

REDESIGN OF GOOD KARMA BIKE'S FACILITY LAYOUT
AND BIKE STORAGE PROCESS

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by
Ryan Phillip Ogan
Derek Kimsor Chung
Tommy S. Chang

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ABSTRACT

Good Karma Bikes is a non-profit organization that services and restores bikes that customers bring into the shop. Good Karma Bikes has plans for a dramatic increase in storage capacity for the next few years. Good Karma Bike's warehouse area is currently overflowing with bikes due to the large increase in demand. A redesign of the warehouse layout is needed to handle the increase of incoming bikes and to improve product flow through the space. The project team's objectives are to:

- Improve accessibility and reduce time it takes to unrack a bike
- Increase space utilization by improving bike storage capacity
- Decrease distance traveled during the process of fixing or stripping down bikes

The project team will follow a Gantt chart throughout the duration of the project and use various Industrial Engineering tools to identify how much space is required for the increased demand, how each tool, rack, and workstation within the facility should be laid out, and create a new way to store bikes in a more efficient manner. First, the team observed the flow of bikes through the facility, gathering value added and non-value added processes. In addition, the team tracked the motion of the workers by creating a spaghetti diagram. The dimensions and current layout were taken to create a current state facility model using Microsoft Visio. Next, the project team dived into gathering specific dimensions on the current bike racks to determine how many can be stored on the racks and the amount of square footage the racks take up on the shop floor. The team then used Microsoft Visio as well to create a digital design of the new proposed layout and the alternative layouts, using employee feedback, space requirements, and distance traveled to produce a final recommended layout. For the bike racks, the new design was created in Solidworks to visualize the looks of the rack and the dimensions of the parts before the actual build. From the findings, the group found that the proposed layout will help decrease the amount of square footage consumed by the racks and improve the flow of bikes through the warehouse. The proposed bike rack design increases the rack's capacity from 6 bikes to 9 bikes while shortening the length of the rack. The total cost of implementing this bike rack will be \$60 in material cost and free with labor because the design is simple enough for volunteers to build the racks from scratch. This low-cost bike rack is beneficial to the Good Karma Bikes because this prevents the company from purchasing a mezzanine which would have cost them about \$11,000. The new layout and bike storage process will shorten the time to unrack and place bikes onto the racks by a minute per bike, decreasing overall cycle time for bike maintenance. The project team highly recommends this new facility layout and bike rack design if Good Karma Bikes hopes to achieve enough capacity for their projected demand.

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I. Introduction

The following report will uncover the step-by-step process on how our project team developed our recommendations and implementations to resolve Good Karma Bike's issues within their facility. As a non-profit organization, Good Karma Bikes seeks minimal cost solutions to its problems because the majority of its earned revenue is put back into its outreach programs that benefit the homeless people and at-risk foster youths in the local community. Due to a recent increase in customers, Good Karma Bikes forces incoming bikes into any open space in a rack due to limited capacity. Limited space between bikes causes difficulty with moving the bikes in and out of the racks. In addition, volunteers and mechanics have to repeatedly retrieve parts and tools, wasting value added service time. Both of these situations inhibit productivity and decrease bike throughput entering the retail store. To address such issues, our team defined the following objectives listed below:

- Understand the current process flow of the bike shop facility and classification of bikes
- Design new alternative facility layouts to address issues regarding accessibility of stored bikes, space utilization of bike racks, and the distance traveled during the bike repair process
- Design new bike racks to allow for more bikes to be stored per square footage in addition to reducing the time it takes to rack and unrack a bike in need of servicing
- Standardize the method and process of storing bikes, essentially increasing worker productivity

Not included in the scope of our project are issues concerning the redesign of the retail store, bike trailer, and the utilization of paid labor versus volunteer labor. The team believes that addressing the retail store does not fall under our project objectives because it does not affect the root cause of the issues presented to us. Additionally, the team left the optimal design of a bike trailer out of the scope of the project because it does not directly benefit the company in terms of generating revenue. This is due to the fact that the company intends to use the bike trailer to store donated bikes that will be used for outreach programs. Finally, the utilization of paid labor versus volunteer labor was defined as beyond our project scope because the team does not have the authority to dictate which volunteers are allowed to work on bikes. The social purpose of Good Karma Bikes is that it offers a place where individuals can build up their self-confidence by learning a skill such as repairing bikes.

