitive in the ever-changing marketplace. Individual managers face increased pressure to generate more revenue with less manpower and fewer resources. In addition, when there is a smaller workforce, a manager must still ensure that they have sufficient staff with flexible skills to handle a variable workload with multiple task deadlines. This increased pressure to juggle the need for production and a flexible staff encourages managers to strategically analyze their employees’ expertise, and the tasks to be completed to determine how to delegate tasks for optimal productivity.

In private business, managers are familiar with supervising specialized employees, cross-trained employees, or a combination thereof. According to the Merriam Webster Online Dictionary (2014), a specialized employee is “designed, trained, or fit for a particular purpose or occupation.” Employees with specialized knowledge are highly valuable because they have an advanced level of expertise and knowledge of the company’s processes (US Department of Homeland Security, 2013). Specialized employees tend to strictly perform a given task. By repeatedly performing the same task, they gain mastery and become very efficient and highly productive. However, specialized employees may lack assignment and scheduling flexibility.

Cross-training affords a high level of assignment and scheduling flexibility. Brusco, et al. (1998) describe cross-training as using employees to satisfy labor needs beyond their primary skill, acknowledging that cross-training creates scheduling and staffing flexibility, and allows a manager to better handle varying product demands with more flexible labor resources. While a cross-trained employee allows for staffing flexibility, the flexibility comes at a cost of potentially reduced productivity. The productivity and flexibility characteristics of specialized and cross-trained employees can be categorized into low, average and high categories, as shown in Table 1.1.

Table 1.1 Comparison of Specialized and Cross-Trained Employees

	Productivity	Flexibility
Specialized Employee	High	Low
Cross-trained Employee	Average	High

A company with purely specialized employees may enjoy exceptionally high productivity; however, they may suffer from low staffing and decreased flexibility. Low staffing and decreased flexibility reduces the company's ability to fulfill obligations and accomplish task deadlines, especially when an employee is absent. A company runs the risk of losing customers when deadlines are missed; therefore, some staffing flexibility may be required. A company with purely cross-trained employees will enjoy high staffing flexibility with the ability to complete various tasks regardless if employees are absent. However, a company with purely cross-trained employees may experience lower productivity, which may not be as profitable. There are diminishing returns to cross-training each employee, as additional resources are required to cross-train. The more people cross-trained for a task lessens specialization on other tasks. A manager's decision is to determine how many resources they should devote to cross-training employees who have specialized strengths and which employees to cross-train.

A manager may find it habitual and nearly effortless to continue assigning tasks to employees as usual. While this method may work for a time, there is increasing pressure for managers to re-evaluate not only how they assign tasks to their employees, but also the department's need for cross-trained individuals, as the status quo changes. A manager that uses objective data to assist in decision-making and assigning tasks will be better equipped to maximize productivity and net returns for the company. The ability to increase productivity and net returns without increasing the workforce is crucial in today's economic environment. Determining how to best optimize one's workforce and task assignments is imperative to increase productivity and revenue without increasing labor costs. Providing management with a tool to determine staffing needs, of specialized verses cross-trained employees, in addition to the assignment of tasks to employees, will allow management to better utilize their staffing resources.

1.2 Purpose Statement and Objectives

The overall purpose of this thesis is to determine the optimal allocation of different tasks to employees and to assess the balance between cross-training and specialization on assigned tasks on this allocation. In this endeavor, management philosophy may impact the optimal allocation, so the optimal allocation is examined through various management strategies, including the maximization of productivity, maximization of revenue, minimization of labor cost, and maximization of net return. Each objective is achieved, while still allowing sufficient workforce flexibility to ensure all tasks are completed. The goal is to determine the optimal allocation of employees' hours and tasks to satisfy a particular management strategy. While determining the optimal allocation, it is imperative to incorporate a mix of both specialized and cross-trained employees, so as to retain productivity, while improving scheduling flexibility. To meet the above goal, the objectives of this study are to:

1. Develop an optimization framework to assess the optimal assignment of employees to tasks satisfying alternative management strategies, while allowing employees to specialize in different assigned tasks. The optimization model will help a manager determine how many hours each employee should be assigned to a given task to generate the maximum value for the company. The model will incorporate:
    a) Employees: their name, hourly wage (labor cost), and relative productivity rating for each task;
    b) Tasks: their name, value, and maximum output per hour;
    c) Constraints: the number of hours available to be assigned to each employee, as well as the minimum and maximum production levels for each task; and,
    d) Various management strategy objectives: While most managers prefer to maximize net return, it is important to note that company cultures vary and not all managers have the same objective. Therefore, four objectives are analyzed: maximize production, maximize revenue, minimize labor cost, and maximize net return.

2. Conduct sensitivity analysis to determine how a proposed change such as employee cross-training or hourly wage adjustments would impact the assignment of tasks. These sensitivity analyses will:

    a) Determine if cross-training increases net returns for the company, and if so, determine which employee(s) should be cross-trained, in which tasks. The optimization model will determine the optimal mix of employee training that maximizes net returns under various assumptions, but also considers missed deadlines due to employee absenteeism. The analyses will help a manager determine:

        - If cross-training should be implemented;
        - Which employees should be cross-trained, on which tasks; and,
        - How much will cross-training increase overall productivity; and

    b) Determine how adjusting an employee's hourly wage impacts the net return and optimal task assignment. A manager may propose adjusting an employee's hourly wage to bring it into parity with other employees' wages. However, the manager may desire to know how wage adjustment would impact the overall labor cost and net return. The sensitivity analysis will help a manager determine:

        - If an underpaid employee's wage is increased by X amount, how much would the company's net returns decrease?
        - If an overpaid employee's wage is decreased by X amount, how much would the company's net returns increase?

- How would the assignment of tasks change if the employee's wage is adjusted?

1.3 Thesis Overview

The following chapters will discuss the literature review, methods, results, and overall conclusions. Chapter 2 is a literature review that provides background information on employee workload optimization modeling and discusses relevant research of employee specialization, cross-training, and a combination thereof. Chapter 3 describes the methods employed to develop the optimization model, including the data and parameters, objective functions, constraints, and logic; followed by a description of the sensitivity analyses performed on the base model. Chapter 4 discusses the results generated by the base model and findings from associated sensitivity analyses. Chapter 5 provides the conclusions, which summarize how the results can assist current managers make well-informed decisions to improve the productivity of their operation, offers suggestions for potential model enhancements, and provides direction for future research.

CHAPTER II: LITERATURE REVIEW

The purpose of this chapter is to discuss previous research pertaining to employee assignment optimization and explain how the research relates to the purpose of this study. Employee assignment optimization has been shown to be an effective tool to improve a company's operation. The type of employees used, specialized, cross-trained, or a combination thereof, are important factors to consider when developing an optimization model. The study begins by summarizing research in the field of employee specialization, proceeds to review cases of cross-training, and concludes with a consideration of situations where a combination of both specialized and cross-trained employees were advantageous.

2.1 Employee Specialization

The proverbial expression "practice makes perfect" suggests that the more frequently a task is performed, the more proficient (and possibly efficient) one becomes. A highly proficient employee is considered to be specialized, meaning they are very productive when exclusively performing the given task. Employee specialization is well illustrated by the following example:

> "[Employee specialization is] the condition in which resources are primarily devoted to specific tasks... Civilized human beings have long recognized that limited resources can be more effectively used in the production [sic] the goods and services that satisfy unlimited wants and needs if those resources specialize. For example, three ice cream parlor workers, can be, in total, more productive if one runs the cash register, another scoops the ice cream, and a third adds the hot fudge topping. By devoting their energies to learning how to do their respective tasks really, really well, these three workers can produce more hot fudge sundaes than if each performed all required tasks (EconGuru, 2008)."

Cosgel and Miceli (1998) examined the productivity of specialized and cross-trained employees. Their research indicated that specialized workers generate higher levels of productivity than non-specialized workers because specialized workers strictly focus their efforts on narrowly defined assignments. Cosgel and Miceli (1998) mathematically explained the gain in productivity when utilizing specialized employees.

> "According to a well-known principle spelled out by Adam Smith, a specialized worker improves his or her skill over time by repetitively performing the same task. The gain from specialization thus arises in the second period if workers remain in the same job for both periods. In that case, we assume that the workers can produce more in the second period. By contrast, if the workers switch jobs in the second period, then each produces the same output in the second period that his or her counterpart had produced in the first period. To capture this, we let Y^1 denote the total output in the first period, and Y^2_r and Y^2_s denote the output in the second period under rotation and specialization respectively. When workers rotate jobs in the second period, $Y^2_r = Y^1$; when they specialize and remain in the same job, $Y^2_s > Y^1$. Specialization thus yields greater output over the two periods by the amount $Y^2_s - Y^2_r$. This differential represents the cost of job rotation in terms of foregone output (Cosgel and Miceli, 1998; p. 7-8)."

While the article clearly demonstrates that increased productivity is gained by employee specialization, the article also alludes to the shortcoming of pure specialization: the lack of scheduling and task flexibility. The article mentions that a company may decide to cross-train employees, despite incurring reduced productivity to improve their ability to handle change (Cosgel and Miceli, 1998). In short, the learnings from the research are important for this study because it affirms that employee specialization increases productivity. In addition, it informs that although cross-trained employees are less productive than specialized employees, a company may need to cross-train so as to be flexible and manage change.

2.2 Employee Cross-training

The idiom of being a “jack of all trades, but master of none” suggests that a person can be competent at performing many tasks; however, those tasks may not necessarily be performed at a highly productive level. Cross-trained employees are beneficial because they can perform tasks in the absence of other workers; however, their task productivity may be compromised. The following two articles discuss cross-training.

Brusco, et al. (1998) noted that many previous studies regarding employee assignment optimization modeling assumed a cross-trained employee would perform at 100% productivity rate once cross-trained. However, they wished to assess the impact of cross-training the employee if that resulted in lower productivity rates. The model assigned a productivity rating to employees for different skills (e.g. 100% for specialized (first-skill), and a percentage from 0-100 for the second skill) to assess how the distribution of productivity on different skills and cross-training would help to optimize worker productivity/flexibility and minimize labor requirements.

The results indicated that substantial workforce savings can be realized with relatively small degrees of cross-training. Diminishing returns were observed when employees were cross-trained at more than 50% productivity in skills beyond their primary skill (Brusco et al., 1998). The key implications from their study are that cross-training employees is most beneficial in situations of high demand variability, and also high task variability, which both require labor flexibility. Additionally, cross-training can be beneficial and realize significant workforce savings, even if the cross-trained employees perform at less than 100% productivity (Brusco et al., 1998).

Brusco et al.'s (1998) research differs from this thesis because it only involved two skills (tasks) whereas this study will consider 6 tasks. However, it does provide insight that cross-training is important and that not all employees need to be cross-trained to 100% productivity, nor in all tasks, to produce benefits. Furthermore, the article is relevant to this study because the results address the need for flexibility to accommodate changes in workload demand and task demand.

Nembhard, et al. (2005) examined the opportunity to cross-train employees as if it were a call option, such that a company has the option but not the obligation, to cross-train their employees. Nembhard, et al. (2005) explains, "Cross-training represents a dynamic investment policy in workforce flexibility which parallels the concept of real options theory and correspondingly may be associated with option values (Nembhard, et al., 2005; p. 96)." Their research quantified the value of cross-training by creating a model to calculate the value of cross-training that incorporated variables typical of a manufacturing environment. They "analyzed a cross-training policy in a stochastic production system with typical workplace factors including production processes, product dynamics, workforce dynamics and task and worker heterogeneities (Nembhard, et al., 2005; p. 114)." For the purpose of this study, worker heterogeneity means that employees complete tasks at varying levels of productivity.

The results of the research conducted by Nembhard et al. (2005) illustrate that while workers are becoming cross-trained (in the learning phase), lower overall productivity exists; however, the unit's overall productivity rate eventually surpasses that of the purely specialized employees' once the employees are fully cross-trained. They noted that cross-training is an up-front investment, with the dividends coming at a future time. While cross-training employees, productivity may initially diminish, but will increase as the employee becomes more proficient at the new task(s) over time (Nembhard et al., 2005). In essence, if the anticipated long-term benefits of cross-training employees exceed the total cost to cross-train the employees, then the company should invest the resources to cross-train.

Overall, the research from Nembhard et al. (2005) is valuable because it illustrates that a company should elect to cross-train only when the anticipated long-term benefits outweigh the initial opportunity cost to train. However, the assumptions used differ from those in the model developed here, therefore results may be different. The model developed by Nembhard, et al. (2005) searched for high-flexibility options; therefore, the results may have inflated the value of cross-training as they assume employees are homogenous. The research is relevant to this thesis as the results indicate cross-training may be a wise decision, especially if conditions will persist into the future that require flexibility in meeting changing demands.

Cross-training can be beneficial to an organization. When managers decide to cross-train employees, in the right circumstances, they may significantly increase overall productivity and flexibility, which is necessary to embrace today’s changing business world. We have learned that cross-training affords flexibility and can potentially increase, or decrease productivity, depending on the company’s situation.

2.3 Combination of Specialized and Cross-Trained Employees

The previous research demonstrates that specialized employees are typically very productive but lack flexibility; whereas purely cross-trained employees can be less productive but afford higher flexibility. It may be wise for a manager to strive for “the best of both worlds." That is, capture the high productivity of specialized employees, and increase flexibility with cross-trained employees.

Tiwari et al. (2009) developed an employee optimization model to reflect a service company with multiple tasks to complete and a heterogeneous staff. The model was designed to assign employees to tasks based on their productivity, and also to identify which employees should be cross-trained to obtain the maximum benefit. Additionally, the research examined the need for flexibility and determined how much cross-training was necessary to ensure project deadlines were met. Essentially, the research identified who should be trained in which area(s) so projects are completed efficiently by considering that various projects occur simultaneously, people have different skill sets, and that some flexibility is necessary.

Tiwari et al. (2009) concluded that a company may increase productivity and flexibility by correctly identifying the employees to be cross-trained, and also correctly identifying the tasks that the employees learn. However, the productivity may not improve if the wrong employees are chosen to be cross-trained. Ultimately, the results indicated that the optimal staff includes a combination of cross-trained and specialized employees.

The research objective of Tiwari et al. (2009) is similar to the objective of this thesis. Their research provides guidance as to how the model can be developed and constraints employed. Additionally, the methods used to develop a base employee labor allocation model and then execute sensitivity analyses from the base model to determine the impact of cross-training, provide direction for gaining understanding of the base model. The research of Tiwari et al. (2009) differs from this thesis because their research incorporated the time required to rectify poor quality work. This was a specific concern to the company in their article; however, the objective and methods used to develop and employ their base model and relevant sensitivity analysis are pertinent to the purpose of this research. Overall, a balance of cross-trained and specialized employees is necessary to achieve optimal resource utilization.

