EVALUATION AND REDESIGN OF POTTING SHED FOR THE NON-PROFIT ORGANIZATION, GROWING GROUNDS FARMS

A Senior Project submitted

In Partial Fulfillment

of the Requirements for the Degree of

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By

Adya Sinha and Julianna Levy

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Checked by:_____________________ Approved By: _______________________

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EXECUTIVE SUMMARY

Growing Grounds, a local nonprofit organization, operates as a fully functioning nursery in San Luis Obispo. Their planting facility is outdated and the process is inefficient. They have new funding available and need to determine if they should automate certain processes or improve existing methods. This report details the current process and presents two possible ergonomic solutions and the accompanying layouts and improvements. An analysis is conducted to determine which new layout is recommended for Growing Grounds based on their current production and revenue, and future recommendations are given.

INTRODUCTION

This report will describe the ergonomic and process flow improvements made to Growing Grounds Farm's planting production process through the design of an ergonomic, efficient layout which will include the design of a new potting table to allow for a higher throughput. Additionally, another set of plans will be provided to accommodate the expected future growth and goal of purchasing a new pot-filling machine called the SB-03 Pot Filler. Then comparison techniques will be used to determine which options best fits Growing Grounds current and expected future needs. .

As a nonprofit organization, Growing Grounds does not have a budget to undertake expensive renovations so last year, Cal Poly Industrial Engineering Faculty Member, Sema Alptekin, and the Program Manager of Growing Grounds Farm, Craig Wilson, worked together to determine a potential senior project area of research at Growing Grounds Farm. This project was determined and Craig Wilson identified that the focus of this project should be on the planting production area. Some of the reasons for choosing this area include employee discomfort during their shifts, lack of work leveling and inefficient processes. The objective of this project is to provide a solution that is both economically and socially viable that includes

- Design a new ergonomic planting table
- Redesign the planting facility
- Decrease potting production cycle time and increase total output
- Design future plans to reflect their expected growth and potential new equipment

To reach these objectives the IDEO and 5s methodologies will be followed. First, employee observations and suggestions will be heard. Next, based on their suggestions, an extensive literature review on relevant topics will be developed. Based on all of these factors, along with the project team's knowledge from their coursework and the constraints presented by Growing Grounds (budget, space, mental capacity of employees etc.) a feasible, efficient and ergonomic solution will be developed. For the table design, design will be first made on Solidworks design software, and a new facility layout will be presented using

Microsoft Visio and ProModel. Both concepts will be presented to Growing Grounds for a design review. Meanwhile, plans to reflect future growth at Growing Grounds will be made, including designing a new table and layout to accommodate the implementation of the SB-03 Pot Filler machinery.

The rest of this report will provide background information on GGF and a more in-depth description of what problems are being addressed. The literature review is summarized and proposed changes discussed. Finally, a discussion of the results and future recommendations will be provided.

BACKGROUND

THE COMPANY

Growing Grounds Farm is a non-profit wholesale nursery located in San Luis Obispo, halfway between Los Angeles and San Francisco. GGF is a program within Transitions-Mental Health Association providing horticultural therapy, socialization opportunities and soft job skills training for adults with severe and persistent mental illness. Horticultural therapy is based on the idea that working in a garden or other natural setting has intrinsic beneficial therapeutic effects. According to the American Horticultural Therapy Association, one of the signers of the Declaration of Independence, Dr. Benjamin Rush, "reported that garden settings held curative effects for people with mental illness."

At the Farm they balance a traditional business model providing employment opportunities in a near competitive environment with the delivery of critically needed social services. Their goal is to grow a large selection of quality plants while providing an empowering environment where our employees progress on their path towards recovery. In business since 1984, Growing Grounds offers California natives, Mediterranean perennials, succulents, restoration and mitigation plants, a wide variety of grasses, and a selection of perennial herbs. Their partnership with local restoration groups, such as the Land Conservancy of San Luis Obispo and the Morro Coast Audubon Society, allows them to collect seeds and cuttings from different areas around the county. The plant bank established by these efforts provides for site specific restoration. It also helps insure the genetic diversity of several native species within the county.

HISTORY

In the early 1980's Barbara "Barb" Fischer, the executive director of then-SLO Mental Health Association saw that clients wanted what everyone wants: a full life. A big part of that "full life" included finding a job. With gaps in resumes and a competitive job market, though, the SLOMHA clients were having little luck. That's when Barb decided to look for land to start a Farm program. It would offer horticultural therapy and plenty of jobs for her clients and grow produce for local restaurants. In 1984, she approached Pacific Gas and Electric Company about using their substation land on Orcutt Road. She began working with James "JT" Haas, an engineer at PG&E. Through their work and planning, the Farm became a reality. In the years that followed, a number of San Luis Obispo County restaurants – Big Sky, for example – served locally-grown produce from the Farm.

Since that time, JT volunteered often at the Farm, building structures and wiring greenhouses. JT has also served on the board of TMHA, most recently as board president. As a board member, JT was a driving force in merging SLO Transitions and SLO Mental Health Association to create TMHA in 1998. Barb has stayed on with TMHA as a board member, as well, guiding her successor Jill Bolster-White. Over the years, the Farm made a change from growing vegetables to nursery plants, a move to anchor it more in a sustainable market niche. Throughout TMHA's growth and merger, Growing Grounds Farm has remained a flagship program of Transitions-Mental Health Association and is recognized as one of California's most compassionate, proactive forms of treatment for adults suffering from mental illness. The Farm now supports a population of 65,000 plants, most suitable for a Mediterranean climate zone, with a strong focus on water-wise California natives, select bearded Iris, restoration and mitigation plants. More than 1,000 people have worked at the Farm and have made real progress in their recovery.

PLANTING BASICS-CURRENT PROCESS

REMOVING PLANTS FROM POTS

Located at one end of the potting shed, the first station is used for removing plants from flats (trays with newly propagated plants) or small plastic containers and preparing them to be repotted. There is one employee who works at this station. The plants being prepared are usually repotted into the four-inch and one-gallon containers. First, the employee obtains a tray of the correct plant type from a trailer outside of the potting shed and brings it to the table. The plants are carefully removed either by hand or pushed out by a tool that fits through a hole on the bottom of the tray. The removed plants are placed into a large basket and the emptied containers are tossed onto the other side of the worktable. When one basket is full (a batch size of 12 per), the worker places a small plastic label in it to indicate the name of the plant. Sometimes, miniature flags are also placed into the bowl to indicate if they will need to be watered, weeded, or placed in the "Not for Sale" area after potting. The completed bowl is then walked over and set on a rack located approximately 4-5 feet away. Once all the flats from the trailer for one order are completed, the employee will stack up the emptied containers and clean up the station.

INVENTORY AND EQUIPMENT

The inventories of all plastic plant containers are stored next to the potting shed. They are placed in stacks on the ground and separated by size with wire fencing. The soil for the pots is stored outside on the open end of the potting shed (opposite of the plant potting preparation area). It sits in a pile on the ground and is covered by a plastic tarp. Inside the shed is the potting bench. The potting bench takes up at least half of the space in the shed, stands at approximately three feet tall, and has a U-shape. Inside the U-shaped table is a ledge that sits lower than the table and holds 4-one-gallon pots. If an employee was to stand in the middle of the table, they could effectively push the soil into the containers. Five to six employees may work around and inside the potting bench simultaneously.

POTTING PLANTS

4" CONTAINER PROCESS

When preparing the four-inch pots, an employee must manually strip pots from their initial stacks and then place them in a tray. Each tray holds 16 plants. When that tray is full, it is set on the ground next to the soil heap. A shovel is used to fill up the pots. Afterwards, the employee must bend over to smooth out and remove unwanted soil from the top before stacking it next to the potting bench. When an employee from the potting bench is free, he/she will retrieve a soil filled tray from the ground and a bowl of plants from the rack and bring it to the table. Using their fingers, the employee makes a hole in one of the four-inch pots and places a plant from the bowl inside. The soil is then packed firmly around the plant. When all the pots on a tray are finished, it is walked to a trailer outside of the potting shed to be transported to its respective area.

1-GALLON CONTAINER PROCESS

For the one-gallon pots, an employee retrieves a stack of empty pots and places it next to the potting bench to use. Meanwhile, another employee uses a shovel to fill fifteen-gallon pots with soil. The fifteen gallon container is transported over to the potting bench and lifted up to pour the soil onto the table. An employee standing in the middle of the U-shaped table pushes the soil from the table into the one gallon containers set on the ledge. Once filled, he/she moves the pot from the ledge to either sides of the table where another employee is waiting. During this time, the employees on the side acquire a bowl of plants from the queue rack to work with. Using their hands, they make a hole in the soil of the one-gallon pot and place a plant in. Then, using the soil from the table, they firmly pack the areas around the plant down before transporting the pot to a trailer outside.

5-15 GALLON CONTAINER PROCESS

The five-gallon and fifteen-gallon pots are potted in the area outside of the potting shed next to the soil heap. Four to six employees work together to separate the stacks of pots and place them on the ground. While one worker moves the plants to be repotted from the trailer to the vicinity, another shovels soil halfway into the pots; others may use additional containers to manually scoop soil in. To remove the plant from the unwanted container, an employee will turn it upside down and carefully squeeze it out. It is then placed into the new container and soil is scooped on top to firmly pack it in. The finished containers are walked over to the trailer.

PROBLEM STATEMENT

Growing Grounds planting facility is outdated and the process is inefficient. They have new funding available and need to determine if they should automate certain processes or improve existing methods.

LITERATURE REVIEW

This literature review will serve as a basis of research on topics relevant to the Growing Grounds Farm's production process. The topics chosen were researched using scholarly journal articles, historical articles, newer articles and text references. This literature review will cover nursery planting processes and methods, 5-S methodology and relevant physical and environmental ergonomic research. Specifically within ergonomics, the effects of outdoor lighting, high or low temperatures and physical circumstances such as average height and its effect on table design will be discussed.