The remainder of this report will go into further explanation on Good Karma Bike's background, our initial research on solutions for these problems through literature reviews, the design strategies our team decided to work on based on the information obtained from the literature reviews, methods on how to come up with the designs and test them, results from our testing, and a summary of the overall project.

II. Background and Literature Review

Good Karma Bikes is a non-profit, full service bike shop located in San Jose, California. Established in 2008, the company works with the organizations to receive donations and grants that allow them to fulfill its ongoing mission to positively impact those in need. Our client from Good Karma Bikes mentioned to us that they desire to increase its annual revenue from \$400k to \$2-3 million as it will allow for a greater impact to the community. This increase would help them expand their service programs, especially the College Outreach & Opportunity Program for youths that were formerly in the foster care system. In addition to the donations and grants, Good Karma Bikes earns revenue by selling refurbished bikes, at an average price of \$200 per bike, used but functional bike parts, and through full bike repair services. While Good Karma Bikes offers the bike repair services, which are performed by paid staff members and bike mechanics, a majority of the bikes are worked on by volunteers. These bikes that volunteers work on are bikes that Good Karma Bikes intends to be donated to the less fortunate, such as the local homeless people and at-risk foster youths.

The easiest way to classify and differentiate the different types of bikes that are worked on is by bikes that earn revenue for the company and bikes that do not. Bikes that earn revenue have a higher priority to be worked on, therefore only paid staff members, mechanics, and experienced volunteers would fix them. Good Karma Bikes makes an effort to ensure that every bike, either sold or donated, undergoes a quality check.

Revenue-Earning Bikes (Floor, Customer, Service):

Shop bikes are bikes that are placed for sale in the front retail store. However, these bikes are further classified into floor bikes and customer bikes depending on whether the shop bike has been purchased yet. These bikes are refurbished and fully serviced by staff workers with the intent of putting them up for sale. These bikes are sold at an average around \$200 and Good Karma Bikes spends roughly \$10 to \$60 on maintenance and parts. Currently, these shop bikes bring in about 40% of the company's revenue. Finally, service bikes are personal bikes that belong to an individual who is in need of a certain service or repair done on his or her bike.

Donation Bikes (Donor, Program):

Donor bikes are bikes donated to Good Karma Bikes with the intention of being recycled and stripped down for its used bike parts. Program bikes are bikes that are intended to be given away to outreach programs, local homeless people, or at-risk youths. Upon receiving these donor and program bikes, the amount of refurbishing necessary varies drastically. Typically, volunteers would service these bikes in order to learn the bike repair process and operations around the bike shop. Once these bikes are fixed and quality assured by a certified staff member or mechanic, these bikes are sent out to social outreach programs to help out the community.

Literature Review

The following literature review topics address issues that are related to this project. These topics include: facility layout methods, bike rack designs, 5S implementation, and inventory control.

Facility Layout:

A well designed facility layout can benefit the overall business operations by increasing efficiencies and work space productivity. The primary objective of a facility layout is to ensure a smooth flow of material and work through the manufacturing system. Because the design of the layout impacts how the work is done, a well-functioning, well-designed facility is essential. A facility with lean manufacturing principles incorporated into the design can help minimize or eliminate waste. Two main measurement tools to increase the productivity and the overall success of the facility are throughput and capacity (Duggan, 1998). The quicker the throughput of the products, the more capacity the facility will have.

Understanding the process flow regarding what tools, equipment, and facility are utilized is important. Creating a process flow map and identifying shared resources are critical parts of lean manufacturing. To achieve a “value-added facility design”, perimeter access must be considered. Perimeter access is the amount of exposure at the borders of a shared resource. This is important for flow and pull manufacturing because various operations and processes pull work through a common process. Therefore, the accessibility to this shared resource is critical.