Rohleder et al. (2012) provide an excellent example of how optimizing employees' assignments can drastically improve a company's operations. The article explains that Mayo Clinic customers (patients, doctors, visitors) experienced unsatisfactory customer service from the call center, mainly due to long wait times. To address the poor customer service, an employee assignment optimization model was developed with the objective to increase efficiency in handling calls, and thus improve customer service. The Mayo Clinic implemented changes based on the optimization results, and concluded that customer service improved about 70 percent, which was measured by average answering-speed (ASA) and average abandonment rate (AAR). In addition, these significant improvements were obtained without any additional staff, despite an increase in call volume by 12 percent (Rohleder et al., 2012).

Rohleder et al. (2012) explained that the Mayo Clinic in Rochester, Minnesota operated a Central Appointment Office (CAO). The CAO ensures a quality call experience for each of the 340,000 calls they receive per day; therefore, calls must be processed very efficiently. Prior to 2010, their customer service was unsatisfactory; their caller abandonment rate was high (22.7 percent in 2008 and 15.7 percent in 2009, well above the 5 percent target) and their average answering speed was greater than the 30-second target (Rohleder et al., 2012).

The Mayo Clinic improved their customer service, which began with developing an employee assignment optimization model and identifying opportunities to cross-train and specialize employees. The objective of the model was to “show how applying simulation and optimization modeling operations research tools resulted in a better staff match to patient call demand (Rohleder et al., 2012; p. 715).” Two aspects were addressed: optimal allocation of employees within a unit (daily and weekly coverage), and cross-training amongst units. There were 60 employees divided among three units in the call center: appointment information, doctor referrals, and patient correspondence. The optimization model addressed the workload variation across the three units, while incorporating the need for staffing flexibility in times of absence and fluctuations in overall call volume (Rohleder et al., 2012). The goal was to optimally allocate resources (employees) across all three units, which required a mix of specialized and cross-trained staff (Rohleder et al., 2012).

Performance data showed that specialized staff were very productive in their single area, but could not cover another units. Cross-trained staff were less productive; however, they provided flexibility to cover other units. Ultimately, the Mayo Clinic decided to cross-train certain employees, while retaining roughly 50% as specialists within their unit (Rohleder et al., 2012). Rohleder et al. (2012) explain that, “providing primary skill assignments allowed patient appointment coordinators to feel confident with the calls they took through repetition, but secondary or tertiary assignments allowed enhanced coverage during peak times (Rohleder et al., 2012; p. 718).” Overall, the Mayo Clinic Central Appointment Office was able to significantly improve customer service by utilizing an employee optimization model that puts the right people in the right place at the right time.

The research by Rohleder et al. (2012) demonstrates how an employee optimization model can improve a company's operation. Their research is similar to this thesis as they identified the need for increased staff flexibility to handle fluctuating task demand; as well as the need for high productivity to handle increasing demands without hiring additional staff. In addition, they consider that employees will be absent (weather emergencies), but yet the company must have sufficient staffing flexibility to continue their operations. Lastly, the article provides useful insight that a company may realize significant improvements by carefully selecting a portion of the workforce to be cross-trained, rather than training everyone.

The research in section 2.1 explaines mathematically that specialized employees are more productive than cross-trained employees, but alludes to the lack of flexibility they afford. The research in section 2.2 explains that while cross-training affords increased staffing flexibility, the impact on productivity is dependent on the company's situation and the employee(s) chosen for cross-training. Section 2.3 demonstrates that substantial benefits may be realized when a combination of cross-trained and specialized employees are used. The research cited offers valuable insight regarding development and implementation of employee assignment optimization modeling, as well as how sensitivity analysis may further improve a company's overall ability to handle increased demand and variability flexibility with limited resources.

CHAPTER III: METHODS

This chapter describes the methods used to develop an employee assignment optimization model to determine the optimal assignment of employees to tasks based on different management strategies. The model is designed based on a case study; however, some of the data has been modified for confidentiality purposes.

3.1 Empirical Situation

The company represented in the model provides evaluation of temperature-controlled meat samples for various companies. The tasks regularly performed include organoleptic assessment, shear-force analysis, component testing, microbiological testing, as well as occasional consulting projects. The company has a core group of employees, most of which are currently specialized to perform specific tasks. The company's workload has become increasingly variable, due to a larger mix of smaller customers, each with slightly different timeframes and service requests. There has been an increasing fluctuation in the demand for the services requested, which is expected to persist into the future.

Although some of the company's services are pre-contracted, they also perform services upon request, especially during periods of seasonality, and for research and development (R&D) test runs. The model is designed to reflect the company's current operations, incorporating key components from the operation. While the model is developed based on a given company, the model has the ability to be modified and accommodate other business operations.

The company has primarily focused their training efforts towards employee specialization. The base model captures their current employee training levels, and examines the optimal strategies in this situation. Therefore, the base model reflects a situation with employee specialization.

The key methods employed to develop the model include determining the parameters and gathering data, identifying the objectives and constraints to be included, and finally creating the base model. First, the parameters and data used in the model's design are presented. Next, alternative objective functions incorporated to address four management strategies are discussed, as well as a description of the constraints. Lastly, four scenarios examined via sensitivity analysis are discussed.

3.2 Parameter and Data Requirements

Parameters provide structure for the model to simulate the company's operation. The parameters are determined, and then objective data are gathered to provide values to determine the parameters. It is crucial that the data be accurate and objective to ensure the results will have integrity and valid implications. While there are a multitude of characteristics that could be included in a model, only the relevant characteristics required for the purpose of this thesis are included. The parameters and data selected for inclusion in the model can be grouped into two categories, employee characteristics and task characteristics.

The employee characteristics relevant to the research, and required to build the model, include: the employee's name, their relative productivity rating for each task, total hours available per week, and hourly wage. The model process uses reference tables to input the key data into the model, so the manager can easily modify source data as necessary.

The employee's names are listed vertically in a reference table. For the purpose of the model, generic names were assigned to Employee #1 to #8. The index for employee names is given by:

$$\mathrm{i} = 1, \ldots, \mathrm{I} \text{ employees.}$$

Employee productivity ratings for each respective task are collected. The productivity rating for each employee-task combination is recorded as a percentage relative to the highest performing employee's productivity. For example, if data indicates that the employee producing the most units of Task A in a given timeframe, completes 50 units, then that employee would have a productivity rating of 100% for Task A. An employee who completes 30 units of Task A in the same timeframe would have a productivity rating of 60% for Task A [(30/50)*100]. If an employee is not trained to perform a given task, then the employee's productivity rating for that task is 0%. The data for each employee's productivity rating was obtained by analyzing three months of production data. The historical data was converted into percentages, and input into the productivity rating table. Each employee's productivity is represented by:

$$\propto_{ij} = Productivity\ of\ Employee_i\ at\ doing\ Task_j$$

The number of hours available per week for each employee is calculated as such: base hours plus overtime hours, less time off and administrative time. The base hours are 40 hours. Overtime (OT) represents the number of hours beyond 40 that the employee is allowed to work. For this model, OT is set to 0. Time off represents the pre-scheduled hours that the employee will be absent, for reasons such as medical appointments and vacation. When a manager knows an employee will be absent, the hours available for that week can be adjusted accordingly. For this model, time off is set to 0. The possibility for OT and time off are included in the model to allow for future sensitivity analysis. Administrative time represents the amount of hours each respective employee must devote towards administrative tasks, such as special projects, training, and travel. The time devoted towards administrative tasks reduces the amount of hours available for the employee to work on tasks. For this model, the administrative time data was derived from work logs. The hours available for each employee is represented by:

$$H_i = Hours\ available\ per\ week\ for\ Employee_i$$

The hourly wage for each employee, in US dollars ($), is determined from payroll information. The hourly wage could be in another currency, if so elected, so long as all units are consistent. The hourly wage for each employee is represented by:

$$w_i = Hourly\ wage\ rate\ for\ Employee_i$$

Figure 3.1 provides an example of the employee characteristics included in the model.

Figure 3.1 Employee Characteristic Data

	Productivity Rating						Availability (Hours per Week)					
Employee	Task A	Task B	Task C	Task D	Task E	Task F	Base Hours	OT	Time off (Vacation, Medical)	Administrative Time (Special Projects, Training, Travel)	**Total Hours Available**	**Hourly Wage**
Employee #1	0%	0%	0%	0%	100%	0%	40	0	0	3	**37**	Private
Employee #2	0%	0%	0%	0%	100%	0%	40	0	0	8	**32**	Private
Employee #3	90%	90%	100%	80%	95%	100%	40	0	0	33	**7**	Private
Employee #4	90%	90%	100%	75%	100%	0%	40	0	0	10	**30**	Private
Employee #5	15%	15%	50%	25%	0%	0%	40	0	0	12	**28**	Private
Employee #6	15%	15%	75%	30%	0%	0%	40	0	0	5	**35**	Private
Employee #7	85%	50%	50%	100%	0%	0%	40	0	0	5	**35**	Private
Employee #8	100%	100%	0%	0%	0%	0%	40	0	0	10	**30**	Private
							Base Hours + OT - Time off - Admin. Time = Total Hours Available					

The task characteristics required to build the model include: the task name, value, and maximum output per hour. Additionally, the minimum and maximum production levels for tasks A to F are necessary. These levels will serve as constraints on feasible production.

For the purpose of this model, generic names were assigned of Task A to Task F. The task names are indexed as:

$$j = 1, \ldots J \text{ tasks} .$$

There is a task value assigned for each task. The task value is how much money, in US Dollars ($), the company charges for each completed task. While there is slight variation in charges due to contracts, the data used for the model was obtained from credible records, and a weighted average applied to determine the value of each task. For the purposes of the model, the task values have been modified slightly for confidentiality reasons. The value of each task is represented by:

$$r_j = Value\ of\ Task_j .$$

The maximum output per hour for each task represents how many units of the task can reasonably and consistently be completed by the most productive employee. The data were obtained from various production and employee work logs. Data were analyzed from a two month time period to ensure that the maximum output number is realistic. If an employee had outstanding production on the task for one day, and one day only, it would not do the model justice to include that production number. The maximum output data chosen must be reasonable and consistent. The maximum output per hour for each task is represented by:

$$\delta_j = Maximum\ output\ for\ Task_j.$$

The minimum production level for each task represent the absolute least amount of each task that can be completed. The minimum production levels were obtained by evaluating historical production data, contract requirements and demand forecasts. In this model, Task A and Task E rely on input data to establish their minimum production levels, whereas the minimum production levels for Tasks B, C, D, and F are calculated from another task's production level. The minimum production level data used for this model for Task A is 40, and the minimum for Task E is 5. The minimum production levels for Tasks B, C, D and F are discussed in section 3.5. The minimum production level is represented by:

$$P_j^{min} = Minimum\ production\ needed\ of\ Task_j.$$

The maximum production level for Task A and Task E represent the absolute maximum of each that can be completed, factoring in technical and logistical concerns. The maximum production levels were obtained by evaluating historical production data and equipment capacity. For the purpose of this model, the maximum for Task A is 80, and the maximum for Task E is 15. The maximum production level is represented as:

$$P_j^{max} = \ Maximum\ production\ needed\ of\ Task_j.$$

Table 3.1 shows an example of the task characteristic data included in the model.

Table 3.1 Task Characteristic Data

Task	Value ($)	Maximum Output / Hour
Task A	6	12
Task B	11	8
Task C	16.5	6
Task D	16	6
Task E	2200	0.05
Task F	111	1

In summary, the parameters established and data used in the model include key aspects of the employee and task characteristics relevant to this study. Just as each employee has different characteristics, so can a manager prefer different strategies. The following section will describe the four objective function options analyzed to address various manager’s strategies.

3.3 Decision Variables and Objective Functions

Company cultures and managerial styles differ. There may be times when one objective is preferred over another; therefore, the model considers various preferences by allowing the manager to select their objective, or appropriate management strategy.

Before presenting the objective functions, the decision variables are determined. These variables represent the number of hours to assign to each employee, to each task. In the model, we assume there are 48 decision variables (i.e. i x j) given there are 6 tasks and 8 employees. The decision variables are represented as:

$$E_{ij} = Hours\ to\ Assign\ to\ Employee_i\ for\ Task_j.$$

The four objective functions or management strategies considered are:

1. Maximize total production: This objective function reflects the management strategy to maximize total production from all tasks without consideration of the revenue generated from the tasks or labor costs. Maximizing total production may be appropriate when high volumes of work are needed regardless of the labor cost or generated incomes. For example, if there are a high number of samples for a low-value task occupying precious freezer space, then a manager may devote resources to clearing out the inventory to regain the freezer space. The objective function to maximize total production is given by:

$$\text{Max} \sum_{i} \sum_{j} E_{ij} * \alpha_{ij} * \delta_j.$$

2. Maximize revenue: This objective function reflects the management strategy to maximize total revenue but does not consider labor costs. Maximizing revenues directs the model to higher-value tasks, despite the labor cost incurred. Maximizing revenue could be used to increase cash flow. The objective function for maximizing revenue is given by:

$$\text{Max} \sum_i \sum_j r_j * E_{ij} * \alpha_{ij} * \delta_j .$$

3. Minimize labor cost: This objective function reflects the management strategy to minimize labor costs, while still satisfying the minimum production levels required. While this is often not the most profitable approach, it can be necessary during times of seasonality. Also, this objective may be necessary if the company is financially struggling to make payroll, or, perhaps the company wishes to satisfy current demand, but not stockpile excess inventory. The objective function for minimizing labor costs is given by:

$$\text{Min} \sum_i \left[\sum_j E_{ij}\right] * w_i .$$

4. Maximize net return: This objective function reflects the widely used management strategy to maximize net returns (above labor costs) by considering production revenue and labor costs. This strategy strives to optimize the system as a whole. It is important to note that only the labor cost is included in the model; therefore, the net return does not

take into account other variable and the fixed costs that are proportional with revenue generated. The objective function for maximizing net returns is given by:

$$\text{Max} \sum_i \sum_j [\ r_j * E_{ij} * \alpha_{ij} * \delta_j - E_{ij} * w_i\ ].$$

In summary, four objective functions are available so the manager can select their preferred strategy, and obtain results for their preferred strategy.