NURSERY PLANT PRODUCTION PROCESS

Planting can be broken down into 4 specific stages; propagation, transplanting, and field work and shipping. Propagation refers to new plants that are started in a specialized area. Four different methods are commonly used in this process; cuttings from mature plants, tissue culture, seeds, and grafting. Propagation is characterized by highly repetitive, hand-intensive work (Meyers, et.all). Step 2 is transplanting, or more commonly known as potting, is the process of taking newly propagated or container-grown plants, and placing them into the appropriate growing containers. Generally, if plants are left in the same medium for too long, they will begin to perish. By transferring plants into a larger container, they can continue to grow and thrive.

Transplanting Process: The process of potting can be broken down into the following steps:

Bring soil mix from storage pile to potting area and placing it on potting bench.

Bring containers from storage area to potting area.

Bring plants from propagation area, which are either in flat trays or small plastic cups, to potting area.

Perform potting operations

Strip containers from sleeves.

Fill containers with soil mix.

Make a hole in soil for plants.

Remove one plant from the flat or a plastic cup.

Place plant in the soil and firm soil around it.

Remove potted container from potting bench and place it on a trailer.

Transport trailers with freshly potted containers to field.

Place potted container in field beds and return to potting area.

Step 3 is referred to as the fieldwork stage where plants are held in outdoor groups until fully mature (Meyers, et.all). During this period, tasks include watering, pruning, fertilizing and weeding, tying-staking-shaping, and spacing as plants grow. Fieldwork is characterized by prolonged stooping, frequent lifting, and hand-intensive tasks (Meyers, et.all).

Since a number of these operations require transportation and manual labor, many potting equipment and tools can be implemented to aid in the process. In the past few years, nurseries have adopted a variety of potting systems that include machines with varying levels of automation and different rates of operating speed. These machines help reduce the time needed for potting so that staff may focus on other things throughout the nursery (Meyers, et.all).

There is no standard solution when it comes to selecting the right process for a nursery; having the most expensive and newest equipment does not necessarily signify an efficient system. The nursery's organization and the techniques, allocation of tasks, level of comfort, and skills of the staff and management all have an effect on the production rate. Other factors are also taken into consideration before deciding on which method to switch to, including the number of plants in production, the types of plants, the different pot sizes, location of potting etc. (Meyers, et.all)

5S METHODOLOGY

5S is a system to reduce waste and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results. The term 5S refers to five steps – sort, set in order, shine, standardize, and sustain – that are also sometimes known as the 5 pillars of a visual workplace. 5S programs are usually implemented by small teams working together to get materials closer to operations, right at workers' fingertips and organized and labeled to facilitate operations with the smallest amount of wasted time and materials. There are many benefits in implementing 5S including raising quality, lowering costs, promoting safety, and building customer confidence. "A place for everything and everything in its place" is the mantra of the 5S method. Table 1 on the next two pages accurately describes each step in a manufacturing setting. (Lista)

Table 1: 5S STEPS IN A MANUFACTURING SETTING

Pillar	What does it mean?	Why is it important?	What problems are avoided?
Sort	1) Remove all items not needed for current production operations. 2) Leave only the bare essentials: When in doubt, throw it out.	1) Space, time, money, energy, and other resources can be managed and used most effectively. 2) Reduces problems and annoyances in the work flow. 3) Improves communication between workers. 4) Increases product quality. 5) Enhances productivity.	1) The factory becomes increasingly crowded and hard to work in. 2) Storage of unneeded items gets in the way of communication. 3) Time wasted searching for parts/tools. 4) Unneeded inventory and machinery are costly to maintain. 5) Excess stock hides production problems. 6) Unneeded items and equipment make it harder to improve the process flow
Set in order	1) Arrange needed items so that they are easy to use. 2) Label items so that anyone can find them or put them away.	1) Eliminates many kinds of waste, including: Searching waste. 2) Waste due to difficulty in using items. 3) Waste due to difficulty in returning items.	1) Motion waste. 2) Searching waste. 3) Waste of human energy. 4) Waste of excess inventory. 5) Waste of defective products. 6) Waste of unsafe conditions.

Shine	Keep everything, every day, swept and clean.	1) Turn the workplace into a clean, bright place where everyone will enjoy working. 2) Keep things in a condition so it is ready to be used when needed.	1) Lack of sunlight can lead to poor morale and inefficient work. 2) Defects are less obvious. 3) Puddles of oil and water cause slipping and injuries. 4) Machines that do not receive sufficient maintenance tend to break down and cause defects.
Standardize	Integrates Sort, Set in Order, and Shine into a unified whole.	By ensuring conditions do not deteriorate to former state, facilitates implementation of the first three pillars.	1) Conditions go back to their old undesirable levels. 2) Work areas are dirty and cluttered. 3) Tool storage sites become disorganized and time wasted searching for tools. 4) Clutter starts to accumulate over time. 5) Backsliding occurs.
Sustain	1) Making a habit of properly maintaining correct procedures. 2) Instill discipline necessary to avoid backsliding.	Consequences of not keeping to the course of action greater than consequences of keeping to it.	1) Unneeded items begin piling up. 2) Tools and jigs do not get returned to their designated places. 3) No matter how dirty equipment becomes, nothing is done to clean it. 4) Items are left in a hazardous orientation. 5) Dark, dirty, disorganized workplace results in lower morale.

A three-step process is generally used to implement 5S; establishing a cross functional team (including employees that work in the associated areas), touring all areas associated with manufacturing process under review, and brainstorming on ways to improve organization to reduce waste. A tool that is useful in analyzing material, process and information flow is value stream mapping. The information is used to develop a current flow of the process. The team then analyzes the current process to identify opportunities for improvement. The key is to observe non value added processes and create an environment to promote value added work through waste elimination. Finally, a proposed model is created, one in which all of the improvements are implemented (Lista). The proposed process then becomes the current process and a continuous improvement process should be used to identify new ways to reduce waste. Waste is defined very broadly, and includes things like waste in the movement of material, carrying too much inventory, defects or rework, producing scrap, waiting or unnecessary motion (Lista).

ERGONOMICS

Wojciech Jastrzębowski, a Polish scholar is credited with naming the field of ergonomics in 1857. It is claimed that Jastrzębowski derived the term ergonomics from the Greek words 'ergon' (meaning work), and 'nomos' (principle or law) because ergonomics according to him was the science of work. (Dempsey, P. G., Wogalter, M. S. & Hancock, P. A). An early definition of ergonomics, made by the Human Factors and Ergonomics Society, was "Human Factors is concerned with the application of what we know about people, their abilities, characteristics, and limitations to the design of equipment they use, environments in which they function, and jobs they perform.

For the purposes of this report, the topics of Physical Ergonomics –which pertains to human physical activity in the areas of anthropometrics, human anatomy and biomechanical characteristics – and environmental ergonomics which is concerned with human interaction with the environment will be discussed. The scope of the research on environmental ergonomics will be on ideal light and temperature conditions.

PHYSICAL ERGONOMICS

As mentioned, physical ergonomics is considered anything that pertains to human physical activity, which covers the areas of anthropometrics, human anatomy and biomechanical characteristics. An area identified as an ergonomic concern is the potting area at Growing Grounds. The potting process is conducted while standing up, so the table used should be designed to be at a comfortable height for the average person, or to be an adjustable design to account for the varying heights of people. The workstation position (including height and distance) is critical because if it is improperly aligned workers may get injured. Injuries include musculoskeletal disorder which includes a herniated disc in the back, muscle strain or ligament sprain. In this case, the employer also needs to be concerned - if the employee is able to prove that the musculoskeletal disorder occurred on the job due to ergonomic problems, the employer will be responsible for the cost of all treatment. For a small non-profit business like Growing Grounds, this would be a major setback. An ergonomic workplace is one that will support neutral posture for the upper body, shoulders and arms. Ideally, a workplace should be customized for each individual employee to match their height and depth needs, however, many times ergonomic workplaces must be based on what the average is for certain characteristics. For Growing Grounds, average height will be a factor in how the bench is designed since customizing each work station would be costly. (Asher). Going to the US Governments Center for Disease Control and Prevention's website, the results from a 2003-2006 average American height study was viewed. For females, a sampling of 9714 participants of varying races in America, between the ages of 20 and 80+ was taken, with the results showing that on average female height proved to be 64.2 inches. For males, a sampling of 8236 participants was taken within the same age and racial guidelines as the females, and the average male height was determined to be 69.1 inches. (McDowell, Ph.D., M.P.H., R.D., Fryar, M.S.P.H, Ogden, Ph.D, and Flegal, Ph.D). Taking these average height statistics into account, an ergonomic bench using the concept of the most good for the greatest number of people can be designed for Growing Grounds.

ENVIRONMENTAL ERGONOMICS

Ideal outdoor workplace lighting was researched because some of the processes take place outdoors. The Occupational Safety and Health Administration have very specific standards pertaining to indoor workplaces, but outdoor workspaces are less thoroughly defined. While there are no specifics, light variation throughout the day and during different seasons was researched. Figure 1 displays common light levels outdoor in various conditions. ("Etoolbox")

Figure 1: COMMON OUTDOOR LIGHT LEVELS IN VARIOUS CONDITIONS

Condition	Illumination	
	(ftcd)	*(lux)*
Sunlight	10,000	107,527
Full Daylight	1,000	10,752
Overcast Day	100	1,075
Very Dark Day	10	107
Twilight	1	10.8
Deep Twilight	.1	1.08
Full Moon	.01	.108
Quarter Moon	.001	.0108
Starlight	.0001	.0011
Overcast Night	.00001	.0001

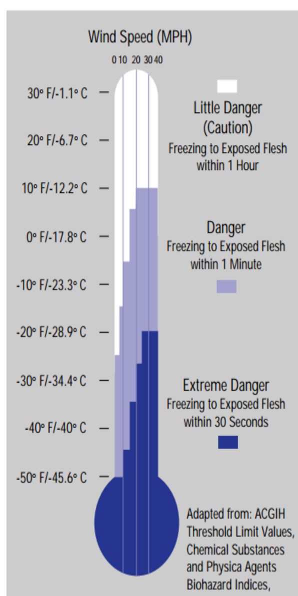
Poor lighting can be a safety hazard to the employees working in these conditions. It can often lead to misjudgment of the position, shape or speed of an object. Additionally, it can affect the quality of work and overall productivity of employees. Physically, too much or too little light strains the eyes and may cause eye discomfort such as burning and headaches. For Growing Grounds employees most of whom are physically and/or mentally disabled this can be detrimental to their conditions as it could impair their patience, ability to think or hand-eye coordination. ("Learning Disabilities In Adulthood: Persisting Problems And Evolving Issues")

Environmental ergonomics is also concerned with the temperature of a workplace. This is because of the various causes that temperature can have on employees, which range from general discomfort to dehydration, muscle fatigue, strains or pulls and even trouble breathing. ("Yale Ergonomics") As a basis, average temperature and historical highs and lows in San Luis Obispo were researched. The highest recorded temperature ever in San Luis Obispo was 112° Fahrenheit, recorded in 1971 and the lowest recorded temperature was 12° Fahrenheit, recorded in 1987. These values appear to be anomalies as the average monthly temperatures in San Luis Obispo have historically ranged from 41°F to 77°F. The warmest month on average is August and the coolest month is December. ("Weather Channel") This is important because environmental ergonomics assigns risk levels based on high and low temperatures data. Figure 2 shows the Occupational Safety and Health Association's (the government agency of regulation) temperature risk indicator for high temperatures.