A simulation model can be helpful in determining potential facility layouts. Simulation models allow experimentation of potential solutions and validation of a new process design. In the article “Simulation in Manufacturing: Review and Challenges”, the author D Mourtzis talks about a few simulation methods and tools that might be beneficial for a bike assembly process such as Material and Information flow design, Factory layout design, and Manufacturing Systems Planning (Mourtzis, Doukas, Bernidaki 2014). When constructing a simulation model for a manufacturing facility, a challenge would be how to present the results so that it’s detailed enough and easily interpretable. The article written by Han, “Automated Post-simulation Visualization of Modular Building Production Assembly Line”, emphasizes the importance of visualization in a simulation model. According to Han, a simulation model with adequate visualization provides “project participants with a detailed-level model to prevent misinterpretation of information and to understand the production process” (Han, Al-Hussein, Al-Jibouri, Yu 2012).

In any manufacturing environment, the layout of a facility can either be beneficial or problematic to the process flow. In the article *Modeling and Simulating a Facility Layout Based on Manufacturing Costs*, three types of facility layouts and the relationship between manufacturing cost and facility layout objectives are analyzed. Additionally, the simulation for the three facility layouts, linear, U-shape, and semi-circular, were simulated and used as part of the conclusions

obtained. The loop layout had the lowest material handling cost and the highest area utilization rate. The U-shape layout had the highest labor utilization (Suo 2014). The facility layout at Good Karma Bikes is one of the issues that the company finds problematic. The current layout of the bikes, bike parts, tooling, and equipment pose an issue when it comes to servicing bikes for the customer. A more efficient layout would minimize the waste of unnecessary motion and waiting for both the employers and customers. The facility height and structure allows a potential mezzanine to be placed inside the facility (Shapiro 2016). This would utilize unused space and allow more storage area to place bikes that either need to be assembled or sold.

Bike Rack Designs:

In order to increase space utilization within Good Karma Bike's warehouse, our team first needs to understand which type of bike racks are designed specifically to increase storage capacity and not necessarily for display purposes. In addition, Good Karma Bike requests the rack design to be ergonomically friendly. Therefore, the racks can not cause strain to the employees and volunteers, ruling out 90 degree vertically hanging racks which requires an employee to physically lift the weight of a bike in order to obtain the bike for usage. Observing different patents on space-saving bike racks will give our team a better sense on how to go about the custom bike rack design for Good Karma Bikes.

The first patent observed is Terrance Smith's bicycle parking and storage rack, as shown in **Figure 23** in the Appendix. Smith's bike rack is a unique circular design in which the bikes are held at an angle forming a tipi shape.

Bicycles parked in this vertical position take up around 40% less space than bicycles parked in the horizontal position. To justify this claim, a normal bicycle length is 70 inches in the horizontal position and with the addition of 24 inches wide for popular handlebars equals to 1680 sq. inches. On the other hand, the same bicycle in the vertical position requires the same 24 inches for handlebars but only 36 to 40 inches for the seat height. 24×40 inches equals 960 sq. inches or nearly 43% less space. And, when you arrange bicycles radially in a circle in the vertical position, the saving in space is even more: $92 \text{ in. dia. for ten bicycles} = (92 \times 92 \times 0.7854) = 6647.6 \text{ sq. inches}$ or 665 sq. inches for each bicycle which is a saving of over 60% in bicycle parking space. Furthermore, the invention can allow vertical bicycle parking on uneven walls or surfaces. Overall, this design is relevant for Good Karma Bikes because of the amount of space saved without the need to lift the bike upward onto a hook (Smith 1992).

Another relevant bike design is Selzer and Bellomo's design of an arc shaped rack allowing an easier way to mount a bicycle vertically without having to lift the bike (**Figure 24** in the Appendix). At Good Karma Bikes, the donated bikes generally weigh from 30 lbs. and up, therefore this bike rack design would alleviate the load and securely hold the bike in place.