3.4 Constraints

Constraints are used to provide realistic bounds to reflect the company's operating constraints. The constraints, or limits, keep the model's results aligned with the company's historical or anticipated demand, and business processes. Additionally, the relationships that exist among tasks, such as their sequential completion, are modeled as constraints. The constraints included in this model are time, minimum/maximum production levels, and non-negativity.

Time is a limited resource, and therefore the primary constraint. While the traditional workweek is 40 hours, reality is that each employee typically has less than 40 hours to devote strictly towards assigned tasks. Also, the amount of time each employee is available each week will vary. To accommodate the variation in time availability, the available hours are made flexible to accommodate planned absences, holidays, travel, etc. as needed. The time constraint indicates that the sum of task hours assigned to a given employee must be less than or equal to the employee's number of available hours. The equations representing the time constraints are given by:

$$\sum_j E_{ij} \leq H_i \; for\; all\; i.$$

Minimum production levels are required to satisfy contracts and baseline demand. The minimum production constraint for each task establishes a floor, essentially restricting the company from abandoning a task to focus strictly on another one. The minimum production levels are very important, for they not only establish a production floor, but also indirectly serve as the constraint requiring staff flexibility. In the absence of minimum task production levels, the model would allocate zero hours to a given task; thereby allowing zero production of the task. The minimum levels ensure that staff flexibility occurs. If the model is unable to find a feasible solution due to the minimum production constraint, it is a strong indicator that insufficient staffing flexibility exists. The equations representing the minimum production constraints are given by:

$$\sum_i E_{ij} * \alpha_{ij} * \delta_j \geq P_j^{min} \; for\; all\; j.$$

Maximum production levels are required to reflect the company's technical and logistical limitations. The maximum production constraint for each task establishes a ceiling, restricting over-allocating to a single task. The opportunity to stockpile (if in a manufacturing environment) excess production may be limited due to perishability concerns; likewise, in a service environment, tools and resources may be limited so that all employees cannot use the same equipment to complete the same task simultaneously. The equations representing production constraints are given by:

$$\sum_{i} E_{ij} * \alpha_{ij} * \delta_j \leq P_j^{max} \, for \, all \, j.$$

All non-constrained variables are set to be non-negative. That is:

$$E_{ij} \geq 0 \, for \, all \, i \, and \, j.$$

In summary, constraints are used to set bounds on the company's operation, and ensure the results align with reality. The constraints incorporated into the model include time, minimum/maximum production levels, and non-negativity. The preceding sections presented the data needs, objective functions, and constraints required to develop the model. The following will present how the model's design integrates the information.

3.5 Empirical Model

The purpose of developing the optimization model is to help inform a manager which employee(s) should work on which task(s) and for how many hours, to achieve the desired objective. The model developed is based on a real company; however, it has been modified for confidentiality reasons. The model is modifiable for accommodating other business situations.

An employee workload optimization model needs to be problem specific as characteristics of employees and tasks are unique and particular to the company. Since a customized model is designed to reflect the nature of the business, the results are more likely to be close to reality. For this reason, the model for this research incorporates key factors a manager may face following the discussion in section 3.1. A well-designed model allows the manager to assess their division's employees and tasks from an objective perspective.

Findings from the literature review are incorporated into the model. First, employee heterogeneity is taken into account. Not all employees have identical production characteristics; therefore, accounting for their differences makes the model more robust. Second, incorporating multiple tasks performed by the business are analyzed rather than analyzing only two tasks for this applicaiton. Third, objectives ofthe model, as well as the constraints, and data, reflect the company's operations. Lastly, the model addresses the need for flexibility to allow periodic updating of the source data and perform sensitivity analysis to identify cross-training opportunities. The business is constantly changing, so the manager will re-evaluate task assignments periodically based on current data.

The model maximizes alternative management strategies (i.e. objective functions) to determine the task(s) each employee should perform, subject to relevant resource constraints. The model calculates the best combination of employees' hours and tasks to satisfy the manager's chosen management strategy. To accomplish this, the model selects the optimal value of the decision variables, E_{ij}, which represent the number of hours an employee should be assigned to each task (see section 3.3).

The empirical model is built in EXCEL. Figure 3.2 presents an EXCEL image of the base model, showing the results when the management strategy selected is maximization of net returns.

Figure 3.2 Excel Image of the Optimal Solution for the Base Model to Maximize Net Return

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	
7		Employee #3	0	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	5.94737	1	7	7	
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	
9		Employee #5	0	1.8	0	1.2	28	3	0	1.5	0	0.00	0	0	28	28	
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	
11		Employee #7	0.74	10.2	0	4	0	3	34.2647	6	0	0.00	0	0	35	35	
12		Employee #8	3.75	12	26.25	8	0	0	0	0	0	0.00	0	0	30	30	
13	Optimized Production			52.5		210		241.5		205.5882353		5		5.94737			$8,665.00
14	Minimum Production			40		105		178.5		205.275		5		4.5			
15	Maximim Production			80		210		241.5		277.725		15		16.5			

	Weekly Production Summary		Revenue			
18	Task A	52.5	$ 315.00			
19	Task B	210	$ 2,310.00			
20	Task C	241.5	$ 3,984.75			
21	Task D	205.588	$ 3,289.41			
22	Task E	5	$11,000.00		Total Revenue	$21,559.32
23	Task F	5.94737	$ 660.16		Labor Cost	$ 8,665.00
24	Totals:	720.536	$21,559.32		Net Return	$12,894.32

The model incorporates final calculations to arrive at the optimal solution, such as each employee's production per hour per task, the total production output of each task, the minimum and maximum production levels for Tasks B, C, D, and F; as well as the total number of hours assigned to each employee, each task's revenue, and each employee's labor cost.

The output per hour, for each employee, per respective task, is the product of the employee's productivity rating for that task and the tasks' maximum output per hour (i.e. $\alpha_{ij} * \delta_j$). For example, if an employee has an 80% productivity rating for Task C, and the maximum output per hour for Task C is 6, then the employee's output per hour for Task C would be 4.8. This calculation occurs for each employee/task pairing. The output per hour for Task C in the empirical model is presented in cells H5:H12, in Figure 3.2.

The total output for each task is calculated by the sum product of each employee’s output per hour and the number of hours the employee is assigned to work on the respective task. For example, regarding Task C: Employee #5 creates 3 units per each of the 28 hours assigned, while Employee #6 creates 4.5 units for each of the 35 hours assigned; therefore, total Task C production is 241.5 units. The total production for Task C is presented in cell H13 in Figure 3.2.

The minimum production levels for Tasks A and E are raw input data, while the minimum production for Tasks B, C, D, and F are calculated from another Task’s production level. Task B’s minimum is twice Task A’s production. Task C’s minimum is 85% of Task B’s production. Task D’s minimum is 85% of Task C’s production. Task F’s minimum is 90% of Task E’s production. For example, Task C’s minimum production is .85*210 (Task B’s production) yielding a minimum of 178.5 units required. The minimum production for Task C is presented in cell H14 in Figure 3.2.

The maximum production levels for Tasks A and E are raw input data, while the maximum production for Tasks B, C, D, and F are calculated based off another Task’s production level. Task B’s maximum is four times Task A’s production. Task C’s maximum is 115% of Task B’s production. Task D’s maximum is 115% of Task C’s production. Task F’s maximum is 110% of Task E’s production. For example, Task C’s maximum production is 1.15*210 (Task B’s production) yielding a maximum of 241.5 units. The maximum production for Task C is presented in cell H15 in Figure 3.2.

The number of total hours assigned for each employee is calculated by summing each of the task hours assigned for that employee. For example, Employee #8 was assigned 3.75 hours to Task A and 26.25 hours to Task B; therefore, the total hours assigned for Employee #8 are 30. The total hours assigned for Employee #8 is presented in cell O12 in Figure 3.2.

The revenue generated from each task is a product of the task production and the respective task's value. For example, Task B shows 210 units completed, each with a task value of $11; therefore, the revenue generated from Task B is $2,310. The Task B revenue is presented in cell H19 in Figure 3.2.

The labor cost for each employee is a product of the employee's total hours assigned and the employee's hourly wage. The labor cost for each employee is presented in cells Q5:Q12 in Figure 3.2; however, it has been removed for confidentiality reasons.

The above metrics are necessary components within the model to arrive at each of the objective cells. The objective cells presented in Figure 3.2 are G24, H24, K23, and K24 for the strategies to maximize production, maximize revenue, minimize labor cost, and maximize net return, respectively. The model does not consider cost the direct training cost of cross-training employees.

The preceding explained how the model becomes a nexus of information, incorporating the parameters and data for employee and task characteristics, various objective functions, and constraints. The model's logic incorporates the information, and provides the optimal solution depending on the manager's chosen management strategy.

3.6 Sensitivity Analysis

A good manager constantly seeks to improve their operation. The base model determines how to best assign tasks based on the employees' current characteristics. A manager may potentially improve the operation, beyond the current optimal solution, by changing key employee characteristics, such as training, to improve productivity. Cross-training is a common practice used to increase flexibility; however, it can also have residual benefit of increasing overall productivity and potentially lowering labor costs. A manager can gather insight as to how a particular change, such as cross-training an employee or adjusting an employee's hourly wage, would affect their operation by performing sensitivity analysis. Performing various sensitivity analyses in a model allows the manager to learn how the optimal solution would change, before they physically invest resources (time and effort) into a change that may not be beneficial. For example, running various sensitivity analyses can help determine which employees to cross train, in which tasks, to derive maximum benefit. Also, a manager may want to see how an employee's salary change would affect the company's net returns. The following scenarios were selected to be tested with sensitivity analysis:

1. Cross-training the least productive employee
2. Cross-training a specialized employee in another task. Examine both a specialized employee currently performing a task constrained by minimum production levels and a specialized employee currently performing a non-constrained task
3. Increase the hourly wage of an underpaid employee
4. Decrease the hourly wage of an overpaid employee

The following provides a description of each scenario, and the data modified to perform the sensitivity analyses.

3.6.1 Cross-training the least productive employee

Cross-training an employee with low productivity ratings to perform other tasks will not only increase staffing flexibility, but also may improve the optimal solution. To examine this change, the employee with the lowest productivity rating is identified (Employee #5). Next, the identified employee's productivity rating for each task is changed from their current percentage to 80%, which was determined to be a realistic productivity rating for cross-trained employees for this situation. A study was conducted by the company to determine the productivity rate at which a cross-trained employee can be expected to perform. The study analyzed data from two foreman, one from each shift, who were experienced employees cross-trained to perform all tasks. Although the foreman were cross-trained in all tasks, they performed the tasks only during times of high demand or employee absenteeism. The foreman averaged roughly 82% productivity across all tasks, compared to the specialized employee.

In addition, the company hired an intern, and cross-trained the intern to perform all tasks, except one. The intern had limited prior experience performing the tasks, and after the training period, the intern's productivity, averaged across the tasks, was roughly 75%. The productivity rating of 82% from the foremen and 75% from the intern were combined together and weighted slightly more towards the foremen's level because any employee selected for cross-training would likely already have experience with the company. Thus, 80% represents the typical rate at which a cross-trained employee, periodically performing various tasks, can complete each task relative to a specialized employee. The model is then re-solved to determine the impact of cross-training the least productive employee.

3.6.2 Cross-train a specialized employee in another task

Cross-training a specialized employee to perform additional tasks will increase staffing flexibility; however, the impact on the optimal solution is unknown. To determine this impact, a specialized employee, with 100% productivity rating in a given task, is identified. Next, the identified employee's productivity rating for each task is increased to 80%, with the exception of their specialized task that remains at 100%. The model is then re-solved to determine the impact of cross-training a specialized employee.

This particular scenario was tested with two different employees, as the literature indicated that the optimal solution may change depending on the employee chosen for cross-training. The first employee chosen (Employee #1) is currently specialized to perform a task that barely meets the minimum production constraint. Essentially, every hour of the employee's time is currently devoted to that specialized task, and due to the high demand, this employee can barely satisfy the minimum production required. The expectation is that the model will satisfy the minimum production constraint; and therefore, will not be able to sacrifice production on the specialized task and assign hours to the newly-learned tasks. The second employee chosen for cross-training (Employee #8) is currently specialized to perform a task that is not constrained. That is, there is some leeway for the employee to perform other tasks while still satisfying the minimum production constraint. The expectation is that the model may satisfy the minimum constraints, and then assign the remaining hours to a mix of tasks depending on what best satisfies the management strategy.

3.6.3 Increase the hourly wage of an underpaid employee

Managers strive to retain valuable, productive employees. In this effort, a manager may assess the employees and their salaries, and contemplate increasing a productive employee's salary if the employee is underpaid for their efforts. Adjusting an underpaid employee's pay to an equitable level, commensurate with their contributions to the business, is one method to retain a valuable employee. While the employee's retention is not examined in this model, the model will examine how increasing the employee's pay would affect the optimal solution, including the impact on total labor cost and net returns. To determine the impact on the optimal solution, a highly productive employee with a low salary, relative to their contributions, is identified (Employee #4). Next, the identified employee's hourly wage is increased by $7 per hour in the model. The model is then re-solved to determine the impact of increasing a productive employee's salary.

3.6.4 Decrease the hourly wage of an overpaid employee

A manager may contemplate decreasing an employee's pay. A reduction in pay could occur if the employee's pay grossly exceeds the value of the employee's contributions to the company. Adjusting an overpaid employee's salary to an equitable level that more accurately reflects their contributions, may upset the employee, but also help alleviate workplace tension and increase the company's net returns. While the employee's sentiment and workplace tension are not considered in the model, the model will show the manager how decreasing the overpaid employee's salary would affect the optimal solution, including the impact on total labor cost and net returns. To determine the impact on the optimal solution, the overpaid employee is identified (Employee #5). Next, the identified employee's hourly wage is decreased by $7 per hour in the model. The model is then re-solved to determine the impact of decreasing an overpaid employee's salary.

3.7 Summary of Methods

In summary, a linear optimization model is developed to determine how many hours each employee should be assigned to a given task to optimize alternative management strategies. The model includes logic to reflect the company's business processes and incorporates quantifiable characteristics of both the employees and the tasks to be performed. Constraints provide bounds of the company's operations. Four objective functions: maximize production, maximize revenue, minimize labor cost and maximize net return, are examined to reflect different managers' preferences. Sensitivity analyses pertaining to cross-training and employee salary adjustments are then considered.