Figure 2: TEMPERATURE RISK INDICATOR FOR HIGH TEMPERATURE

Heat Index	Risk Level	Protective Measures
Less than 91°F	Lower (Caution)	Basic heat safety and planning
91°F to 103°F	Moderate	Implement precautions and heighten awareness
103°F to 115°F	High	Additional precautions to protect workers
Greater than 115°F	Very High to Extreme	Triggers even more aggressive protective measures

Figure 3: TEMPERATURE AND WIND INDICATOR



The table indicates that there is not any reason for concern until temperatures range above 103°F, which is a rare occurrence in San Luis Obispo. ("OSHA").

On the other hand, the OSHA guide to determining whether work should be done at certain low temperature is a little more advanced. Figure 3 shows a diagram from the OSHA Cold Stress Card, which is available for free online. Again, looking at the diagram, it appears that workers in San Luis Obispo will not have to worry about the dangers associated with working in weather that is too cold. Therefore, no further research on temperature-based environmental ergonomics was conducted. ("OSHA Cold Stress Equation").

WORK STATION DESIGN – STANDING VS. SITTING

Currently, Growing Grounds has a standing workstation design for their potting production process. According to the OSHA website, "Standing work, compared to sitting when working, is recommended when the task cannot be performed with the employees keeping their arms comfortably at their side." Furthermore, the website suggest a standing workstation when the work area is too large to be comfortably reached when seated because a person is able to reach further when they are standing versus seated. However, some negative side effects of standing for long periods of time include varicose veins, poor circulation causing swelling of legs and feet, foot problems, joint damage and heart and circulatory problems.

Studies have been conducted on how to lessen the risk of side effects due to standing. One study showed that the use of a footrest or padded shoes results in less discomfort and fatigue. (King, 2002). The results of the study found that workers preferred to use either padded shoes and/or a mat, finding them equally as satisfying and also finding no additional benefits from using both at the same time, with padded shoes referring to athletic style shoes. It is also recommended that the purchased shoes run ½ to one size larger than would otherwise be purchased to account for possible foot swelling.

Finally, another important consideration found is that standing workstations must allow the worker sufficient foot space or else the worker will be forced to stand further away and lean forward (which injures the spine). According to OSHA, the recommended amount of foot clearance space is 150 mm deep, 150 mm high, and 500 mm wide

POT-FILLING MACHINE

A pot-filling machine drops soil from a hopper down into the pot as workers manually set the plant. There are different types and sizes of pot filling machines. The simpler ones consist of a soil hopper which is filled with soil. An electric motor powers a conveyor with paddles that continuously raises soil and drops it into a chute. A worker places a pot under the chute and lets a little soil fall in to cover the bottom of the pot. Then he or she places the transplant in the pot and returns the pot to the platform to be filled with soil. The worker puts the pot on a tray and gets the next pot to fill. Most models are designed to recycle the overflow soil. Some pot filling machines accommodate a range of sizes such as 4.5" to 3 gallons; others take a specific size pot. These machines work best on a hard, level surface, and require an electric power source hopper (University of Wisconsin Healthy Farmers).

With a pot filling machine the task of lifting soil by hand is eliminated and time spent transplanting is shortened. Workers who scoop soil into pots for hours on end can suffer overstrain injury. Repeated use causes wear and tear on muscles and joints in the fingers, hands, wrists, arms, shoulders and neck. These kinds of injuries do not recover overnight, and can become chronic, leading to time off work, increased medical costs and reduced productivity hopper (University of Wisconsin Healthy Farmers).

Some nursery growers purchase a pot-filling machine and made their own simple modifications to further increase efficiency. Custom workbenches can be built around the filler to hold containers and filled pots hopper (University of Wisconsin Healthy Farmers). A machine is usually not cost effective unless nurseries pot up at least 20,000 plants a year. Pot filling machines don't take up much space. Some are on wheels so they can be set up as required and stored away in compact spaces when not in use. Filling the hopper of the soil filler is easy as well, Forklifts can be operated to lift loose soil or bales into the hopper (University of Wisconsin Healthy Farmers).

METHODOLOGY RESEARCH

HUMAN CENTERED DESIGN

Human Centered Design methodology is the result of a project funded by the Bill & Melinda Gates Foundation (BMGF). The BMGF brought together four organizations—IDEO, IDE, Heifer International, and ICRW—to partner in the creation of a method for guiding innovation and design for people living under $2/day (IDEO). Its fundamental principles will be used and applied to the Growing Grounds project.

Human-Centered Design (HCD) is a process used to create new solutions to existing problems through examining the needs, dreams, and behaviors of the people the solution is being created for. The process includes three “lenses”- desirability, feasibility and viability. It starts with the desirability lens of listening and understanding the organization’s needs, asking, “What do the people desire?” Once the organizations desires are identified, solutions can be made that are feasible, through asking the question “What is technically and organizationally feasible?” and viable, with the question “What can be financial viable for the project?” (IDEO). Through following the steps of this methodology, a practical solution can be designed. Figure 4 below shows how the three lenses work together. Figure 5 shows the different phases of HCD and how they work together (IDEO).

Figure 4: HUMAN CENTERED DESIGN

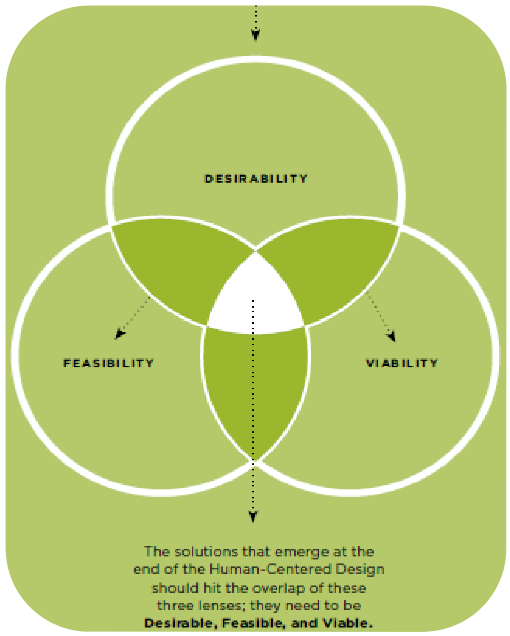
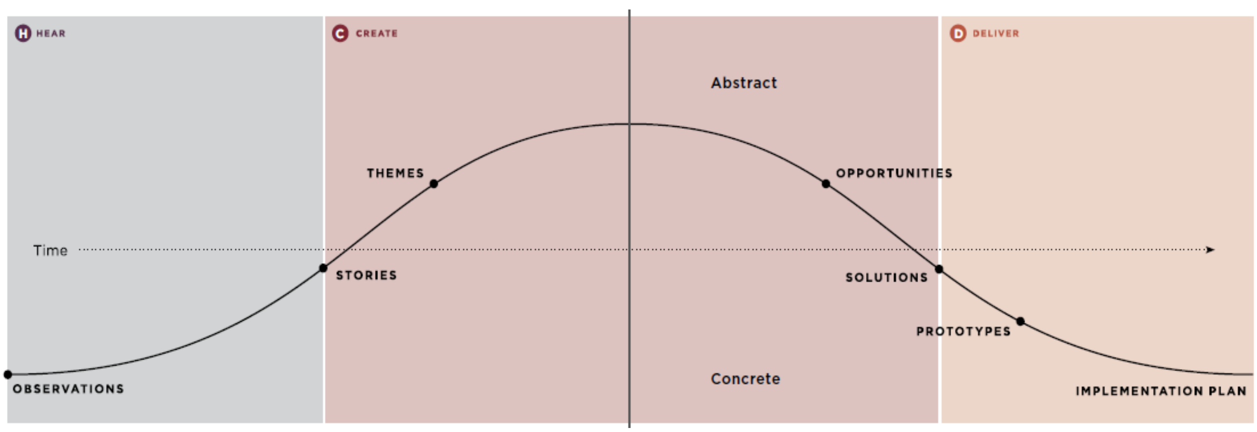


Figure 5: PHASES OF HUMAN CENTERED DESIGN



There are three main areas that are focused on in the HCD process; Hear, Create and Deliver. In the hear phase of this project, the project team talks to the employees to ask what features would be ideal and listen to any suggestions offered. Design needs, barriers and constraints will also be discovered (IDEO).