Lastly, taking the bikes off this rack will take no effort at all as gravity will allow the bike to easily roll down with no force applied at all (Selzer, Bellomo 2009).

5S Implementation and Inventory Control:

There are a variety of methods when it comes to implementing process improvement strategies in operations. The article *Steps and Strategies In Process Improvement* recognizes the importance of applying statistical methods in quality improvement projects. In order to eliminate variation in the series of interconnected processes, identifying, quantifying, and controlling improvement opportunities are essential to process improvement. Some strategies that were highlighted in the article were SPC, Taguchi's methods, Shainin System, and Six Sigma. A global comparison of these strategies analyzed which strategies are best used for stabilization or optimization and in which phase of the project is best suitable. For finding optimal settings for process parameters, Taguchi's methods and Six Sigma are ideal. For stabilization that identifies process disturbances, SPC is more desirable. For both optimization and stabilization, the Shainin System should be put into use (Mast, Wener, Does, 2000). As a form of transportation, bikes must undergo some sort of quality control to ensure safety for the bike rider. Therefore, the manufacturing process at Good Karma Bikes is subject to variation. The variation reduction methods in the Shainin System seem like a practical strategy to utilize for the bikes that are being serviced, fixed, and assembled at Good Karma Bikes.

Inventory management is essential to minimize total cost or maximize total profit. In the article *Optimizing Inventory's Contribution to Profitability in a Regulated Utility: The Averch-Johnson Effect*, the inefficiency in inventory management of utilities is examined. The Averch-Johnson Effect, or A-J Effect, is basically the incentive to use utilities to obtain higher inefficient levels of inventory than the base level (Li, Miller, Schmidt, 2016). For Good Karma Bikes, the reinvestment of the money they put into purchasing new bike parts must be optimized. It would be incredibly wasteful if they purchased parts that would not be utilized or bought by customers. Additionally, keeping excessive-unused bike parts in inventory takes up storage space. Therefore, the A-J Effect must be avoided to improve the inventory utilization at Good Karma Bikes. Although the goal for Good Karma Bikes is to change lives by giving bikes, it is only possible through generating money. In order to accomplish this, throughput must be increased while both inventory and operational expenses are decreased. For Good Karma Bikes, inventory is basically money invested into purchasing parts which it intends to sell. In order to generate more sales, or in this case, fully assembled bikes, a proper inventory management is essential.

Lean principles can be applied to inventory control in order to reduce excess inventory and increase overall production efficiency. Some of the wastes or "muda" mentioned in the article "The Move to Lean: Inventory Management at the Foundation" are: waiting due to batch production, over-processing, or accumulation of products that are made ahead of schedule. A

solution suggested by the study is to create a standard work sequence and establish a clear material flow in the manufacturing process (Agarwal 2005).

One of the first go-to tools in an industrial engineer's toolbox is to incorporate a 5S system to a place that seems disorganized and full of clutter. According to Christiano Purto's dissertation, 5S is a management tool used to improve housekeeping, environmental conditions, and health and safety standards that are relevant to everyone at the company. There are 5 stages to the 5S process: Seiri (Sort), Seiton (Set in Order), Seiso (Shine), Seiketsu (Standardize), Shitsuke (Sustain). Sort ensures that there are limited obstacles in the path of getting to an object or tool. The majority of the time at a bike shop, there are tires lying on the ground not being properly stored away, forming a hazard every time a person walks by. In addition, sort focuses on eliminating unnecessary items that have been taking up space for a long period of time.

Since Good Karma is a non-profit organization, donations are always accepted. However when it comes to those donated bike parts, they tend to be broken parts that a previous owner just wanted to get rid of. Instead of keeping those parts to fix later, the sort process encourages employees to throw away those items that are no use to the company. Next, set in order is to place objects in their proper place. At Bengkel ABC, shadow boards were used to easily identify where the proper place for parts and tools to be stored. Shine focuses on the cleanliness of the shop so that if a problem occurs, it can simply be identified due to the fact that there will be a noticeable clutter in a certain section of the shop. Standardize means that every process has a standard so there is no room for disorganization. Lastly, sustain is to maintain the status of the previous four processes by training employees to uphold the standards. Through these 5S implementations, Bengkel ABC became a more efficient workplace (Purto, 2013).