CHAPTER IV: RESULTS

This chapter discusses the results from the employee assignment optimization model. First, an explanation of how the optimization model functions in EXCEL is presented, followed by the base model results, which uses the management strategy to maximize net returns. Next, the results for each of the alternative management strategies are presented, followed by the results from each of the four sensitivity analyses examining cross-training and employee wages. Finally, the practical implications from the model results are discussed, including the overall conclusions, which parallel findings in previous literature.

4.1 Base Model Results (with Net Returns Management Strategy)

It is important to understand how the model with data and constraints incorporated, functions to arrive at the results found. First, a manager must indicate what their management strategy is, by selecting the management strategy they prefer. Then the manager must provide the necessary productivity, output and wage data for employees and tasks. The model uses the linear programming simplex algorithm to solve the problem in EXCEL using Solver and the LP Simplex method, made by Frontline Systems (Frontline Systems, 2014). The model will either find an optimal solution or indicate that no feasible solution is obtainable if the constraints are too limiting.

The base results generated by the model primarily answer two questions:

1. What will the optimal objective function value be (i.e. total production, revenue, labor cost, and net return)?; and
2. How many hours should each employee work on each task?

The answers to the above questions vary depending on the management strategy selected. Often, managers maximize net returns because maximizing net returns incorporates revenues and labor costs. For this reason, the results discussed in this section are from the perspective of this management strategy; however, the results from the other management strategies are discussed in section 4.2.

The results indicate that assigning employee hours to complete tasks, with the objective of maximizing net returns yields a weekly net return of $12,894.32. It is important to remember that the scope of the model incorporates only labor costs, so other variable costs and the fixed costs are not reflected in the net returns provided. It is assumed that these other costs are constant for the purposes of this model. To achieve the optimal net return, the manager would assign each employee to work on each task for the number of hours shown in Table 4.1.

The current management strategy, or status quo, for employee training at the company being examined, as reflected in the base model, is specialization. For example, Employee #3 is the only employee trained for Task F, as this is a very specialized task that has a high training cost.

Table 4.1 Hours Assigned to Maximize Net Returns

	Task A	Task B	Task C	Task D	Task E	Task F
Employee #1	0	0	0	0	37	0
Employee #2	0	0	0	0	32	0
Employee #3	0	0	0	0	1.05	5.95
Employee #4	0	0	0	0	30	0
Employee #5	0	0	28	0	0	0
Employee #6	0	0	35	0	0	0
Employee #7	0.74	0	0	34.26	0	0
Employee #8	3.75	26.25	0	0	0	0

The model assigned hours based on the characteristics of each employee and task to be performed. No hours were assigned to any employee that was not trained to perform a given task. The model assigned all of Task F hours to Employee #3, as that employee is the sole employee ableto perform that task. Also, even though Employees #3 to #7 are trained to perform Task B; they were not assigned any hours as their relative productivity is lower than Employee #8's.

As the objective function chosen was to maximize net returns, the model incorporates labor costs for each employee, as well as the revenue generated for each task. The model searches to increase net returns, by finding the best combination of low labor costs and high revenue. Assuming the constraints are satisfied, the model assigns hours to the employees that generate the most value per hour on a given task, assuming the marginal cost does not exceed the marginal benefit.

The model defaults to assigning tasks to employees that have the highest productivity (specialized employees) if the marginal return from doing so is positive (i.e. marginal revenue exceeds the employee's hourly wage for performing the task). Hence, while specialization may help to increase productivity, it only makes sense to do it for tasks that can produce a high return. Thus, a strategy may be to train employees with lower labor costs to increase their productivity if doing so can increase the net return from them doing the given task.

Task D is not assigned to Employee #5. Although Employee #5 is trained to perform the task, the company would lose money by assigning him/her to do so. Employee #5's productivity for Task D is 25%, and 6 units of Task D can be completed at a 100% productivity level, indicating that Employee #5 produces 1.5 units of Task D per hour (25%

of 6 = 1.5). Each completed unit of Task D is valued at $16, indicating that Employee #5 produces $24 (1.5 of $16 = $24) of value each hour he/she is assigned to Task D. Since Employee #5's hourly wage is greater than $24/hour, the company would lose money for every *hour* that Employee #5 was assigned to Task D. Therefore, the model did not assign Employee #5 to work on Task D because the marginal cost was greater than the marginal benefit.

Tasks B and C were assigned to their maximum production levels; while Task D was assigned the minimum. Tasks E and F generate more revenue per hour than other tasks; however, the model was constrained by the available hours of employees trained to complete Tasks E and F. Due to the lack of trained employees for those tasks, the model only assigned the minimum production level for Task E, and just over the minimum for Task F.

There are six employees trained to complete Task B. However, upon factoring in each employee's productivity rating and labor cost, the model found it best to assign all hours to the most productive employee, despite that employee having the highest labor cost per hour. The model assigned the hours to Employee #8, because although this employee earns a higher wage, the value of their production less the labor cost (i.e. marginal net return) is higher than that of fellow employees. Not all managers may choose the same management strategy, which will likely have an effect on the effects of specialization and eventually cross-training.

The shadow price for all employees' hours in the base model are positive, ranging from 2.14 (Employee #5) to 88.84 (Employee #4), which indicates that net revenues are expected to increase if more labor hours are available. This means that for every additional hour that Employee #5 is assigned, the net revenue is expected to increase by $2.14. For every additional hour that Employee #4 is assigned, the net revenue is expected to increase by $88.84.

4.2 Alternative Management Strategies

The model is used to determine the optimal assignment of employees' hours to available tasks, depending on the manager's chosen strategy. Understanding that management strategies vary, the model was designed to optimize four different management strategies: maximize production, maximize revenue, minimize labor cost, and maximize net returns, which would affect how a manager may decide to use specialization and cross-training. Each strategy yields different results. Table 4.2 presents the results for each management strategy examined, with the optimal solution for each strategy in bold and the corresponding values of the other objective function values when that management strategy is chosen.

Table 4.2 Optimal Solution for each Management Strategy

Management Strategy (Objective Function):	Production Units	Total Revenue	Labor Cost	Net Return
Maximize Production	**738**	$ 21,433.73	$ 8,665.00	$ 12,768.73
Maximize Revenue	721	**$ 21,559.32**	$ 8,665.00	$ 12,894.32
Minimize Labor Cost	255	$ 14,666.30	**$ 5,038.77**	$ 9,627.53
Maximize Net Returns	721	$ 21,559.32	$ 8,665.00	**$ 12,894.32**

4.2.1 Maximize Production

The management strategy of maximizing production causes the model to search for the best combination of employee hours and tasks that create the most production units, regardless of the value of each task produced, and regardless of the labor cost. When the goal is to maximize production, hours are shifted to the employee/task combinations that yield the most output per hour, while still satisfying the constraints, picking the tasks employees are most specialized in. The results show that 738 total units can be produced. A key observation is that when the production output is maximized, the total revenue and net returns decrease. The number of total units of production possible can be important when a manager is contemplating bidding a new contract, so they can determine their maximum production capacity. Table 4.3 shows how many hours are assigned to each employee, per task, to maximize production.

Table 4.3 Hours Assigned to Maximize Production

	Task A	Task B	Task C	Task D	Task E	Task F
Employee #1	0	0	0	0	37	0
Employee #2	0	0	0	0	32	0
Employee #3	1.45	0	0	0	1.05	4.5
Employee #4	0	0	0	0	30	0
Employee #5	0	0	26.95	1.05	0	0
Employee #6	0	0	35	0	0	0
Employee #7	1.50	0	0	33.50	0	0
Employee #8	4.09	25.91	0	0	0	0

4.2.2 Maximize Revenue

The management strategy of maximizing revenue causes the model to search for the best combination of employee hours and tasks that will generate the most revenue, regardless of labor costs. When the goal is to maximize revenue, the objective is to assign hours to employee/task value combinations that yield the most revenue while satisfying the constraints. While employees may be assigned to tasks they specialize in, this is done for tasks that create the most value for the company. Maximizing the revenues slightly lowers overall production, because it focuses resources on the higher-valued tasks. For example, with production maximized, 80 units of Task A are produced at $6/each, and 238 units of Task C are produced at $16.50/each. When revenues are maximized, the units of Task A produced are reduced to 58.5; whereas the units of Task C produced are increased to 241.50. The model shifts hours from lower-valued tasks to higher-valued tasks. When revenues are maximized, total production decreases slightly, but total revenue increases $125 compared to when production is maximized. When the management strategy is to maximize revenue, the total revenue is $21,559. Table 4.4 shows how many hours are assigned to each employee, per task, in order to maximize revenue.

Table 4.4 Hours Assigned to Maximize Revenue

	Task A	Task B	Task C	Task D	Task E	Task F
Employee #1	0	0	0	0	37	0
Employee #2	0	0	0	0	32	0
Employee #3	0	0	0	0	1.05	5.95
Employee #4	0	0	0	0	30	0
Employee #5	0	0	28	0	0	0
Employee #6	0	0	35	0	0	0
Employee #7	0.74	0	0	34.26	0	0
Employee #8	3.75	26.25	0	0	0	0

4.2.3 Minimize Labor Cost

The management strategy to minimize labor cost cuases the model to search for the best combination of employee hours and tasks that creates the lowest total labor cost, and does not incorporate task revenues. The model assigns hours to the employees with the lowest relative hourly wage, while meeting production requirements. All available hours were assigned for the four employees with the lowest hourly wage. The model then assigned hours to the remaining employees based on which employee had the highest relative productivity compared to their wage. In this scenario, specialization is not necessarily advantageous, unless specialized employees have lower wage rates, which may be unlikely if the company values their productivity and skills. The results show that minimizing labor costs is not the most profitable management strategy, as net returns decreased by $3,267 when minimizing labor was the management strategy. While a manager may need to minimize labor costs for a period, a higher net return is possible by investing in more labor hours. Table 4.5 shows how many hours are assigned to each employee, per task, in order to minimize labor cost.

Table 4.5 Hours Assigned to Minimize Labor Cost

	Task A	Task B	Task C	Task D	Task E	Task F
Employee #1	0	0	0	0	37	0
Employee #2	0	0	0	0	32	0
Employee #3	0	0	1.45	0	1.05	4.50
Employee #4	0	0	0	0	30	0
Employee #5	0	0	0	0	0	0
Employee #6	0	0	13.18	0	0	0
Employee #7	3.92	0	0	9.63	0	0
Employee #8	0	10	0	0	0	0

4.2.4 Maximize Net Return

The optimal solution results determined by maximizing net returns are discussed in detail in section 4.1. However, there are a couple key observations shown in Table 4.2. First, the level of production units completed decreases when net returns is maximized, as compared to production being maximized. This is attributed to the model assigning more hours to higher-valued tasks, rather than trying to complete more lower-valued tasks. Also, net returns are the same for both management strategies of maximizing revenue and maximizing net return, because all employees are assigned all available hours for both objectives.

4.3 Additional Sensitivity Analysis

Sensitivity analysis allows a manager to change a parameter within the model, and see the impact that the change would have on the optimal solution. Performing sensitivity analysis within the model is beneficial for a manager, because they can test a proposed change before they physically invest the resources to make that change. For example, if the manager believes that net returns would increase if a given employee was cross-trained to perform other tasks, then the manager can test this with the model before weeks of time to train are invested into a potentially poor decision.

Four scenarios were chosen to be examined using sensitivity analysis: cross-training the least productive employee, cross-training a specialized employee, increasing an underpaid employee’s salary, and decreasing an overpaid employee’s salary. The cross-training scenarios were chosen to evaluate the possibility of further increasing production and flexibility, beyond what is possible with purely optimizing the base model. Each change was entered into the model, and the model re-solved for each of the management strategies. The analyses provide valuable information as to how the change impacts the optimal solution results. The first scenario to be presented is cross-training the least productive employee.

4.3.1 Cross-training the least productive employee

A manager may ponder the idea of cross-training an employee with low productivity at performing current task(s), in an effort to increase staffing flexibility, and also perhaps increase productivity, revenue, and net returns, as well as trying to achieve a reduction in labor costs. To analyze this idea, the employee with the lowest productivity ratings was identified, and their productivity rating for each task was increased from their previous amount up to 80%. For example, the the productivity rating was increased from 0% to 80% for the tasks they weren't previously trained to perform, and from 50% to 80% for Task C. The model was executed with the modified productivity ratings, and the results show that cross-training the least productive employee improved the optimal solution in each of the four management scenarios examined. Results are summarized in Table 4.6.

Table 4.6 Optimal Objective Function Value from Cross-training the Least Productive Employee for each Management Strategy

Scenario	Production Units	Revenue	Labor Cost	Net Return
Base Result	738	$ 21,559.32	$ 5,038.77	$ 12,894.32
With Cross-training the Least Productive Employee	809	$ 22,624.65	$ 4,626.77	$ 13,959.65

The results of cross-training the least productive employee indicate that cross-training the selected employee would improve the optimal solution for each of the four management strategies. That is, if the manager's strategy was to maximize production, cross-training the employee would increase production by 71 production units; if the manager's strategy was to maximize revenues, cross-training the employee would increase revenues by $1,056; if the manager's strategy was to minimize labor costs, cross-training the employee would decrease labor costs by $412; and, if the manager's strategy was to maximize net returns, cross-training the employee would increase net returns by $1,056.

In this situation, there was a strong demand for increased output; however, the employee identified was not performing at a high productivity rate. Also, the results provide insight that perhaps the employee was cross-trained into a task that was a better opportunity for that specific employee. In reality, a manager must decide whether the improved optimal solution, and the increased flexibility afforded by cross-training the selected employee, are worth the time, effort, and resources to fully cross-train the employee. However, the results do indicate that the change would have a positive, or beneficial, impact on the manager's strategy. In addition, the manager would need to account for the cost to train the employee as the model does not incorporate these training costs.

In this scenario, cross-training reduced the labor cost, when minimization of labor costs was the objective, because the least productive employee became more productive all around; therefore, a reduction in labor costs increased net returns, while the production and revenues remained the same. The cost reduction will be dependent on the cross-trained employee's salary.

4.3.2 Cross-training a specialized employee in another task

A manager may debate cross-training an employee that is currently specializing in a given task, in an effort to increase staffing flexibility and potentially increase productivity, revenue, or net returns, or to reduce labor costs. To assess the idea and determine the impact, an employee that currently specializes in a single task was identified, and the productivity ratings for the non-specialized tasks were increased from 0% to 80%, assuming cross-training was successful with the employee. This sensitivity analysis was re-solved for two different specialized employees, as the literature review suggested that it is important to test across different types of employees.