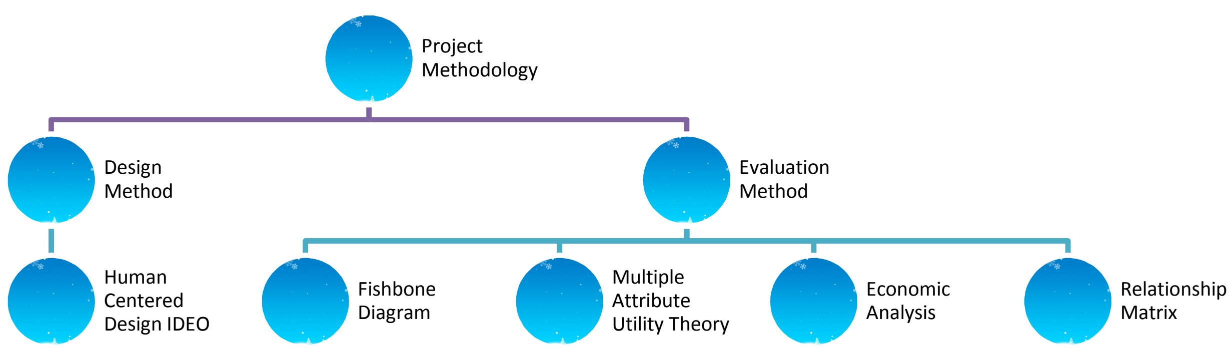
QUALITY ENGINEERING

Some quality engineering tools are often used to evaluate designs and determine the best design options. One such tool is ProModel Simulations which are a way to look at proposed layouts to evaluate which layout is optimal, looking at the efficiency of the layout, operator throughput and which workstations will be over and under-utilized. Relationship Matrix Analysis looks at the relative importance of the options, making it clear which solution is the most effective. This tool is useful when priorities aren't clear, the options are completely different and evaluation criteria are subjective. Multiple attribute utility theory quantifies the desirability of certain alternatives, for design situations where uncertainty and risk are considered the end result and it represents the designer's preferences given a certain set of design attributes.

METHODOLOGY

For this project two main methodologies will be used – Human Centered Design (HCD) and quality engineering evaluation. HCD will be used during the design phase of this project and quality engineering principles will be used during the evaluation phase. The tools used in the evaluation phase will be Multiple Attribute Utility Theory, Fishbone Diagram, Relationship Matrix, Economic Analysis and Simulation to determine the optimal design. During the design phase, two designs will be proposed, the first one using a pot filling machine to automate part of the process, and the second design will not be automated. The evaluation phase will look at the designs using quality engineering tools and determine which design is optimal, looking at all aspects of the designs. The relationships between the methodologies are shown in the hierarchical graph below.

Figure 6: EVALUATION METHODOLOGIES



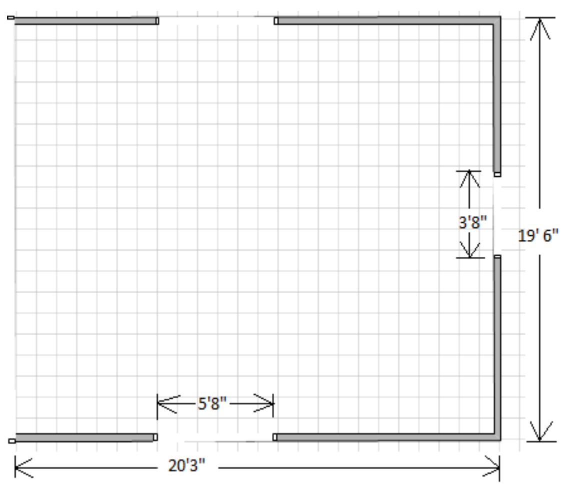
To complete the design phase, review sessions with the Growing Grounds management will be held and the project team will observe employees working and talk to them. During the create stage of this project, potential solutions will be proposed and necessary designs created. For the potting table designs, Solidworks software will be used to model the designs which will then be discussed with Growing Grounds and changed based on any additional suggestions presented. During the evaluation phase, feasibility of the previously completed work will be assessed using the tools mentioned above to determine the optimal solution. Questions and concerns during this phase by the project team will be directed at the Growing Grounds management and Cal Poly professor’s familiar with these decision metrics. Finally, both options will be presented to Growing Grounds along with the findings from the evaluation phase.

DESIGN

As mentioned in the problem statement, the goal of this project is to design two new ergonomic planting tables. One will be designed to meet the current needs of Growing Grounds Farm and the second will be designed to meet their future needs and implementing automation into their process. In addition to this, workplace layouts will be designed to maximize efficiency with the new tables or machinery. Currently, the potting process takes place in a shed that was built about 20 years ago; it is a basic rectangular shape (See Figure 7 below to view shed layout).

There are a few design constraints in the project, one of them being limited funds since Growing Grounds is a non-profit nursery. Additionally, the alternative designs are limited by the existing sheds dimensions and the door placements. Within the shed, the floor is a very uneven dirt floor and the electricity is limited to 110V outlets. Other constraints are related to preserving the therapeutic benefits to the employees while increasing the efficiency of the processes without increasing stress and complexity in the planting procedure. Finally, as far as potting processes, 4 inch, 1 gallon and 5 gallon containers are reused and the soil is delivered loosely and placed in a heap. There is no option to buy the soil in a bale because it is a special mixture made just for Growing Grounds.

Figure 7: SHED DIMENSIONS AND LAYOUT

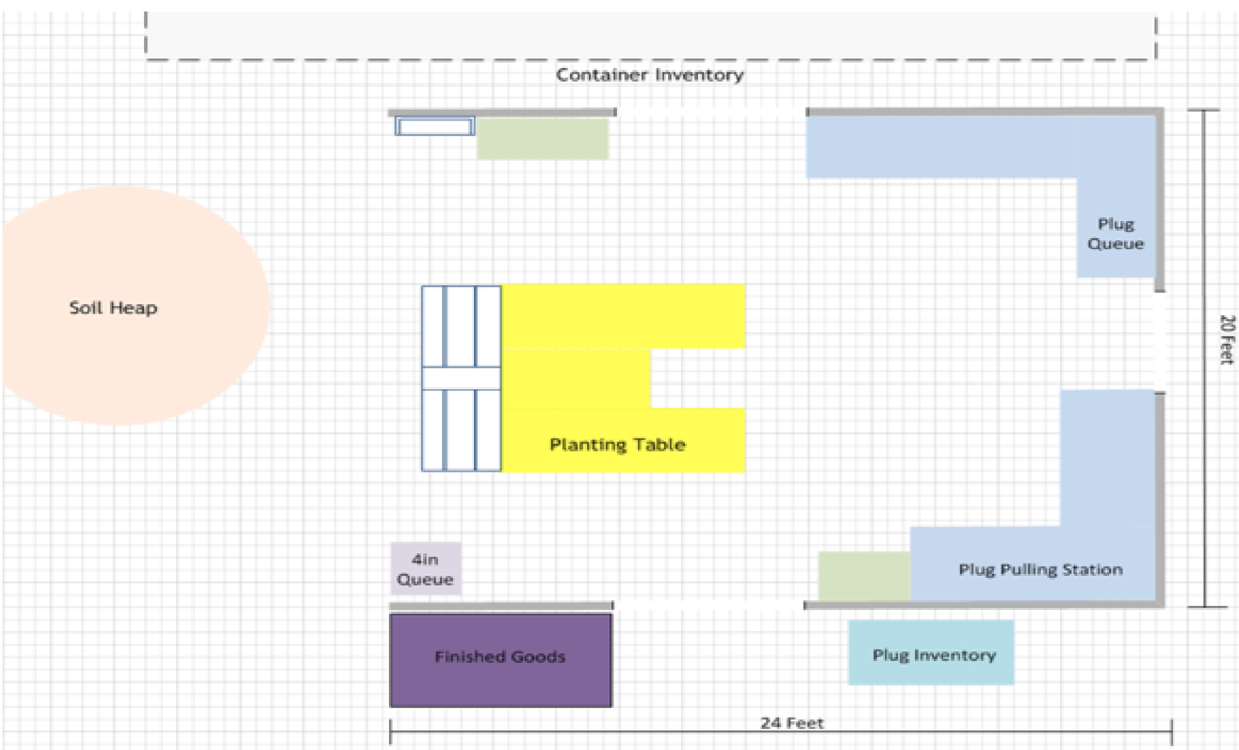


After consulting with Craig Wilson and other Growing Grounds employees, the following specifications list was derived:

- Efficient design
- Easy height for multiple people
- Economic Alternatives
- Potential potting machine implementation into planting process

Prior to designing new layout, certain measurements had to be made. Every surface and wall was dimensioned to develop an accurate layout in Visio (Figure 5). The current planting method was also observed in order to determine their current throughput as well as identify key problem areas in the process. It was determined that the soil was not a significant bottleneck area, which was the initial assumption but rather the plug popping station was. Using this data collected on process times from the first generation project, a simulation was created to determine the baseline. Location utilization helped determine the efficiency of each location and which were in need of additional workers or improved process methods. (See Appendix A for planting processes)