A majority of Good Karma Bike workers are volunteers, meaning that there is variability in the methods used to fix or assembly the bikes. According to Berger, creating a standard operating procedure helps employees perform routine operations while reducing the amount of miscommunications and failures to comply with industry regulations. By setting a standard operating procedure at Good Karma Bikes, volunteers will be able to properly assemble bikes together while limiting the chance of any rework.

Having written rules and steps on how to assemble a bike will decrease the amount of time it takes for an employee to be trained in that subject. The standard operating procedures will have the best procedures on how to assemble a bike therefore; the variability in time to assemble a bike will decrease dramatically and lead to higher efficiency. Implementing a standard operating procedure is a crucial way to ensure that bikes are assembled at the same rate as customer demand.

III. Design

This section will provide an overview of our approach towards the redesign of the facility layout, along with the design of the bike racks that will be implemented in one of the alternative layouts. Upon reception of the project, our client from Good Karma Bikes presented issues regarding space utilization and accessibility of the bikes in its facility. Therefore, our team decided that as our initial steps of the project, we would understand the overall workflow and classification of the different types of bikes stored in the facility. Based on our observations, our team decided to focus our efforts on the facility located in the back of the shop and not the front, where they display and store bikes they intend to sell. This facility in the back consists of the workstations for fixing bikes, bike racks used to store the various types of bikes, cabinets of bike parts and equipment, and other facility departments that will be discussed later. In order to meet the potential increase in demand within the next couple years, the flow of bikes that need to be worked on will be addressed through making changes to the space utilization and accessibility of stored bikes.

Current State Facility:

The current state facility at Good Karma Bikes consists of the following departments: Workstations, Parts, Bike Racks, Rest Area, Admin, and Office. Table 1 shown below lists the current square footage occupied by each of the departments.

Table 1 Current State Department Minimum Space Requirements

Department	Required Square Footage
Workstations	624
Parts	35
Bike Racks	800
Rest Area	572
Admin	98
Office	330

Figure 1 represents the current state layout. As shown, there are eight workstations located in the upper left of the facility. At these workstations, workers, depending on their role and experience, would either fix bikes or strip down bikes for spare parts. The parts area consists of both second handed or used bike parts and new bike parts. Depending on the type of bike being worked on, the worker would choose to fix the bike with a used or new bike part. Currently, the parts area is located close to the main entrance to ensure easy access for potential customers looking to

purchase these second hand bike parts for a relatively cheap price. The rest area is shown in the upper right and that is where volunteers receive initial training and have access to a TV with tutorial repair videos. Because of the utility design, the compressed air station is oddly located in the rest area. Some things that the client told us to consider for alternative layout designs are for the office and admin space to be left alone.

Figure 1 Current Facility Layout



In Figure 2, the bike racks are shown to be categorized based on the type of bike being work on. Refer to Section II Background and Literature Review for the classification of the different types of bikes located in the Good Karma Bikes facility. Below, Table 2 lists the type of bike associated with the given number shown in Figure 2:

Table 2 Current State Bike Rack Classification Legend

1	Staff
2	Service
3	Floor & Customer
4	Customer (Ready for Pickup)
5	Quality Check
6	Program & Donor

Figure 2 Bike Rack Classification



Current State Bike Racks:

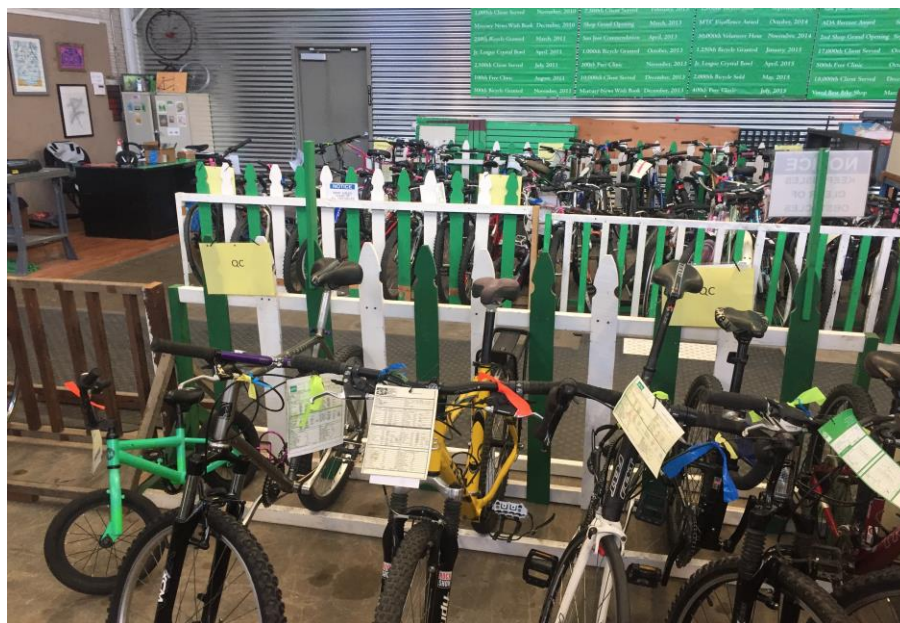
There are two different types of bike racks currently used in the facility to store the bikes. The first type is what our team defined as a “brown” bike rack that has the capacity to hold three to six bikes, depending on how tightly jammed in the bikes are. There is currently only one of these bike racks located in the facility. The second type of bike rack, the more commonly used one, is a “green and white picket fence”. There are a total nine of these placed in the current layout, with a capacity ranging from six to ten bikes per rack.

Due to Good Karma Bikes operating on donations, these “green and white picket fence” bike racks were made and given to the company by the local community boy scouts. This poses issues regarding the design of the bike racks, specifically the spaced out gaps for the tire placement of a racked or stored bike. These spaced gaps currently range from 2.75” to 4.75”, causing the bike tires to slant when placed on the rack. Essentially, this causes the overall utilization of space to decrease, in terms of number of bikes stored per square feet, along with increasing the difficulty of accessing the stored bikes. A summary of the information regarding these two different bike racks currently used in the facility is listed below in Table 3. It is important to note that the bike capacity of the racks has a large variation due to the inconsistent design of the “green and white picket fence” bike racks. Therefore the range of bikes listed for the bike capacity ranges from how tightly jammed the bikes are racked onto the bike racks (Refer to Figure 3). A more jammed packed setting would make it difficult for the accessibility of the bike, in terms of unranking, due to the handlebars and pedals interference caused by the surrounding bikes.

Table 3 Current State Bike Rack Quantity, Capacity, and Dimensions

	Brown Bike Rack	Green and White Picket Fence Bike Rack
Quantity	1 rack	9 racks
Bike Capacity	3 to 6 bikes	6 to 10 bikes
Dimensions (bike included)	66”W x 64”L	66”W x 93”L 66”W x 99”L