The first specialized employee (Employee #1) selected for cross-training was specialized in the task (Task E) most constrained by minimum output levels. The results show that cross-training this specialized employee did not have any impact on the optimal solution for any of the four management scenarios. The model still assigned the original task hours rather than use the employee's newly acquired cross-trained skills to satisfy the minimum production constraint for Task E. Cross-training this employee could be a poor investment decision.

The second employee identified for cross-training, in this scenario, was Employee #8. Employee #8 was specialized to perform only Task A and Task B; however, for the purpose of this sensitivity analysis, the productivity ratings for Employee #8 in Tasks C-F were raised to 80%, assuming cross-training was successful. The base model, before incorporating the sensitivity analysis scenario, was able to choose from a variety of employees to complete Task A and B, and neither Task A nor Task B were bound by minimum production constraints. The model was re-solved with the modified task productivity ratings for Employee #8, and the results show that cross-training this employee improved the optimal solution for minimizing labor costs: the total labor cost decreased by $25.96. The other three management strategy optimal solutions remained the same. Ultimately, the model was able to assign hours to Employee #8 for newly-learned tasks to lower the total labor cost, because Employee #8 was not forced to continue performing only their specialized tasks. The model was able to assign hours to other employees for Task A and B; which allowed the model to assign Employee #8 hours to other tasks. Table 4.7 summarizes the results from cross-training specialized employees for both a low and high productivity employee.

Table 4.7 Optimal Objective Function Value from Cross-training a Specialized Employee for each Management Strategy

Scenario	Production Units	Revenue	Labor Cost	Net Return
Base Result	738	$ 21,559.32	$ 5,038.77	$ 12,894.32
With Cross-training a Specialized Employee, constrained task	738	$ 21,559.32	$ 5,038.77	$ 12,894.32
With Cross-training a Specialized Employee, non-constrained task	738	$ 21,559.32	$ 5,012.81	$ 12,894.32

In summary, cross training can be beneficial to the company: it affords scheduling flexibility, and, if the correct employee is selected to be cross-trained, the optimal solution can improve. The sensitivity analysis results indicate that cross-training an the least productive employee to a productivity level of 80% in each task yields improvement in each of the four management strategy optimal solutions. If the manager decides to cross-train a specialized employee to perform other tasks; the manager must carefully choose the employee; otherwise, there may be no improvement in the optimal solution. Tiwari et al. (2009) found similar results, noting that "to achieve the greatest benefits of cross-training, it is critical to identify and clearly evaluate the individual workers current skill-set … and also evaluate the impact of an individual's cross-training on the department's overall effort (Tiwari et al., 2009; p. 789)."

4.3.3 Increase the salary of an underpaid employee

A manager may contemplate increasing the salary, or hourly wage, of an employee, especially if the employee is underpaid for their relative contributions to the company. This may be necessary to retain the employee, or encourage others to perform at a higher level. To learn how increasing an employee's wage would impact the optimal results of each management strategy, a lower paid, highly productive employee was identified. Next, the identified employee's hourly wage was increased by $7, which brings their wage to an equitable amount, in parity with others' in the company. Then, the model was resolved and results generated. The results indicate that increasing the employee's pay would increase the total labor cost by $210, while decreasing net returns by the same amount. The production units and revenues did not change, as those numbers do not incorporate the employee's wage. Table 4.8 summarizes the results from increasing the wage of an underpaid employee.

Table 4.8 Optimal Objective Function Value from Increasing the Hourly Wage of an Underpaid Employee for each Management Strategy

Scenario	Production Units	Revenue	Labor Cost	Net Return
Base Result	738	$ 21,559.32	$ 5,038.77	$ 12,894.32
Increasing Salary of Underpaid Employee	738	$ 21,559.32	$ 5,248.77	$ 12,684.32

The practical implication of this scenario is that the manager would expect net returns to decrease by $210 per week if the employee's wage was increased by $7.00 per hour. The manager, equipped with this information, can decide if the employee's contributions warrant the increased pay; or perhaps, the manager could run a different sensitivity analysis to see how much net returns would decrease if the employee resigned, and no longer contributed to the company's production efforts. Additionally, the wage in the model could be increased to determine at what wage level would induce a change in the optimal solution.

4.3.4 Decrease the salary of an overpaid employee

A manager may contemplate decreasing the salary, or wage, of an employee, especially if the employee is overpaid for their relative contributions to the company. This may be necessary to reduce workplace tensions among employees, or encourage the employee to perform at a higher level. To learn how decreasing an employee's wage would impact the optimal results of each management strategy, the lowest producing, overpaid employee was identified. Next, the identified employee's hourly wage was decreased by $7, which brings it to an equitable amount. Then, the model was re-solved and the results generated. The results indicate that decreasing the employee's pay did not change the overall labor cost when labor costs were minimized, primarily because neither the base model nor the modified model for the sensitivity analysis assigned hours to the employee. However, when the manager's strategy was to maximize net returns, the net returns increased by $196. The production units and revenues did not change, as those numbers do not incorporate the employee's wage.

The practical implication of this scenario is that the manager could expect net returns to increase slightly when an overpaid employee's wage is reduced by $7.00 per hour. The manager, equipped with this information, could have a conversation with the employee, or union representatives. Alternately, if there are extenuating circumstances that require the employee remain at the same wage within the company, the manager could request a subsidy, from the President/Board, to justify keeping this employee at the same salary. Table 4.9 summarizes the results from decreasing the wage of an overpaid employee.

Table 4.9 Optimal Objective Function Value from Decreasing the Hourly Wage of an Overpaid Employee for each Management Strategy

Scenario	Production Units	Revenue	Labor Cost	Net Return
Base Result	738	$ 21,559.32	$ 5,038.77	$ 12,894.32
Decreasing Salary of Overpaid Employee	738	$ 21,559.32	$ 5,038.77	$ 13,090.32

4.4 Discussion

The model generated many valuable results, both from the various management strategy objectives, as well as the sensitivity analyses. The general implications from the model are applicable to every day management. In addition, some of the results from the optimizations are very similar to results noted in the literature review articles.

The results indicate that it is more beneficial to select a lower producing employee, rather than a highly productive specialized employee, to cross-train into a new task, assuming they both will learn the same new task and perform at the same productivity rate. This conclusion is logical, because there is more opportunity on the margin to improve from a low level up to a higher level, as compared to taking an already highly productive employee and potentially lowering their productivity by focusing some of their effort on a different task. These findings agree with Nembhard et al. (2005), who stated “for the same training level, the greater investment reward should come from those workers with relative lower production capability while being assigned to a more difficult task (Nembhard et al., 2005; p. 110)”. The practical implication for a manager is that they may be better off to focus their resources on training and improving the less-productive employees, rather than cross-training an already highly productive specialized employee.

A manager must carefully choose the employee(s) selected for cross-training. Cross-training a specialized employee on another task may increase flexibility; however, it may not increase overall productivity or net returns. This finding is similar to findings from Nembhard et al. (2005) who found that the marginal value to cross-train somebody already performing at an optimal level is near zero. The practical implication to a manager is that cross-training a specialized employee on another task, with the hopes of increasing productivity, could potentially be a poor investment.

The various scenarios consistently indicated that minimizing labor costs may not be the most profitable management strategy. The practical implication to a manager is that, although there may be situations in which they are forced to purely minimize costs, they may be able to increase the overall net return by investing more labor hours, as long as the marginal benefit of using more hours is greater than the marginal labor cost.

Maximizing production does not directly correlate to maximizing revenues or the net returns. It may be more profitable to produce a lower quantity of a higher value task, rather than a higher quantity of a lower valued task, depending on the specific production characteristics (i.e. value) and labor costs. This study indicated that maximizing net returns reduced the overall production, because hours were allocated to higher-value tasks, although each task took more hours to complete. The practical implication is that a manager should not strive to purely maximize production, under the assumption it will generate the highest net return.

A manager should analyze the full situation, including the task demand, to determine which employee(s) to cross-train. The minimum production level for each task must be satisfied. Hence, a specialized employee performing a task that is barely achieving the minimum production level will not be allocated hours to another task, regardless if they're cross-trained to perform other tasks. Thus, it would be a poor decision to cross-train a specialized employee currently performing a task in which the minimum production level is just being satisfied, unless another individual was cross trained to cover that minimum production level. Conversely, an employee performing a task that is well above the minimum production level would be freer to perform other tasks, if they were cross-trained. The practical implication for a manager is that cross-training a specialized employee that cannot be spared from performing their regular task due to the task's minimum production requirement would be a poor decision, as neither production nor flexibility would increase.

Cross-training is most beneficial when the employee to be cross-trained is trained to a relatively high productivity level in a higher-valued task. A manager that is considering cross-training an employee should carefully select the employee to be cross-trained, as well as carefully select the tasks in which the cross-trained employee will learn. Cross-training an employee to perform a task currently constrained by minimum production levels would increase flexibility; whereas training an employee to perform a task in which there's already an abundance of production may not be a wise investment.

Cross-training an employee with a lower salary can help reduce overall labor costs, as well as increase flexibility. A manager may be wise to consider the employee's relative wage when determining who to cross-train. Cross-training a lower-paid employee can be very beneficial when the management strategy is to minimize labor costs.

Sensitivity analysis regarding wage adjustment provides insight as to how bottom lines would be affected for each scenario and management strategy. In this example, decreasing an overpaid employee's wage did not reduce labor costs when minimization of labor costs was the objective, because the model did not allocate hours to this employee.

The results from each optimized management strategy provide valuable insight as to the potential for the company. The sensitivity analyses shed light as to potential cross-training opportunities, as well as the impact that adjusting an employee's salary would have on production, revenue, labor cost and the net return. The information provided by the results equips a manager to make more informed decisions.

CHAPTER V: CONCLUSION

Company managers continually face challenges in the market, such as increased demand for their services and variability in the types of service requested. In addition, managers may face internal challenges during periods adjustment such as moving the company forward through a hiring freeze. In these situations, a manager must be able to allocate their scarce resources in a way to continue to perform. For employees, this could mean specializing in tasks or increasing cross-training to improve work schedule flexibility. The objective of this research was to determine the optimal allocation of employees to tasks, given resource constraints and the need for staff flexibility, to satisfy alternative management strategies.

Literature relating to optimization of employee assignments indicates that a workforce of specialized employees has high productivity; however, assignment flexibility may be very limited. A workforce of cross-trained employees has greater assignment flexibility; however, they may have reduced productivity. However, a workforce consisting of a mix of specialized and cross-trained employees can strike a balance between needed flexibility and productivity. The literature indicates that employee assignment optimization models can provide insight as to how to optimize workforce allocations, and determine if cross-training could be beneficial.

For this thesis, an employee assignment optimization model was developed that incorporated data from both the employee and task characteristics, as well as relevant parameters, objective functions, and constraints, to reflect an actual empirical business situation. Optimization was used to consider various management strategies: maximize production, maximize revenues, minimize labor costs, and maximize net returns. Each model provided not only the optimal assignment of employees to tasks, but also indicated what the expected production, revenue, labor cost, and net return would be in each situation. Beyond that, sensitivity analysis was performed to examine various cross-training and labor wage scenarios, to explore potential situations that could further benefit the company. The results from the model and the sensitivity analyses provide valuable implications for business managers.

Results from the base model, tested under various management strategies, yielded the following practical implications:

- Although there may be situations in which management is forced to purely minimize costs, they may be able to increase overall net returns by investing more labor hours, as long as the marginal benefit of using more hours is greater than the marginal labor cost.
- A manager should not strive to purely maximize production, under the assumption it will generate the highest net return. It may be more profitable to produce a lower quantity of a higher value task, rather than a higher quantity of a lower valued task, depending on the specific production characteristics (i.e. value) and labor costs.

Results generated from the sensitivity analyses indicate that cross-training increases flexibility, and may be beneficial to increase productivity however, the manager must carefully select the employee to be cross-trained, as well as the task to be learned. More specifically, the sensitivity analyses yielded the following practical implications:

- It may be more beneficial to focus resources on training and improving the less-productive employees, rather than cross-training an already highly productive employee. There is more opportunity on the margin to improve from a low productivity up to a higher level, as compared to taking an already highly productive employee and potentially lowering their productivity by focusing some of their effort on a different task.

- Cross-training a specialized employee on another task, with the hopes of increasing productivity, could potentially be a poor investment.
- It may be possible to realize benefits in flexibility and productivity by cross-training only a few, carefully-selected, employees.
- Cross-training a specialized employee that cannot be spared from performing their regular task due to the task's minimum production requirement could be a poor decision, as potentially neither production or flexibility would increase.
- Cross-training may be most beneficial when the employee to be cross-trained is trained to a relatively high productivity level in a high-value task.
- Cross-training an employee to perform a task currently constrained by its minimum production level may impart increased flexibility.
- Training an employee to perform a task in which there is already an abundance of production may be a poor investment.
- Cross-training an employee with a lower salary may help reduce overall labor costs, as well as increase flexibility.

The results from this study allow a manager to see how the optimal solutions change depending on the management strategy selected. The results from the various sensitivity analyses allow a manager to test a proposed change before physically making the investment.

A suggestion for future research would be to use sensitivity analysis to determine if it is better to hire another employee, or offer overtime to the existing employees, knowing that overtime is typically paid at a higher hourly wage than regular time. Also, if overtime is offered, then use the model to determine which employee(s) should be offered the extra hours. An enhancement to the model would be to expand the model to incorporate the cost of cross-training an employee.

Expanding the model to incorporate the cost to train an employee would be beneficial and strengthen the model. Physically cross-training an employee typically involves the time of the employee being trained, the trainer's time, the cost of reduced output while the trainer is teaching, as well as additional managerial oversight. Additionally, the model could be used to consider quantifyable quality characteristics, such as customer satisfaction with processing times.

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APPENDIX A

Appendix A includes a collection of excel images presenting the optimal solution results from each of the 24 optimization model runs. The optimal solution results indicate the hours to be assigned to each employee per task, as well as the total production, revenue, labor cost, and net returns.