Figure 8: CURRENT LAYOUT

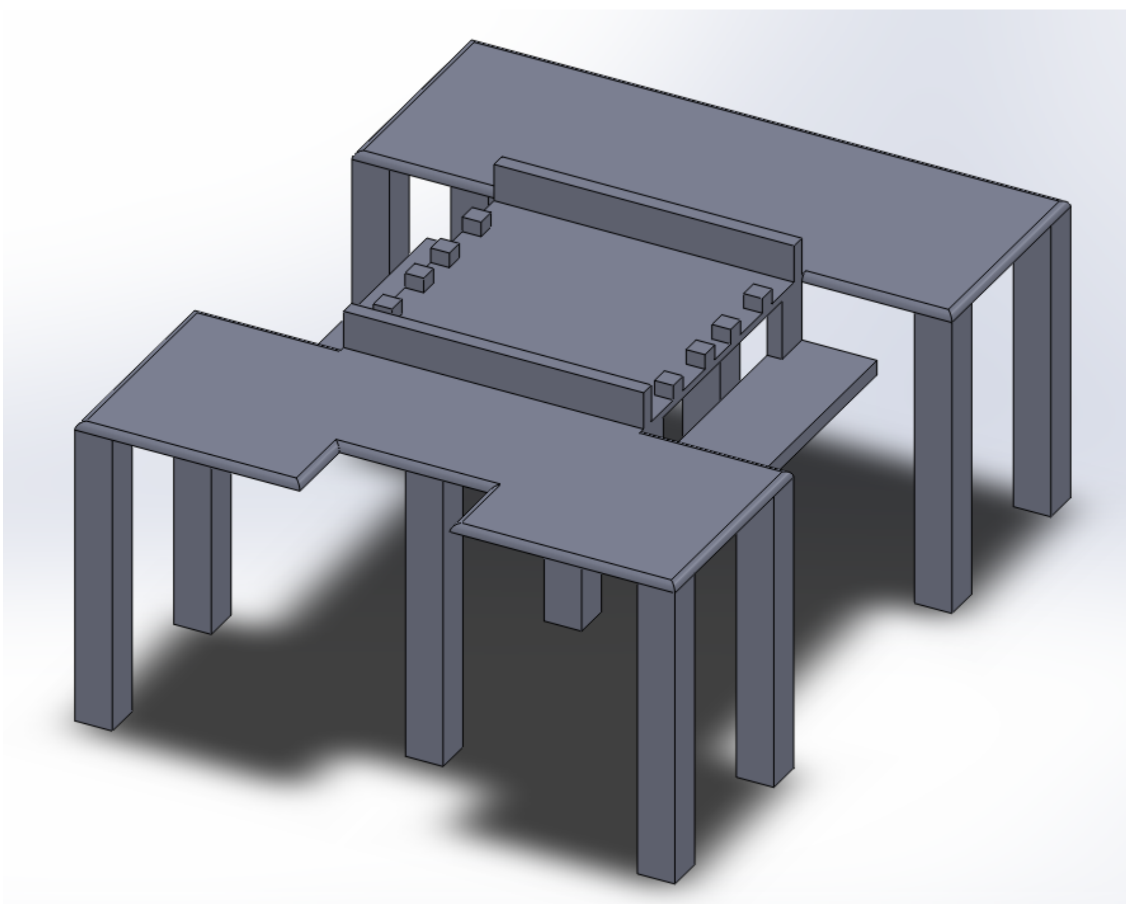


Following this, two alternative layouts were generated; one with an enhanced table design implemented the other with partial automation due to the soil filler machine. Initially two table designs were created but the one chosen was far superior since it allowed for the soil transporter to have access to the center of the table to dump the soil. For the automation design, a streamlined flow was the goal; materials in one door and out the other. This was done to avoid confusion and ensure that workers performed tasks only listed in their job descriptions. Cost analysis and benefits were determined for both designs.

ENHANCED TABLE LAYOUT

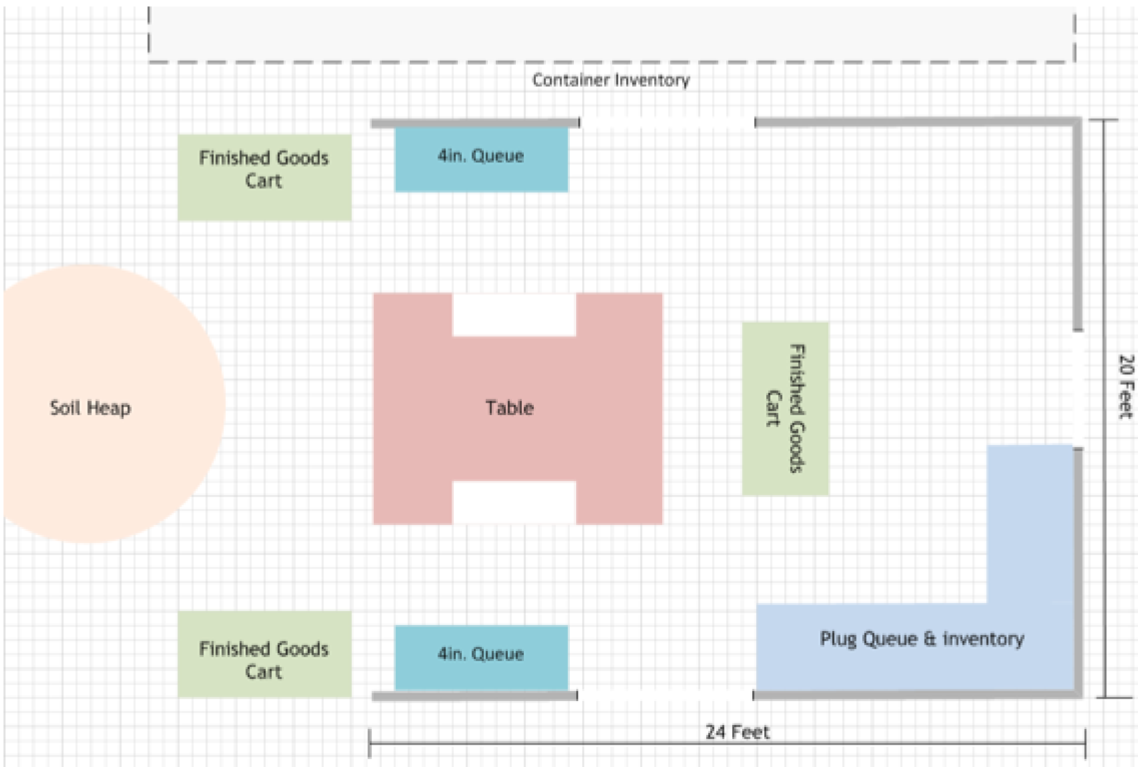
The first table design explored was the enhanced table design. This layout was to consist of a superior table design and streamlined flow within the shed for the planting processes. After two table designs were generated the following was selected.

Figure 9: ENHANCED TABLE DESIGN



This table can hold 5 planters, two soil filler and a niche for the soil transporter to access the center of the soil heap on the table. The table's dimensions are 8' x 10' x 3.25'. With this table the layout of the shed would change to the layout in figure 10 below.

Figure 10: LAYOUT IMPLEMENTING ENHANCED TABLE



With this process the orbiter is no longer necessary for the following reasons

- Planters have access to the finished goods carts
- Soil transporter can simultaneously separate pots and transport soil
- Plug popper can transport plug baskets to table or have planters retrieve them as necessary

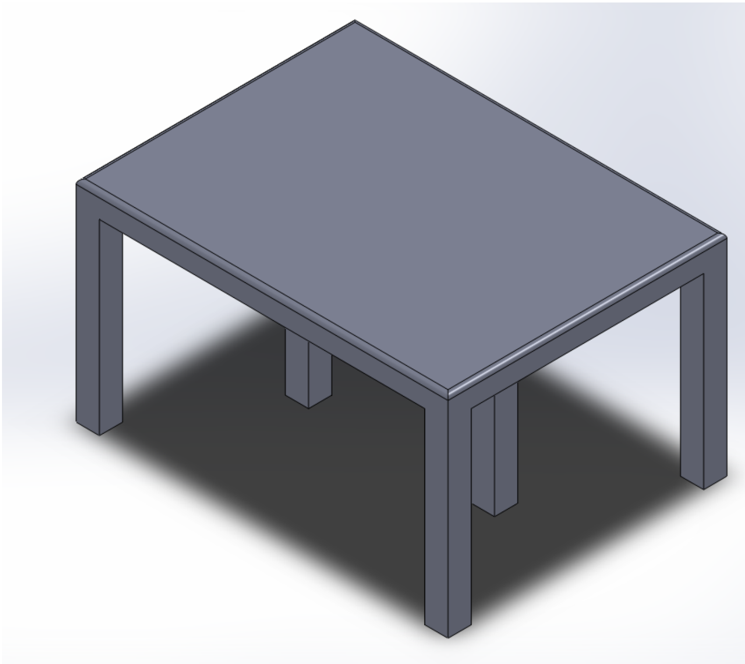
The group also suggested installing interlocking deck tiles in the shed; since the soil filler has to quickly fill up pots and hand them off to planters; a good portion of the soil falls off the table onto the ground and settles, this has resulted a buildup of soil and making the table uneven and unstable. Interlocking deck tiles would make it easy to simply sweep the excess soil out of the shed and help maintain a clean work area. Below is an image of the suggested interlocking tiles; there are 16"x16" and simply snap into place making installation easy.

Figure 11: INTERLOCKING DECK TILES

SEMI-AUTOMATION LAYOUT

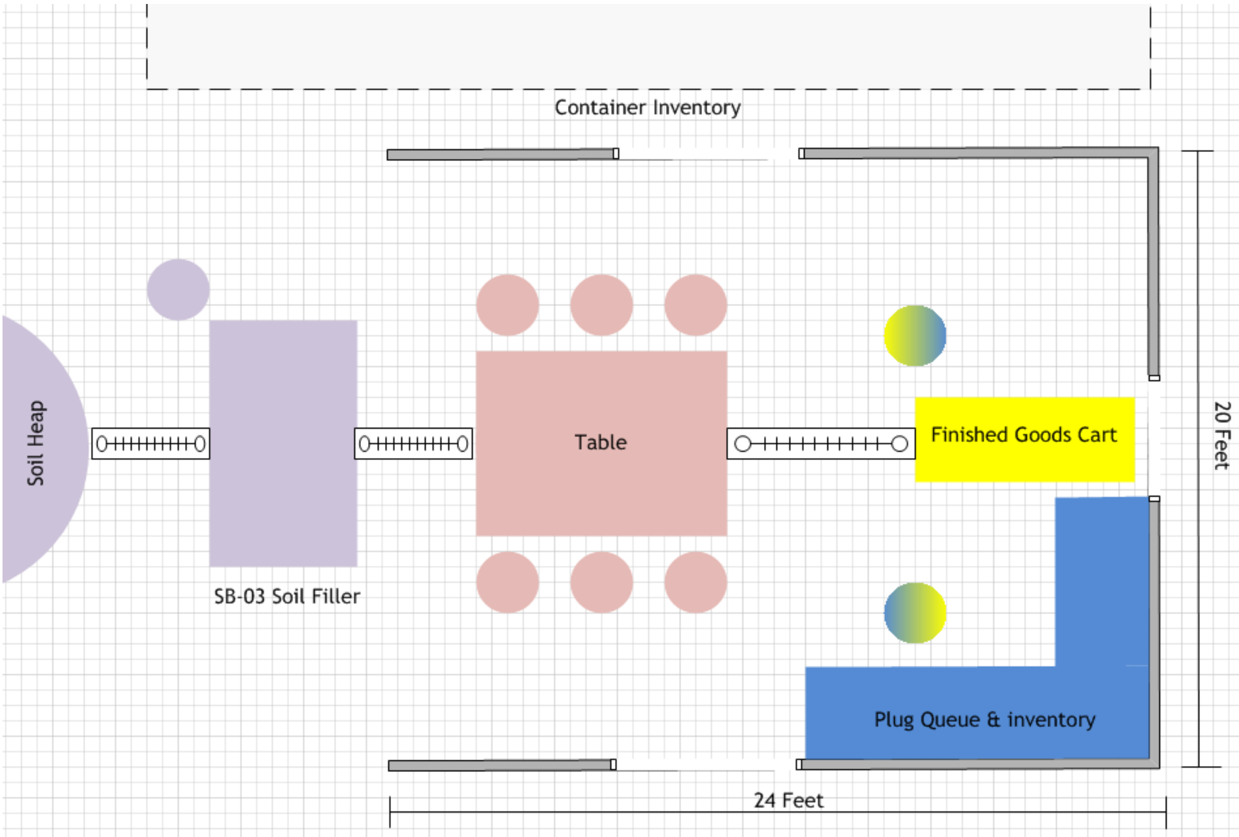
The second table design that was explored was the one to compliment the soil filler machine. Since this machine removed the soil filler position there was no need to have a complicated design. So the group went with a simple rectangular table design as shown below.