Figure A1. Excel Image of Optimal Solution for the Base Model to Maximize Production

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[illegible]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[illegible]
7		Employee #3	1.44737	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	4.5	1	7	7	[illegible]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[illegible]
9		Employee #5	0	1.8	0	1.2	26.9502	3	1.04981	1.5	0	0.00	0	0	28	28	[illegible]
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[illegible]
11		Employee #7	1.49612	10.2	0	4	0	3	33.5039	6	0	0.00	0	0	35	35	[illegible]
12		Employee #8	4.09233	12	25.9077	8	0	0	0	0	0	0.00	0	0	30	30	[illegible]
13		Optimized Production		80		207.261		238.350562		202.5979781		5		4.5			$8,665.00
14		Minimum Production		40		160		176.172155		202.5979781		5		4.5			
15		Maximim Production		80		320		238.350562		274.1031469		15		16.5			
16																	
17				Weekly Production Summary				Revenue									
18					Task A		80	$ 480.00									
19					Task B		207.261	$ 2,279.87									
20					Task C		238.351	$ 3,932.78									
21					Task D		202.598	$ 3,241.57									
22					Task E		5	$11,000.00		Total Revenue	$21,433.73						
23					Task F		4.5	$ 499.50		Labor Cost	$ 8,665.00						
24					Totals:		737.71	$21,433.73		Net Return	$12,768.73						

Figure A2. Excel Image of Optimal Solution for the Base Model to Maximize Revenue

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[illegible]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[illegible]
7		Employee #3	0	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	5.94737	1	7	7	[illegible]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[illegible]
9		Employee #5	0	1.8	0	1.2	28	3	0	1.5	0	0.00	0	0	28	28	[illegible]
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[illegible]
11		Employee #7	0.73529	10.2	0	4	0	3	34.2647	6	0	0.00	0	0	35	35	[illegible]
12		Employee #8	3.75	12	26.25	8	0	0	0	0	0	0.00	0	0	30	30	[illegible]
13		Optimized Production		52.5		210		241.5		205.5882353		5		5.94737			$8,665.00
14		Minimum Production		40		105		178.5		205.275		5		4.5			
15		Maximim Production		80		210		241.5		277.725		15		16.5			
16																	
17				Weekly Production Summary				Revenue									
18					Task A		52.5	$ 315.00									
19					Task B		210	$ 2,310.00									
20					Task C		241.5	$ 3,984.75									
21					Task D		205.588	$ 3,289.41									
22					Task E		5	$11,000.00		Total Revenue	$21,559.32						
23					Task F		5.94737	$ 660.16		Labor Cost	$ 8,665.00						
24					Totals:		720.536	$21,559.32		Net Return	$12,894.32						

Figure A3. Excel Image of Optimal Solution for the Base Model to Minimize Labor Cost

Optimal Allocation of Employee Hours

	Task A Hours to Assign	Task A Output / Hour	Task B Hours to Assign	Task B Output / Hour	Task C Hours to Assign	Task C Output / Hour	Task D Hours to Assign	Task D Output / Hour	Task E Hours to Assign	Task E Output / Hour	Task F Hours to Assign	Task F Output / Hour	Hours Assigned	Hours Available / Week	Labor Cost
Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[illegible]
Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[illegible]
Employee #3	0	10.8	0	7.2	1.44737	6	0	4.8	1.05263158	0.05	4.5	1	7	7	[illegible]
Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[illegible]
Employee #5	0	1.8	0	1.2	0	3	0	1.5	0	0.00	0	0	0	28	[illegible]
Employee #6	0	1.8	0	1.2	13.1813	4.5	0	1.8	0	0.00	0	0	13.18129	35	[illegible]
Employee #7	3.92157	10.2	0	4	0	3	9.63333	6	0	0.00	0	0	13.5549	35	[illegible]
Employee #8	0	12	10	8	0	0	0	0	0	0.00	0	0	10	30	[illegible]
Optimized Production		40		80		68		57.8		5		4.5			$5,038.77
Minimum Production		40		80		68		57.8		5		4.5			
Maximim Production		80		160		92		78.2		15		16.5			

Weekly Production Summary		Revenue
Task A	40	$ 240.00
Task B	80	$ 880.00
Task C	68	$ 1,122.00
Task D	57.8	$ 924.80
Task E	5	$11,000.00
Task F	4.5	$ 499.50
Totals:	255.3	$14,666.30

Total Revenue	$14,666.30
Labor Cost	$ 5,038.77
Net Return	$ 9,627.53

Figure A4. Excel Image of Optimal Solution for the Base Model to Maximize Net Returns

Optimal Allocation of Employee Hours

	Task A Hours to Assign	Task A Output / Hour	Task B Hours to Assign	Task B Output / Hour	Task C Hours to Assign	Task C Output / Hour	Task D Hours to Assign	Task D Output / Hour	Task E Hours to Assign	Task E Output / Hour	Task F Hours to Assign	Task F Output / Hour	Hours Assigned	Hours Available / Week	Labor Cost
Employee #1	0.00	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[illegible]
Employee #2	0.00	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[illegible]
Employee #3	0.00	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	5.94737	1	7	7	[illegible]
Employee #4	0.00	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[illegible]
Employee #5	0.00	1.8	0	1.2	28	3	0	1.5	0	0.00	0	0	28	28	[illegible]
Employee #6	0.00	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[illegible]
Employee #7	0.74	10.2	0	4	0	3	34.2647	6	0	0.00	0	0	35	35	[illegible]
Employee #8	3.75	12	26.25	8	0	0	0	0	0	0.00	0	0	30	30	[illegible]
Optimized Production		52.5		210		241.5		205.5882353		5		5.94737			$8,665.00
Minimum Production		40		105		178.5		205.275		5		4.5			
Maximim Production		80		210		241.5		277.725		15		16.5			

Weekly Production Summary		Revenue
Task A	52.5	$ 315.00
Task B	210	$ 2,310.00
Task C	241.5	$ 3,984.75
Task D	205.588	$ 3,289.41
Task E	5	$11,000.00
Task F	5.94737	$ 660.16
Totals:	720.536	$21,559.32

Total Revenue	$21,559.32
Labor Cost	$ 8,665.00
Net Return	$12,894.32

Figure A5. Excel Image of Optimal Solution for the Base Model to Maximize Production when the Least Productive Employee is Cross-trained

Optimal Allocation of Employee Hours

	Task A		Task B		Task C		Task D		Task E		Task F			Hours	
	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
Employee #3	0	10.8	0	7.2	7	6	0	4.8	0	0.05	0	1	7	7	[redacted]
Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
Employee #5	0	9.6	13.89	6.4	7.23503	4.8	0	4.8	1.25	0.04	5.625	1	28	28	[redacted]
Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
Employee #7	0	10.2	0	4	0	3	35	6	0	0.00	0	0	35	35	[redacted]
Employee #8	6.66667	12	23.3333	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
Optimized Production		80		275.563		234.228125		210		5		4.5			$8,665.00
Minimum Production		40		160		234.228125		199.0939063		5		4.5			
Maximim Production		80		320		316.896875		269.3623438		15		16.5			

Weekly Production Summary		Revenue
Task A	80	$ 480.00
Task B	275.563	$ 3,031.19
Task C	234.228	$ 3,864.76
Task D	210	$ 3,360.00
Task E	5	$11,000.00
Task F	4.5	$ 499.50
Totals:	**809.291**	**$22,235.45**

Total Revenue	**$ 22,235.45**
Labor Cost	**$ 8,665.00**
Net Return	**$ 13,570.45**

Figure A6. Excel Image of Optimal Solution for the Base Model to Maximize Production when a Specialized Employee devoted to a Constrained Task is Cross-trained

Optimal Allocation of Employee Hours

	Task A		Task B		Task C		Task D		Task E		Task F			Hours	
	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
Employee #1	0	9.6	0	6.4	0	4.8	0	4.8	37	0.05	0	1	37	37	[redacted]
Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
Employee #3	1.44737	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	4.5	1	7	7	[redacted]
Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
Employee #5	0	1.8	0	1.2	26.9502	3	1.04981	1.5	0	0.00	0	0	28	28	[redacted]
Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
Employee #7	1.49612	10.2	0	4	0	3	33.5039	6	0	0.00	0	0	35	35	[redacted]
Employee #8	4.09233	12	25.9077	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
Optimized Production		80		207.261		238.350562		202.5979781		5		4.5			$8,665.00
Minimum Production		40		160		176.172155		202.5979781		5		4.5			
Maximim Production		80		320		238.350562		274.1031469		15		16.5			

Weekly Production Summary		Revenue
Task A	80	$ 480.00
Task B	207.261	$ 2,279.87
Task C	238.351	$ 3,932.78
Task D	202.598	$ 3,241.57
Task E	5	$11,000.00
Task F	4.5	$ 499.50
Totals:	**737.71**	**$21,433.73**

Total Revenue	**$ 21,433.73**
Labor Cost	**$ 8,665.00**
Net Return	**$ 12,768.73**

Figure A7. Excel Image of Optimal Solution for the Base Model to Maximize Production when a Specialized Employee of a Non-Constrained Task is Cross-trained

	Optimal Allocation of Employee Hours														
	Task A		Task B		Task C		Task D		Task E		Task F				
	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Hours Available / Week	Labor Cost
Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
Employee #3	1.44737	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	4.5	1	7	7	[redacted]
Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
Employee #5	0	1.8	0	1.2	26.9502	3	1.04981	1.5	0	0.00	0	0	28	28	[redacted]
Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
Employee #7	1.49612	10.2	0	4	0	3	33.5039	6	0	0.00	0	0	35	35	[redacted]
Employee #8	4.09233	12	25.9077	8	0	4.8	0	4.8	0	0.04	0	1	30	30	[redacted]
Optimized Production		80		207.261		238.350562		202.5979781		5		4.5			$8,665.00
Minimum Production		40		160		176.172155		202.5979781		5		4.5			
Maximim Production		80		320		238.350562		274.1031469		15		16.5			

Weekly Production Summary		Revenue
Task A	80	$ 480.00
Task B	207.261	$ 2,279.87
Task C	238.351	$ 3,932.78
Task D	202.598	$ 3,241.57
Task E	5	$11,000.00
Task F	4.5	$ 499.50
Totals:	737.71	$21,433.73

Total Revenue	$ 21,433.73
Labor Cost	$ 8,665.00
Net Return	$ 12,768.73

Figure A8. Excel Image of Optimal Solution for the Base Model to Maximize Production when Wages are Increased for an Underpaid Employee

	Optimal Allocation of Employee Hours														
	Task A		Task B		Task C		Task D		Task E		Task F				
	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Hours Available / Week	Labor Cost
Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
Employee #3	1.44737	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	4.5	1	7	7	[redacted]
Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
Employee #5	0	1.8	0	1.2	26.9502	3	1.04981	1.5	0	0.00	0	0	28	28	[redacted]
Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
Employee #7	1.49612	10.2	0	4	0	3	33.5039	6	0	0.00	0	0	35	35	[redacted]
Employee #8	4.09233	12	25.9077	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
Optimized Production		80		207.261		238.350562		202.5979781		5		4.5			$8,875.00
Minimum Production		40		160		176.172155		202.5979781		5		4.5			
Maximim Production		80		320		238.350562		274.1031469		15		16.5			

Weekly Production Summary		Revenue
Task A	80	$ 480.00
Task B	207.261	$ 2,279.87
Task C	238.351	$ 3,932.78
Task D	202.598	$ 3,241.57
Task E	5	$11,000.00
Task F	4.5	$ 499.50
Totals:	737.71	$21,433.73

Total Revenue	$ 21,433.73
Labor Cost	$ 8,875.00
Net Return	$ 12,558.73

Figure A9. Excel Image of Optimal Solution for the Base Model to Maximize Production when Wages are Decreased for an Overpaid Employee

	Task A Hours to Assign	Task A Output / Hour	Task B Hours to Assign	Task B Output / Hour	Task C Hours to Assign	Task C Output / Hour	Task D Hours to Assign	Task D Output / Hour	Task E Hours to Assign	Task E Output / Hour	Task F Hours to Assign	Task F Output / Hour	Hours Assigned	Hours Available / Week	Labor Cost
Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
Employee #3	1.44737	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	4.5	1	7	7	[redacted]
Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
Employee #5	0	1.8	0	1.2	26.9502	3	1.04981	1.5	0	0.00	0	0	28	28	[redacted]
Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
Employee #7	1.49612	10.2	0	4	0	3	33.5039	6	0	0.00	0	0	35	35	[redacted]
Employee #8	4.09233	12	25.9077	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
Optimized Production		80		207.261		238.350562		202.5979781		5		4.5			$8,469.00
Minimum Production		40		160		176.172155		202.5979781		5		4.5			
Maximim Production		80		320		238.350562		274.1031469		15		16.5			

Weekly Production Summary		Revenue
Task A	80	$ 480.00
Task B	207.261	$ 2,279.87
Task C	238.351	$ 3,932.78
Task D	202.598	$ 3,241.57
Task E	5	$11,000.00
Task F	4.5	$ 499.50
Totals:	737.71	$21,433.73

Total Revenue	$ 21,433.73
Labor Cost	$ 8,469.00
Net Return	$ 12,964.73

Figure A10. Excel Image of Optimal Solution for the Base Model to Maximize Revenue when the Least Productive Employee is Cross-trained

	Task A Hours to Assign	Task A Output / Hour	Task B Hours to Assign	Task B Output / Hour	Task C Hours to Assign	Task C Output / Hour	Task D Hours to Assign	Task D Output / Hour	Task E Hours to Assign	Task E Output / Hour	Task F Hours to Assign	Task F Output / Hour	Hours Assigned	Hours Available / Week	Labor Cost
Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
Employee #3	0	10.8	0	7.2	4.18478	6	0	4.8	0	0.05	2.81522	1	7	7	[redacted]
Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
Employee #5	0	9.6	0	6.4	0	4.8	0	4.8	10.8940217	0.04	17.106	1	28	28	[redacted]
Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
Employee #7	0	10.2	0	4	0	3	35	6	0	0.00	0	0	35	35	[redacted]
Employee #8	4.28571	12	25.7143	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
Optimized Production		51.4286		205.714		182.608696		210		5.38576		16.5			$8,665.00
Minimum Production		40		102.857		174.857143		155.2173913		5		4.5			
Maximim Production		80		205.714		236.571429		210		15		16.5			

Weekly Production Summary		Revenue
Task A	51.4286	$ 308.57
Task B	205.714	$ 2,262.86
Task C	182.609	$ 3,013.04
Task D	210	$ 3,360.00
Task E	5.38576	$11,848.67
Task F	16.5	$ 1,831.50
Totals:	671.637	$22,624.65

Total Revenue	$ 22,624.65
Labor Cost	$ 8,665.00
Net Return	$ 13,959.65

Figure A11. Excel Image of Optimal Solution for the Base Model to Maximize Revenue when a Specialized Employee devoted to a Constrained Task is Cross-trained

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	9.6	0	6.4	0	4.8	0	4.8	37	0.05	0	1	37	37	[redacted]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
7		Employee #3	0	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	5.94737	1	7	7	[redacted]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
9		Employee #5	0	1.8	0	1.2	28	3	0	1.5	0	0.00	0	0	28	28	[redacted]
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
11		Employee #7	0.73529	10.2	0	4	0	3	34.2647	6	0	0.00	0	0	35	35	[redacted]
12		Employee #8	3.75	12	26.25	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
13		Optimized Production		52.5		210		241.5		205.5882353		5		5.94737			$8,665.00
14		Minimum Production		40		105		178.5		205.275		5		4.5			
15		Maximim Production		80		210		241.5		277.725		15		16.5			

Weekly Production Summary		Revenue
Task A	52.5	$ 315.00
Task B	210	$ 2,310.00
Task C	241.5	$ 3,984.75
Task D	205.588	$ 3,289.41
Task E	5	$11,000.00
Task F	5.94737	$ 660.16
Totals:	720.536	$21,559.32

Total Revenue	$ 21,559.32
Labor Cost	$ 8,665.00
Net Return	$ 12,894.32

Figure A12. Excel Image of Optimal Solution for the Base Model to Maximize Revenue when a Specialized Employee of a Non-Constrained Task is Cross-trained

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
7		Employee #3	0	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	5.94737	1	7	7	[redacted]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
9		Employee #5	0	1.8	0	1.2	28	3	0	1.5	0	0.00	0	0	28	28	[redacted]
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
11		Employee #7	0.73529	10.2	0	4	0	3	34.2647	6	0	0.00	0	0	35	35	[redacted]
12		Employee #8	3.75	12	26.25	8	0	4.8	0	4.8	0	0.04	0	1	30	30	[redacted]
13		Optimized Production		52.5		210		241.5		205.5882353		5		5.94737			$8,665.00
14		Minimum Production		40		105		178.5		205.275		5		4.5			
15		Maximim Production		80		210		241.5		277.725		15		16.5			

Weekly Production Summary		Revenue
Task A	52.5	$ 315.00
Task B	210	$ 2,310.00
Task C	241.5	$ 3,984.75
Task D	205.588	$ 3,289.41
Task E	5	$11,000.00
Task F	5.94737	$ 660.16
Totals:	720.536	$21,559.32

Total Revenue	$ 21,559.32
Labor Cost	$ 8,665.00
Net Return	$ 12,894.32

Figure A13. Excel Image of Optimal Solution for the Base Model to Maximize Revenue when Wages are Increased for an Underpaid Employee

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
7		Employee #3	0	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	5.94737	1	7	7	[redacted]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
9		Employee #5	0	1.8	0	1.2	28	3	0	1.5	0	0.00	0	0	28	28	[redacted]
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
11		Employee #7	0.73529	10.2	0	4	0	3	34.2647	6	0	0.00	0	0	35	35	[redacted]
12		Employee #8	3.75	12	26.25	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
13	Optimized Production			52.5		210		241.5		205.5882353		5		5.94737			$8,875.00
14	Minimum Production			40		105		178.5		205.275		5		4.5			
15	Maximim Production			80		210		241.5		277.725		15		16.5			
16																	
17				Weekly Production Summary				Revenue									
18					Task A		52.5	$ 315.00									
19					Task B		210	$ 2,310.00									
20					Task C		241.5	$ 3,984.75									
21					Task D		205.588	$ 3,289.41									
22					Task E		5	$11,000.00		Total Revenue	$ 21,559.32						
23					Task F		5.94737	$ 660.16		Labor Cost	$ 8,875.00						
24					Totals:		720.536	$21,559.32		Net Return	$ 12,684.32						

Figure A14. Excel Image of Optimal Solution for the Base Model to Maximize Revenue when Wages are Decreased for an Overpaid Employee

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
7		Employee #3	0	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	5.94737	1	7	7	[redacted]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
9		Employee #5	0	1.8	0	1.2	28	3	0	1.5	0	0.00	0	0	28	28	[redacted]
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
11		Employee #7	0.73529	10.2	0	4	0	3	34.2647	6	0	0.00	0	0	35	35	[redacted]
12		Employee #8	3.75	12	26.25	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
13	Optimized Production			52.5		210		241.5		205.5882353		5		5.94737			$8,469.00
14	Minimum Production			40		105		178.5		205.275		5		4.5			
15	Maximim Production			80		210		241.5		277.725		15		16.5			
16																	
17				Weekly Production Summary				Revenue									
18					Task A		52.5	$ 315.00									
19					Task B		210	$ 2,310.00									
20					Task C		241.5	$ 3,984.75									
21					Task D		205.588	$ 3,289.41									
22					Task E		5	$11,000.00		Total Revenue	$ 21,559.32						
23					Task F		5.94737	$ 660.16		Labor Cost	$ 8,469.00						
24					Totals:		720.536	$21,559.32		Net Return	$ 13,090.32						

Figure A15. Excel Image of Optimal Solution for the Base Model to Minimize Labor Cost when the Least Productive Employee is Cross-trained

Optimal Allocation of Employee Hours

	Task A Hours to Assign	Task A Output / Hour	Task B Hours to Assign	Task B Output / Hour	Task C Hours to Assign	Task C Output / Hour	Task D Hours to Assign	Task D Output / Hour	Task E Hours to Assign	Task E Output / Hour	Task F Hours to Assign	Task F Output / Hour	Hours Assigned	Hours Available / Week	Labor Cost
Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[illegible]
Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[illegible]
Employee #3	0	10.8	0	7.2	7	6	0	4.8	0	0.05	0	1	7	7	[illegible]
Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[illegible]
Employee #5	0	9.6	0	6.4	5.41667	4.8	0	4.8	1.25	0.04	5.625	1	12.2917	28	[illegible]
Employee #6	0	1.8	0	1.2	0	4.5	0	1.8	0	0.00	0	0	0	35	[illegible]
Employee #7	3.92157	10.2	0	4	0	3	9.63333	6	0	0.00	0	0	13.5549	35	[illegible]
Employee #8	0	12	10	8	0	0	0	0	0	0.00	0	0	10	30	[illegible]
Optimized Production		40		80		68		57.8		5		4.5			$4,926.77
Minimum Production		40		80		68		57.8		5		4.5			
Maximim Production		80		160		92		78.2		15		16.5			

Weekly Production Summary		Revenue
Task A	40	$ 240.00
Task B	80	$ 880.00
Task C	68	$ 1,122.00
Task D	57.8	$ 924.80
Task E	5	$11,000.00
Task F	4.5	$ 499.50
Totals:	255.3	$14,666.30

Total Revenue	$ 14,666.30
Labor Cost	$ 4,926.77
Net Return	$ 9,739.53

Figure A16. Excel Image of Optimal Solution for the Base Model to Minimize Labor Cost when a Specialized Employee devoted to a Constrained Task is Cross-trained

Optimal Allocation of Employee Hours

	Task A Hours to Assign	Task A Output / Hour	Task B Hours to Assign	Task B Output / Hour	Task C Hours to Assign	Task C Output / Hour	Task D Hours to Assign	Task D Output / Hour	Task E Hours to Assign	Task E Output / Hour	Task F Hours to Assign	Task F Output / Hour	Hours Assigned	Hours Available / Week	Labor Cost
Employee #1	0	9.6	0	6.4	0	4.8	0	4.8	37	0.05	0	1	37	37	[illegible]
Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[illegible]
Employee #3	0	10.8	0	7.2	1.44737	6	0	4.8	1.05263158	0.05	4.5	1	7	7	[illegible]
Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[illegible]
Employee #5	0	1.8	0	1.2	0	3	0	1.5	0	0.00	0	0	0	28	[illegible]
Employee #6	0	1.8	0	1.2	13.1813	4.5	0	1.8	0	0.00	0	0	13.1813	35	[illegible]
Employee #7	3.92157	10.2	0	4	0	3	9.63333	6	0	0.00	0	0	13.5549	35	[illegible]
Employee #8	0	12	10	8	0	0	0	0	0	0.00	0	0	10	30	[illegible]
Optimized Production		40		80		68		57.8		5		4.5			$5,038.77
Minimum Production		40		80		68		57.8		5		4.5			
Maximim Production		80		160		92		78.2		15		16.5			

Weekly Production Summary		Revenue
Task A	40	$ 240.00
Task B	80	$ 880.00
Task C	68	$ 1,122.00
Task D	57.8	$ 924.80
Task E	5	$11,000.00
Task F	4.5	$ 499.50
Totals:	255.3	$14,666.30

Total Revenue	$ 14,666.30
Labor Cost	$ 5,038.77
Net Return	$ 9,627.53

Figure A17. Excel Image of Optimal Solution for the Base Model to Minimize Labor Cost when a Specialized Employee of a Non-Constrained Task is Cross-trained

Optimal Allocation of Employee Hours	Task A		Task B		Task C		Task D		Task E		Task F				
	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Hours Available / Week	Labor Cost
Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
Employee #3	0	10.8	0	7.2	2.5	6	0	4.8	0	0.05	4.5	1	7	7	[redacted]
Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
Employee #5	0	1.8	0	1.2	0	3	0	1.5	0	0.00	0	0	0	28	[redacted]
Employee #6	0	1.8	0	1.2	0	4.5	0	1.8	0	0.00	0	0	0	35	[redacted]
Employee #7	3.92157	10.2	0	4	0	3	9.63333	6	0	0.00	0	0	13.5549	35	[redacted]
Employee #8	0	12	10	8	11.0417	4.8	0	4.8	1.25	0.04	0	1	22.2917	30	[redacted]
Optimized Production		40		80		68		57.8		5		4.5			$5,012.81
Minimum Production		40		80		68		57.8		5		4.5			
Maximim Production		80		160		92		78.2		15		16.5			

Weekly Production Summary		Revenue
Task A	40	$ 240.00
Task B	80	$ 880.00
Task C	68	$ 1,122.00
Task D	57.8	$ 924.80
Task E	5	$11,000.00
Task F	4.5	$ 499.50
Totals:	255.3	$14,666.30

Total Revenue	$ 14,666.30
Labor Cost	$ 5,012.81
Net Return	$ 9,653.49

Figure A18. Excel Image of Optimal Solution for the Base Model to Minimize Labor Cost when Wages are Increased for an Underpaid Employee

Optimal Allocation of Employee Hours	Task A		Task B		Task C		Task D		Task E		Task F				
	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Hours Available / Week	Labor Cost
Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
Employee #3	0	10.8	0	7.2	1.44737	6	0	4.8	1.05263158	0.05	4.5	1	7	7	[redacted]
Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
Employee #5	0	1.8	0	1.2	0	3	0	1.5	0	0.00	0	0	0	28	[redacted]
Employee #6	0	1.8	0	1.2	13.1813	4.5	0	1.8	0	0.00	0	0	13.1813	35	[redacted]
Employee #7	3.92157	10.2	0	4	0	3	9.63333	6	0	0.00	0	0	13.5549	35	[redacted]
Employee #8	0	12	10	8	0	0	0	0	0	0.00	0	0	10	30	[redacted]
Optimized Production		40		80		68		57.8		5		4.5			$5,248.77
Minimum Production		40		80		68		57.8		5		4.5			
Maximim Production		80		160		92		78.2		15		16.5			

Weekly Production Summary		Revenue
Task A	40	$ 240.00
Task B	80	$ 880.00
Task C	68	$ 1,122.00
Task D	57.8	$ 924.80
Task E	5	$11,000.00
Task F	4.5	$ 499.50
Totals:	255.3	$14,666.30

Total Revenue	$ 14,666.30
Labor Cost	$ 5,248.77
Net Return	$ 9,417.53

Figure A19. Excel Image of Optimal Solution for the Base Model to Minimize Labor Cost when Wages are Decreased for an Overpaid Employee

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
7		Employee #3	0	10.8	0	7.2	1.44737	6	0	4.8	1.05263158	0.05	4.5	1	7	7	[redacted]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
9		Employee #5	0	1.8	0	1.2	0	3	0	1.5	0	0.00	0	0	0	28	[redacted]
10		Employee #6	0	1.8	0	1.2	13.1813	4.5	0	1.8	0	0.00	0	0	13.1813	35	[redacted]
11		Employee #7	3.92157	10.2	0	4	0	3	9.63333	6	0	0.00	0	0	13.5549	35	[redacted]
12		Employee #8	0	12	10	8	0	0	0	0	0	0.00	0	0	10	30	[redacted]
13	Optimized Production			40		80		68		57.8		5		4.5			$5,038.77
14	Minimum Production			40		80		68		57.8		5		4.5			
15	Maximim Production			80		160		92		78.2		15		16.5			
16																	
17				Weekly Production Summary				Revenue									
18					Task A		40	$ 240.00									
19					Task B		80	$ 880.00									
20					Task C		68	$ 1,122.00									
21					Task D		57.8	$ 924.80									
22					Task E		5	$11,000.00		Total Revenue	$14,666.30						
23					Task F		4.5	$ 499.50		Labor Cost	$ 5,038.77						
24					Totals:		255.3	$14,666.30		Net Return	$ 9,627.53						

Figure A20. Excel Image of Optimal Solution for the Base Model to Maximize Returns when the Least Productive Employee is Cross-trained

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
7		Employee #3	0	10.8	0	7.2	4.18478	6	0	4.8	0	0.05	2.81522	1	7	7	[redacted]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
9		Employee #5	0	9.6	0	6.4	0	4.8	0	4.8	10.8940217	0.04	17.106	1	28	28	[redacted]
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
11		Employee #7	0	10.2	0	4	0	3	35	6	0	0.00	0	0	35	35	[redacted]
12		Employee #8	4.28571	12	25.7143	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
13	Optimized Production			51.4286		205.714		182.608696		210		5.38576		16.5			$8,665.00
14	Minimum Production			40		102.857		174.857143		155.2173913		5		4.5			
15	Maximim Production			80		205.714		236.571429		210		15		16.5			
16																	
17				Weekly Production Summary				Revenue									
18					Task A		51.4286	$ 308.57									
19					Task B		205.714	$ 2,262.86									
20					Task C		182.609	$ 3,013.04									
21					Task D		210	$ 3,360.00									
22					Task E		5.38576	$11,848.67		Total Revenue	$22,624.65						
23					Task F		16.5	$ 1,831.50		Labor Cost	$ 8,665.00						
24					Totals:		671.637	$22,624.65		Net Return	$13,959.65						

Figure A21. Excel Image of Optimal Solution for the Base Model to Maximize Returns when a Specialized Employee devoted to a Constrained Task is Cross-trained