Figure 12: AUTOMATION LAYOUT TABLE



The tables dimensions are 6’ x 8’ x 3.25’ and can accommodate 6 planters. The implementation of this table as well as the machinery would change the layout of the shed to the layout shown below.

Figure 13: LAYOUT IMPLEMENTING AUTOMATION



With this layout, the products would move continuously in one direction from left to right and avoid confusion and clutter in the work area. As with the enhanced table design; the group suggests laying down interlocking deck tiles.

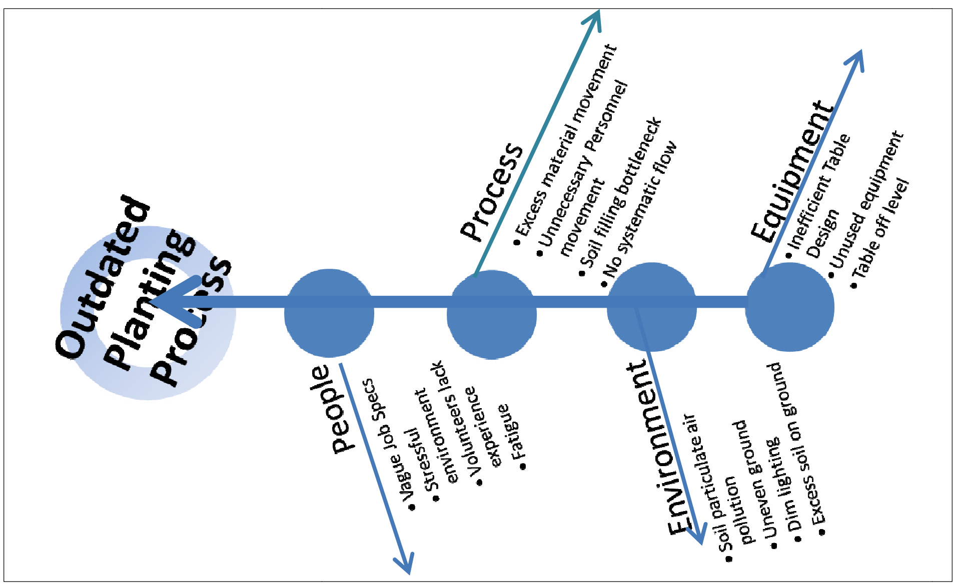
METHODS

In this section the methods of analysis used to compare the two layout options are described. In addition to the Fishbone Diagram, four main evaluation methods were used. They are Multiple Attribute Utility Theory, a Modified Relationship Matrix, an Economic Analysis and Simulation.

QUALITY ENGINEERING PRINCILPLES

The Fishbone Diagram (Figure 10) displays the major reasons leading to the outdated planting process that Growing Grounds currently has. The four main areas targeted were the people, the environment, the equipment and the process. Based on the customer requirements, employee suggestions and findings from the fishbone diagram, the two table designs and layouts were created.

Figure 14: FISHBONE DIAGRAM



The Multiple Attribute Utility Theory allowed the team to quantify how well each design met the needs of Growing Grounds and to assign a weight to each design consideration. Design considerations that were assigned a higher weight then affected the overall score more drastically then less design considerations that Growing Grounds found less critical. The results are shown below in Figure 11. The results found were that, at the current time, the Enhanced design had the highest score with a value of

0.411, the Semi-Automated design was the next highest scoring at 0.382 and the current design received the lowest score of 0.344.

Figure 15: MULTI ATTRIBUTE UTILITY THEORY

		Alternatives			Alternatives		
	Weight	Current Design	Automated Design	Enhanced Table Design	Current Design	Automated Design	Enhanced Design
No Soil Bottleneck	0.05	Poor	Good	Moderate	0.005	0.03	0.015
Cost Effective	0.25	Good	Poor	Moderate	0.15	0.025	0.075
More Throughput over existing	0.02	Poor	Good	Moderate	0.002	0.012	0.006
Amount of time spent planting	0.07	Poor	Good	Moderate	0.007	0.042	0.021
Number of workers needed	0.04	Moderate	Good	Moderate	0.012	0.024	0.012
Start-up time reduced	0.03	Moderate	Poor	Moderate	0.009	0.003	0.009
Amount of space in barn used	0.01	Poor	Moderate	Good	0.001	0.003	0.006
Ability for future growth	0.1	Poor	Good	Moderate	0.01	0.06	0.03
Benefits of horticultural therapy intact	0.1	Good	Moderate	Good	0.06	0.03	0.06
Ensures organization of process and space	0.02	Poor	Good	Moderate	0.002	0.012	0.006
Low ongoing costs	0.05	Good	Poor	Good	0.03	0.005	0.03
Low environmental impact	0.04	Good	Poor	Good	0.024	0.004	0.024
Standardized Process	0.02	Poor	Good	Good	0.002	0.012	0.012
Good Flow within shed	0.05	Poor	Good	Good	0.005	0.03	0.03
Ergonomic Design	0.1	Poor	Good	Good	0.01	0.06	0.06
Weatherproof	0.05	Moderate	Good	Moderate	0.015	0.03	0.015
Totals:	1.00				**0.344**	**0.382**	**0.411**

For the modified relationship matrix, the team first started by analyzing the current design and process to see what workstations are typically used together. Figure 12 shows the results of this analysis. Items in the table marked with a “1” represent a strong usage between the relationship shown. For example, after using the pulling table it is essential to have the plug queue nearby because that is the next step in the process. Items marked with a “2” would be convenient to have nearby but closeness is not entirely essential to the process. Those marked with a “3” are rarely or never used together and thus for the most part were ignored in the following analysis.

Figure 16: RELATIONSHIP MATRIX

From / To	Pulling Area	Plug Queue	Container Inventory	4 inch Queue	Soil Inventory	Potting Table	Finished Good Queue
Pulling Area		1	3	3	3	1	3
Plug Queue	3		3	3	3	1	3
Container Inventory	1	3		2	3	1	2
4 inch Queue	3	3	3		3	1	2
Soil Inventory	3	3	3	2		1	2
Potting Table	3	3	3	1	1		1
Finished Good Queue	3	3	3	1	3	1	

The above relationship matrix was then used as a basis for creation of each layout. Following that, each layout was analyzed on how well it met the needs shown by the relationship matrix. To start, the enhanced table design will be discussed. From the relationship matrix, each relationship that had been previously ranked a "1" was shaded blue on the table and each "2" was shaded green. Relationships that were given a "3" were ranked as N/A since they would skew the data and were not at all important to be near each other. Then each of the blue and green relationships were ranked on a scale of successfully, moderately and not at all. Figure 14 shows the results of this analysis.

Figure 17: RELEVANCY OF ENHANCED DESIGN

From To	Pulling Area	Plug Queue	Container Inventory	4 inch Queue	Soil Inventory	Potting Table	Finished Good Queue
Pulling Area		Successfully	N/A	N/A	N/A	Moderately	N/A
Plug Queue	Successfully		N/A	N/A	N/A	Moderately	N/A
Container Inventory	N/A	N/A		Not at All	N/A	Moderately	Successfully
4 inch Queue	N/A	N/A	N/A		N/A	Successfully	Successfully
Soil Inventory	N/A	N/A	N/A	Successfully		Successfully	Successfully
Potting Table	N/A	N/A	N/A	Successfully	Successfully		Successfully
Finished Goods Cart	N/A	N/A	N/A	Successfully	N/A	Successfully	

No longer included	Not Applicable
Ranked 1 on RD	Successfully
Ranked 2 on RD	Moderately
Ranked 3 on RD	Not at All
Break Line	

- 1's ranked successfully: 9/12 – 75%
- 2's ranked successfully: 4/5 – 80%
- Total: 13/17 – 76.47%

The number of "Successfully" answers was then counted. Figure 14 shows these results. Overall, "1's" and "2's" were given successfully answers in 13 of the 17 relationships and three of the remaining relationships were ranked as moderately.

The same procedure was followed for analyzing the semi-automated layout. Figure 15 shows the relevancy of the semi-automated layout and the resulting statistics. One change to be noted is that he Semi-Automated Layout eliminates the need for the 4 inch queue area so those relationships have been removed.