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	9.6	0	6.4	0	4.8	0	4.8	37	0.05	0	1	37	37	[redacted]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
7		Employee #3	0	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	5.94737	1	7	7	[redacted]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
9		Employee #5	0	1.8	0	1.2	28	3	0	1.5	0	0.00	0	0	28	28	[redacted]
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
11		Employee #7	0.73529	10.2	0	4	0	3	34.2647	6	0	0.00	0	0	35	35	[redacted]
12		Employee #8	3.75	12	26.25	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
13		Optimized Production		52.5		210		241.5		205.5882353		5		5.94737			$8,665.00
14		Minimum Production		40		105		178.5		205.275		5		4.5			
15		Maximim Production		80		210		241.5		277.725		15		16.5			
16																	
17				Weekly Production Summary				Revenue									
18					Task A		52.5	$ 315.00									
19					Task B		210	$ 2,310.00									
20					Task C		241.5	$ 3,984.75									
21					Task D		205.588	$ 3,289.41									
22					Task E		5	$11,000.00		Total Revenue	$ 21,559.32						
23					Task F		5.94737	$ 660.16		Labor Cost	$ 8,665.00						
24					Totals:		720.536	$21,559.32		Net Return	$ 12,894.32						

Figure A22. Excel Image of Optimal Solution for the Base Model to Maximize Returns when a Specialized Employee from a Non-Constrained Task is Cross-trained

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
7		Employee #3	0	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	5.94737	1	7	7	[redacted]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
9		Employee #5	0	1.8	0	1.2	28	3	0	1.5	0	0.00	0	0	28	28	[redacted]
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
11		Employee #7	0.73529	10.2	0	4	0	3	34.2647	6	0	0.00	0	0	35	35	[redacted]
12		Employee #8	3.75	12	26.25	8	0	4.8	0	4.8	0	0.04	0	1	30	30	[redacted]
13		Optimized Production		52.5		210		241.5		205.5882353		5		5.94737			$8,665.00
14		Minimum Production		40		105		178.5		205.275		5		4.5			
15		Maximim Production		80		210		241.5		277.725		15		16.5			
16																	
17				Weekly Production Summary				Revenue									
18					Task A		52.5	$ 315.00									
19					Task B		210	$ 2,310.00									
20					Task C		241.5	$ 3,984.75									
21					Task D		205.588	$ 3,289.41									
22					Task E		5	$11,000.00		Total Revenue	$ 21,559.32						
23					Task F		5.94737	$ 660.16		Labor Cost	$ 8,665.00						
24					Totals:		720.536	$21,559.32		Net Return	$ 12,894.32						

Figure A23. Excel Image of Optimal Solution for the Base Model to Maximize Returns when Wages are Increased for an Underpaid Employee

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
7		Employee #3	0	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	5.94737	1	7	7	[redacted]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
9		Employee #5	0	1.8	0	1.2	28	3	0	1.5	0	0.00	0	0	28	28	[redacted]
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
11		Employee #7	0.73529	10.2	0	4	0	3	34.2647	6	0	0.00	0	0	35	35	[redacted]
12		Employee #8	3.75	12	26.25	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
13		Optimized Production		52.5		210		241.5		205.5882353		5		5.94737			$8,875.00
14		Minimum Production		40		105		178.5		205.275		5		4.5			
15		Maximim Production		80		210		241.5		277.725		15		16.5			
16																	
17				Weekly Production Summary				Revenue									
18					Task A		52.5	$ 315.00									
19					Task B		210	$ 2,310.00									
20					Task C		241.5	$ 3,984.75									
21					Task D		205.588	$ 3,289.41									
22					Task E		5	$11,000.00		Total Revenue	$ 21,559.32						
23					Task F		5.94737	$ 660.16		Labor Cost	$ 8,875.00						
24					Totals:		720.536	$21,559.32		Net Return	$ 12,684.32						

Figure A24. Excel Image of Optimal Solution for the Base Model to Maximize Returns when Wages are Decreased for an Overpaid Employee

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2			Optimal Allocation of Employee Hours														
3			Task A		Task B		Task C		Task D		Task E		Task F			Hours	
4			Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours to Assign	Output / Hour	Hours Assigned	Available / Week	Labor Cost
5		Employee #1	0	0	0	0	0	0	0	0	37	0.05	0	0	37	37	[redacted]
6		Employee #2	0	0	0	0	0	0	0	0	32	0.05	0	0	32	32	[redacted]
7		Employee #3	0	10.8	0	7.2	0	6	0	4.8	1.05263158	0.05	5.94737	1	7	7	[redacted]
8		Employee #4	0	10.8	0	7.2	0	6	0	4.5	30	0.05	0	0	30	30	[redacted]
9		Employee #5	0	1.8	0	1.2	28	3	0	1.5	0	0.00	0	0	28	28	[redacted]
10		Employee #6	0	1.8	0	1.2	35	4.5	0	1.8	0	0.00	0	0	35	35	[redacted]
11		Employee #7	0.73529	10.2	0	4	0	3	34.2647	6	0	0.00	0	0	35	35	[redacted]
12		Employee #8	3.75	12	26.25	8	0	0	0	0	0	0.00	0	0	30	30	[redacted]
13		Optimized Production		52.5		210		241.5		205.5882353		5		5.94737			$8,469.00
14		Minimum Production		40		105		178.5		205.275		5		4.5			
15		Maximim Production		80		210		241.5		277.725		15		16.5			
16																	
17				Weekly Production Summary				Revenue									
18					Task A		52.5	$ 315.00									
19					Task B		210	$ 2,310.00									
20					Task C		241.5	$ 3,984.75									
21					Task D		205.588	$ 3,289.41									
22					Task E		5	$11,000.00		Total Revenue	$ 21,559.32						
23					Task F		5.94737	$ 660.16		Labor Cost	$ 8,469.00						
24					Totals:		720.536	$21,559.32		Net Return	$ 13,090.32						

APPENDIX B

Appendix B includes a collection of graphs illustrating the optimal solution results from each sensitivity analysis, for each management strategy.

Figure B1. Graph Illustrating the Total Task Production per Scenario, when the Management Strategy is to Maximize Production

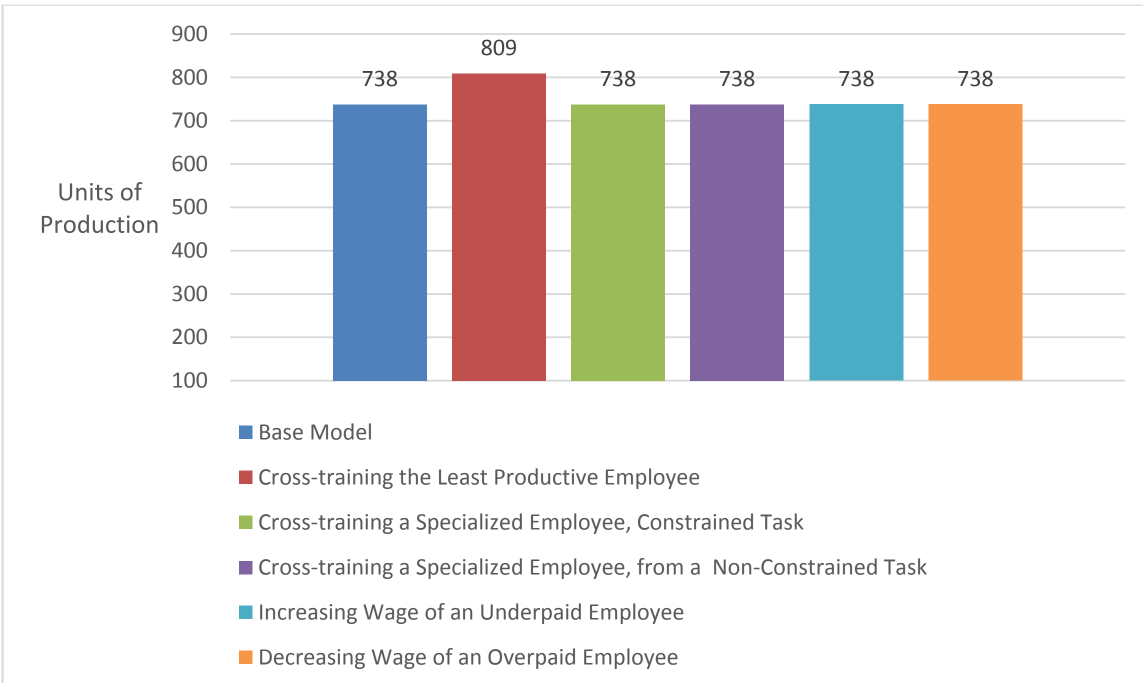

Figure B2. Graph Illustrating the Total Revenue Generated, per Scenario, when the Management Strategy is to Maximize Revenue

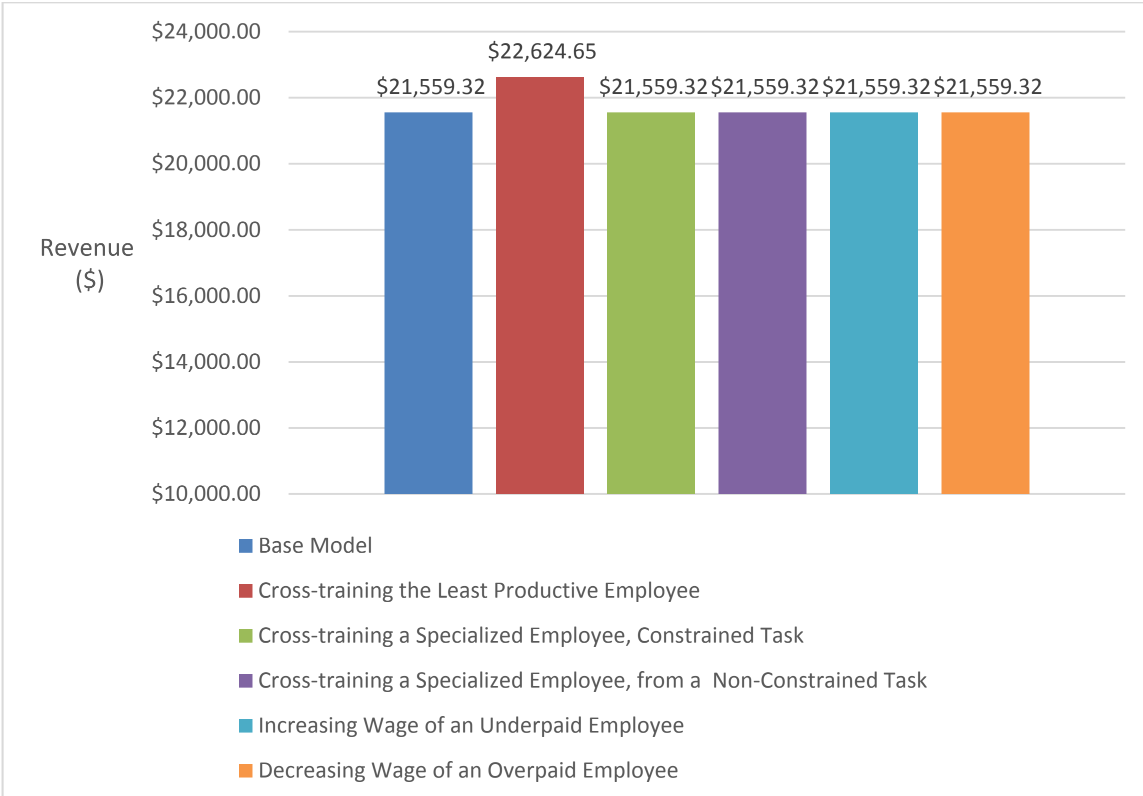

Figure B3. Graph Illustrating the Total Labor Cost Incurred, per Scenario, when the Management Strategy is to Minimize Labor Cost

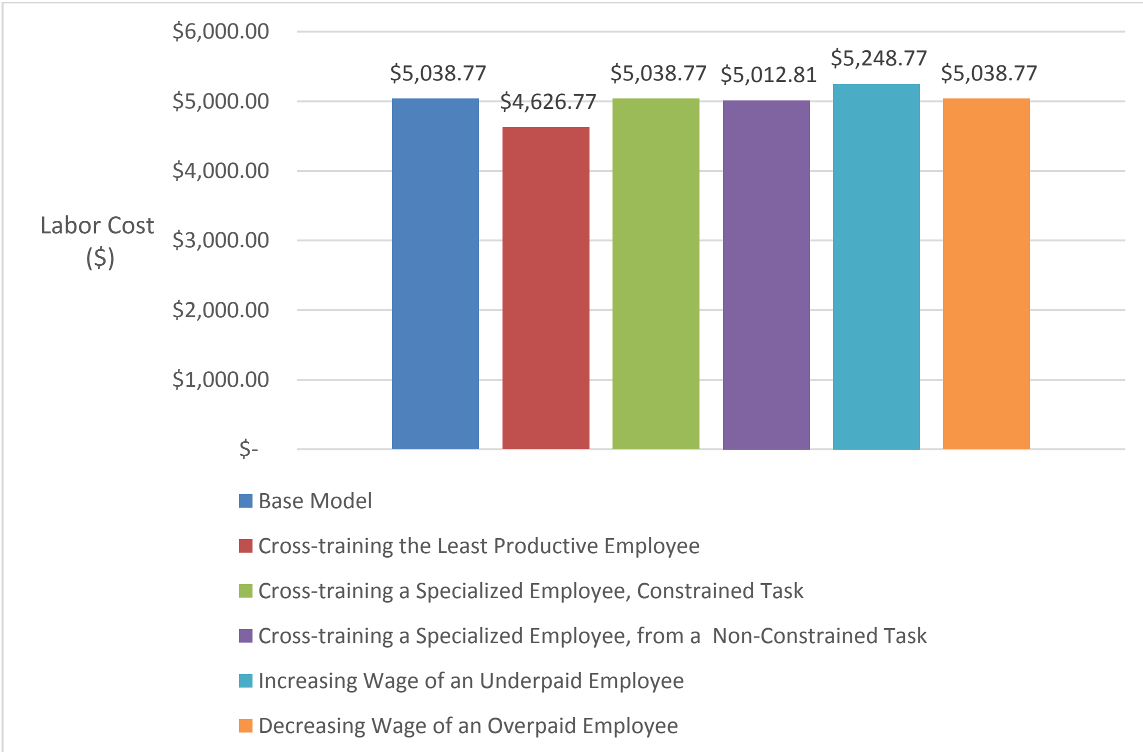

Figure B4. Graph Illustrating the Net Return, per Scenario, when the Management Strategy is to Maximize Net Return