Figure 18: RELEVANCY OF SEMI-AUTOMATED LAYOUT

From To	Pulling Area	Plug Queue	Container Inventory	4 inch Queue	Soil Inventory	Potting Table	Finished Good Queue
Pulling Area		Successfully	N/A	N/A	N/A	Successfully	N/A
Plug Queue	Successfully		N/A	N/A	N/A	Successfully	N/A
Container Inventory	N/A	N/A		N/A	N/A	Successfully	Moderately
4 inch Queue	N/A	N/A	N/A		N/A	N/A	N/A
Soil Inventory	N/A	N/A	N/A	N/A		Moderately	Not at all
Potting Table	N/A	N/A	N/A	N/A	Moderately		Successfully
Finished Goods Cart	N/A	N/A	N/A	N/A	N/A	Successfully	

No longer included	Not Applicable
Ranked 1 on RD	Successfully
Ranked 2 on RD	Moderately
Ranked 3 on RD	Not at All
Break Line	

- 1's ranked successfully: 7/9 – 78%
- 2's ranked successfully: 0/2 – 0%
- Total: 7/11 – 64%

In this design, 7 out of the 9 items ranked as "1's" were given successfully rankings. However, none of the items ranked as "2's" were ranked as successfully which means that only 7 out of 11 were ranked successfully.

Another small comparison between the two designs that was made was how much square footage was gained over the current design. Figure 18 shows these metrics. The current layout takes up 125 square feet of the barn space. The enhanced layout takes up 118 square feet, and the semi-automated layout takes up the least amount of space with 108 square feet when operating.

Figure 19: AMOUNT OF SQUARE FOOTAGE USED-BY LAYOUT

	Current Layout	Enhanced Layout	Automation Layout
Area Used (ft^2)	125	118	107
% Increase	0.00%	5.60%	14.40%

A comprehensive economic analysis was completed. Due to different plants making different amounts in profit, the graphs are based on a sliding scale. A breakdown of the costs to implement each design is listed below in figure 20. For the automated process the breakeven amount for given profit margins is shown in the sliding scale graph in Figure 21.

Figure 20: SEMI-AUTOMATED LAYOUT COST BREAKDOWN

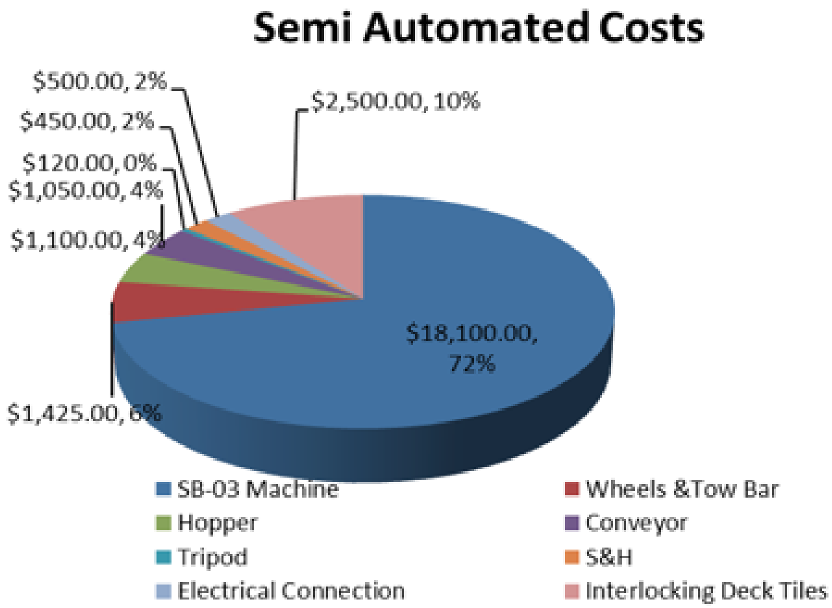
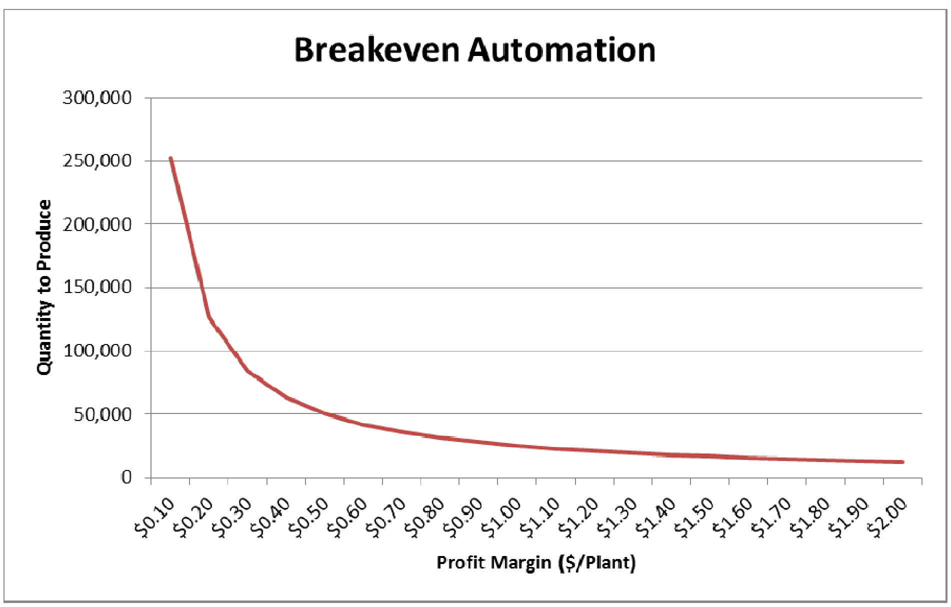


Figure 21: BREAKEVEN AMOUNTS FOR AUTOMATED LAYOUT GIVEN VARYING PROFITS



The same analysis was completed for the enhanced table design and is shown in Figures 22 and 23.

Figure 22: ENHANCED LAYOUT COST BREAKDOWN

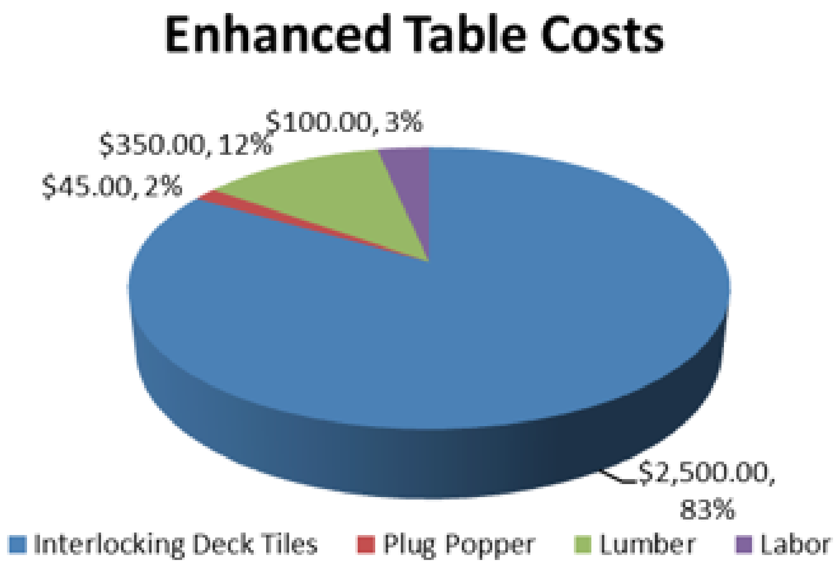
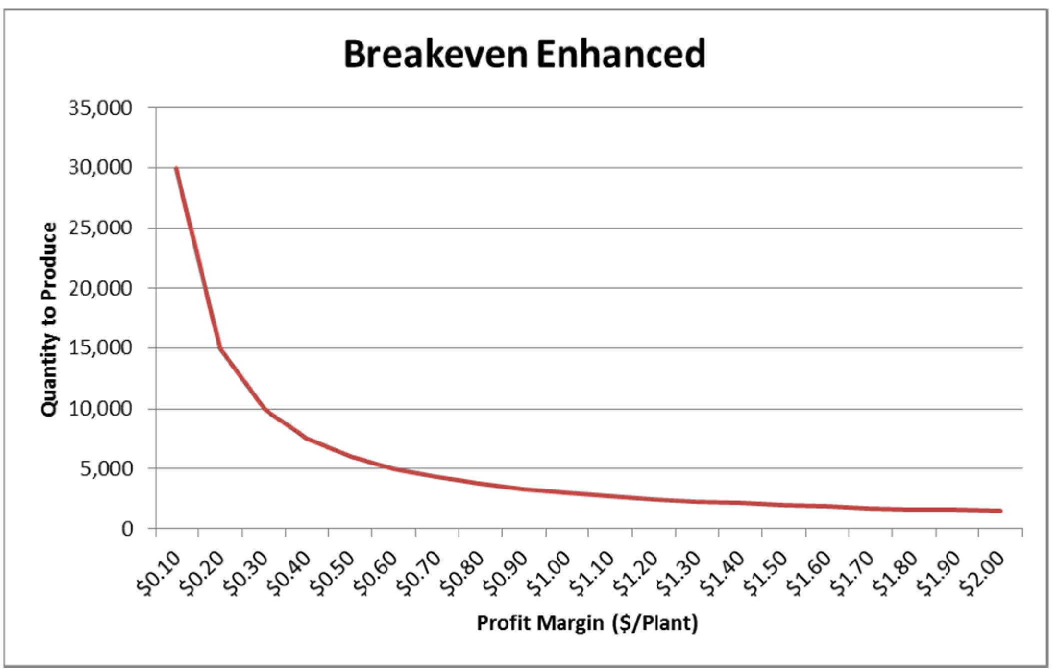


Figure 23: BREAKEVEN AMOUNTS FOR ENHANCED LAYOUT GIVEN VARYING PROFITS



SIMULATION

In order to ensure that the proposed designs actually had an effect on the total throughput simulations were generated. Since this is a second generation project, the simulation for the baseline was already created and did not need to be regenerated. This showed that the baseline output for the planting process was 715 in a 3 hour shift. The simulation for the enhanced table layout was then created including the necessary changes to times such as removing the orbiter and adding additional planters and soil fillers. With the calculated data the new throughput came to be 1035 plants in a 3 hour shift; a 50% increase over the baseline. The simulation for the automated layout was then created including the necessary changes to times such as removing the orbiter soil filler and adding additional planters. With the calculated data the new throughput came to be 2137 plants in a 3 hour shift; a 200% increase over the baseline. Even though these are all theoretical calculations; many steps were taken to make the simulation as realistic as possible. A triangular distribution was used to show the varying levels of planting experience. Also a speed of 3 miles per hour was taken into account when calculating walking times for workers in the shed.

RESULTS AND DISCUSSION

In this section, the overall results and recommendations from the project group will be presented and explored.

Given the findings in the evaluation portion of the methodology; it is recommended that Growing Grounds use the enhanced table layout and make smaller changes in their planting process. At this time, investment in a soil filler machine would not be advised. The results were as expected; even though the automated layout would increase production dramatically, it would take away significantly from the horticultural therapy that Growing Grounds strives to offer its volunteers. The resulting design is efficient, simple and 5S friendly. Cost estimates for the design were reasonable; the largest investment is in the new flooring which is to be expected.

Based on the evaluations made and the clarity of the designs presented, implementation of the chosen design should be very successful. While the semi-automated design will take more effort to implement because it includes hiring someone to run a 220V power supply out to the barn and will be a more complicated process to train employees on, the project team is confident that, with training, either design will be easy to implement and will yield higher production rates while still keeping employment satisfaction high and staying in line with the mission statement of Growing Grounds. In the future, if Growing Grounds does not choose to semi-automate their processes initially, the project team could see them using the proposed design in several years when they are able to spend more money to upgrade their processes.

As it stands they most likely do not have the budget to take on the $25,245 cost of upgrading their process. However, if they spend the $2,995 now, they can save the (net) profit made by the additional throughput gained with the enhanced table design and layout to buy the SB-03 (or future equivalent) machine and upgrade their layout accordingly. Furthermore, majority of the cost for the enhanced design is labor and materials for the interlocking deck tile flooring that needs to be installed in the barn. This cost of $2,500 is a one-time cost and is necessary for both designs and can be subtracted from the $25,245 cost of the semi-automated design if Growing Grounds decides on the enhanced table design with the intention of further upgrading in the future.

One problem that might occur if Growing Grounds initially implements the semi-automated design is that there may be resentment from the employees. Currently the potting process is social with the employees talking casually while they work, but still being a little competitive with themselves to try to meet new personal records on plants potted. With the implementation of the semi-automated machine the workplace atmosphere may change. It will be harder initially to get used to the new machinery and process, while at the same time management will be expecting to see results since they spent all of the money to get the expensive machinery. This could cause stress and would weaken the team-like attitude that employees currently have during the potting process. Also, as with any new process or new technology, either new process will have a long learning curve for the employees and may initially be slower than the previous method until all job roles are learned fully.

CONCLUSION

In this project an outdated planting method was analyzed to determine new solutions to make the process more efficient, ergonomic and able to yield more plants during the three-hour planting shift. The objectives were to propose two new layouts for the planting shed; a non-automated, relatively low cost option and a higher cost, semi-automated layout that would incorporate using the SB-03 pot filler. Two methodologies were used to design and analyze the two layouts. For the design phase the IDEO Human Centered Design methodology was used to make sure that all customer needs were met by the proposed designs. The other methodology was to use the quality engineering tools of Multiple Attribute Utility Theory, Relationship Matrix, Fishbone diagram and Economic Analysis Methods to quantify our findings and determine which solution would be optimal for implementation at Growing Grounds Farms.

Based on the project team's findings, enhancing the current table and layout and not investing in semi-automating the planting process would be the recommended course of action. This is due to the limited funding that Growing Grounds has available for this project, the ability of each to meet the customer requirements and the results shown by the quality engineering analysis tools used. However, both layouts will be presented to Growing Grounds with the team's findings and they will ultimately chose the design that they believe fits their needs best.

Throughout this project the project team learned a lot about working on a small team project that was largely guided by themselves without very much faculty intervention during the project. Below is a summarized list of some of the lessons learned by the team throughout the project:

- Narrow down and solidify the scope as early as possible. Last minute and/or multiple scope changes by the company lead to more stress and less elaborate projects than originally planned.
- There are always hidden problems that aren't very apparent at the beginning
- Sometimes what is assumed to be the main problem is not the main problem
- Automation is not always better

- It is very important to listen to what the customer would like and to not overcommit

As with most projects, this project could be carried out further with more areas being investigated. Some recommended next step would be to look into a way to eliminate workers having to bend down at all, both during the 5 gallon potting process and when gathering soil for the other potting process to put the soil into the SB-03 machine or onto the planting table (depending on the new planting method chosen). Another future project would be to look at the quality of the plants being produced – on occasion plants are given away or thrown away due to various quality factors such as fungus growth on plants or plants dying prematurely. To review the project objectives, while constantly changed, the solution presented to Growing Grounds did meet all of their final requests and met all of the objectives which were to design a new ergonomic planting table, redesign the planting facility layout, decrease potting production cycle time and increase total output, and design future plans to reflect their expected growth and potential new equipment.

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APPENDICES

APPENDIX A: PLANTING PROCESSES

APPENDIX 1-A: 4-INCH PLANTING PROCESS

Pulling Table (1 Puller)

1. Obtain list of what orders are needed.
2. Gather plants and move to barn area on trailer.
3. Carry plants in barn and place on pulling table.
4. Poke plants out one at a time from flats using a dowel.
5. Check quality of plug.
6. Place 16-32 plants in a basket.
7. Place tag indicating plant type in basket.
8. Move basket to queuing shelf.

Soil Filling Station (1 Soil Filler)

1. Put flats on ground.
2. Place 16 4-inch containers in each flat.
3. Use shovel to fill 4-inch containers with soil.
4. Use hands to smooth out surface of soil.
5. Stack filled flats on queue next to potting bench.

Potting Bench (4 Planters)

1. 4 planters work at the potting bench (2 on each side).
    a. Each planter has one flat and shares 1 basket between them.
2. Planter creates hole in a 4-inch container with fingers.
3. Planter puts a plug from basket into hole and tucks it in.

1 Orbiter (sometimes the same person as the puller or soil filler and works at both)

- Moves finished flats from potting bench to trailer.
- Replaces empty baskets on potting bench with full ones from queuing shelf.
- Transports and unloads full trailers at designated locations.

APPENDIX 2-A: 1 GALLON PLANTING PROCESS

Pulling Table (1 Puller)

1. Obtain list of what orders are needed.
2. Gather plants and move to barn area on trailer.
3. Carry plants in barn and place on pulling table.
4. Poke plants out one at a time from flats using a dowel.
5. Check quality of plug.
6. Place 16-32 plants in a basket.
7. Place tag indicating plant type in basket.
8. Move basket to queuing shelf.

Soil Station (1 Soil Filler)

1. Shovel soil into 15-gallon container.
2. Carry filled 15-gallon container to potting bench.
3. Lift container to pour soil onto work surface.
4. Repeat steps 1-3 (takes 5-6 trips to fill entire work surface).

Potting Bench (1 Soil Filler & 4 Planters)

** 9:00-10:00 AM Set-Up: 1 person separates 1-gallon containers and places them on ground by the filling station on bench

1. Soil filler standing in the middle of the U-shaped potting bench places empty 1-gallon containers on table ledge and pushes soil from table into pots.
2. Soil filler lifts filled containers onto work surface for planters.
3. 4 planters work at the potting bench (2 on each side).
    a. Planters share 1 basket between them.
4. Planter creates hole in container with fingers.
5. Planter puts a plug from basket into hole and tucks it in.

1 Orbiter (sometimes the same person as the puller or soil filler and works at both)

- Moves finished plants from potting bench to trailer.

- Replaces empty baskets on potting bench with full ones from queuing shelf.
- Transports and unloads full trailers at designated locations.
- Separates 1-gallon containers for soil filler.

APPENDIX B: SUGGESTED MATERIALS

APPENDIX 1-B: INTERLOCKING DECK TILES

ITEM	LINK	PRICE	COST
Interlocking Deck Tile - 6 Slat Style	http://www.samsclub.com/sams/interlocking-deck-tile-6-slat-style/prod1150144.ip	Price: $7.00/sqft	$3,360.00
LifeCycle/EcoDek Floor Tile - Redwood - 10 pk.	http://www.samsclub.com/sams/lifecycle-ecodek-floor-tile-redwood-10-pk/prod1210266.ip	Price: 64.00/box (48 Boxes)	$3,072.00
Copacabana Itauba	http://www.builddirect.com/Interlocking-Deck-Tiles/Copacabana-Itauba/ProductDisplay_9645_p1_10077486.aspx	Price: $5.99/sqft (52 boxes)	$2,915.45
Kontiki Teak Interlocking Wood Deck Tiles	http://www.builddirect.com/Interlocking-Deck-Tiles/Parquet---Select/ProductDisplay_9645_p1_10068955.aspx	Price: $5.89/Box (48 Boxes)	$2,827.20
Rio Ipe Champagne (12"x24"x1")	http://www.builddirect.com/Interlocking-Deck-Tiles/Rio-Ipe-Champagne/ProductDisplay_9645_p1_10082192.aspx	Price: 7.99/Sqft (35 Boxes)	$2,617.52
Kontiki Hardwood Interlocking Deck Tiles (16”x16”x1”)	http://www.builddirect.com/Interlocking-Deck-Tiles/9-Slat/ProductDisplay_9645_p1_10079544.aspx	Price: 4.89/Sqft (47 Boxes)	$2,374.83

APPENDIX 2-B: PLUG POPPER

ITEM	LINK	PRICE
Gro Mor Plug Pusher	http://www.waldoinc.com/2010_grower_catalog/equipment.pdf	$40.00/each
Hummert international Plug Pusher	http://www.hummert.com/ProductDetail.aspx?Page=ProductSearchList.aspx&ID=6284&Text=pusher	$40.00-45.00 each

APPENDIX 3-B: SOIL FILLER MACHINERIE

ITEM	LINK	PRICE
SB-03 SOIL FILLER	http://www.sbmachinerie.com/web/sb-01/sb-03/	$18,100
Wheels and Tow Bar		$1,425
Hopper		$1,100
Conveyor (3)		$1,050
Tripod		$120
S&H		$450
Electrical Connection		$500