Figure 3 Current Bike Racks

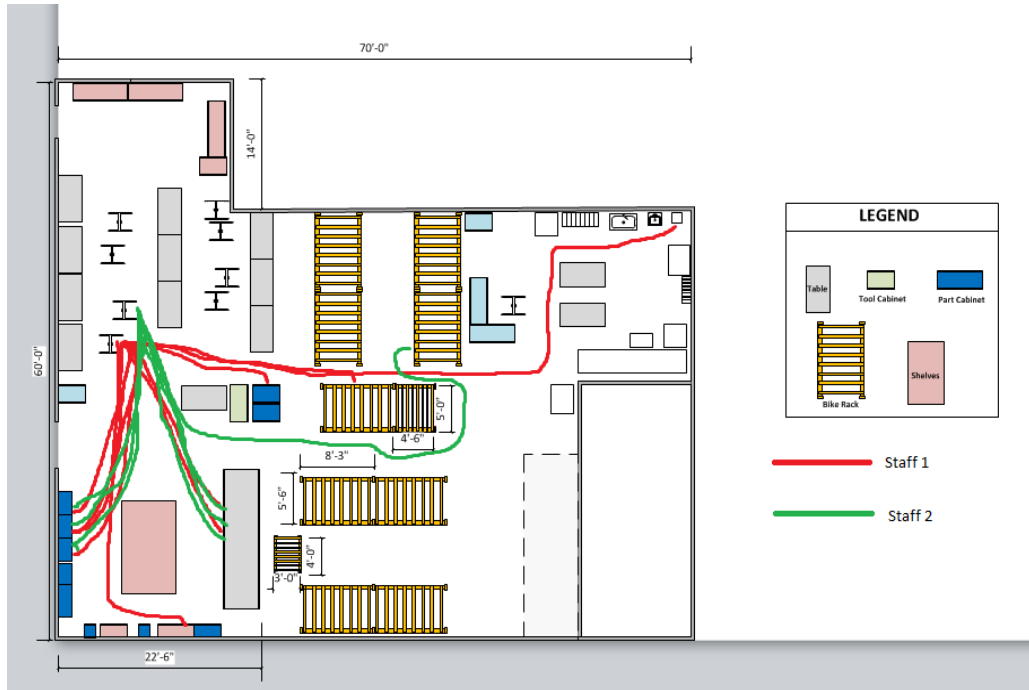


Current State Spaghetti Diagram:

The team decided to develop a spaghetti diagram to identify the travel paths of a worker fixing bikes in the current facility layout. Through this diagram, the team was able to identify non-value added or wasted motion performed throughout the bike repair process. As seen in Figure 4, the spaghetti diagram follows the movements of two staff members repairing one bike each during a two hour observed time period. The red line represents one worker and the green line represents another worker. The team concluded that workers repeatedly move from the workstations to the cabinets containing the bike parts and equipment tools. In addition to this, the staff member’s travel path indicated in red showed that he walked across to facility to simply use the compressed air station to pump up a bike tire. Unnecessary motion such as the ones observed during the creation of the spaghetti diagram adds time to the bike repair process, lowering worker’s

productivity and the overall throughput of putting finished bikes into the retail store or donating out to outreach programs.

Figure 4 Current State Spaghetti Diagram



Design Constraints:

Based on our conversations with our client, the team was able to understand the limitations regarding alternative facility layouts and bike rack designs. The first limitation was that Good Karma Bikes is physically limited to the current facility space available, as it is not looking to expand its square footage within the warehouse. Additionally, there are limitations to the productivity and quality of labor of the volunteers working at the facility. The skillset and bike repair experience of volunteers varies significantly person to person. Additionally, the amount of time each volunteer had available to work varies. This inconsistency in volunteer hours contributes to different levels of familiarity for the bike repair process. Our client from Good Karma Bikes also mentioned that bikes cannot be stored in a vertical position due the possibility of a volunteer injuring themselves while unranking or racking the bikes. A potential injury can occur because one must lift the bike in order to reach the hook that is capable of securely mounting the bike into place. Many of the bikes that Good Karma Bikes receives are over thirty pounds, a weight that is not ideal for repeatedly racking and storing bikes in a vertical position.

Because Good Karma Bikes operates on donations and funds provided to them, the team made an effort to keep additional costs at a minimum. Therefore, our team aimed to have low implementation, material, and equipment costs for our alternative layouts and bike rack designs.

Specifically, the company does not have the budget to spend money on a retail bike rack, some of which can cost up to six hundred dollars. However, it was made clear to our team that the client desires a new bike rack design that allows for better space utilization and accessibility. This is due to the fact that the bikes stored in the current rack latch onto each other while in the process of unranking a desired bike from the rack. Ultimately, the client desires to have a bike rack design that is able to provide clearance for the handlebars, minimizing the time it takes to unrank the bikes and also the potential of damaging neighboring bike frames.

New Alternative Layout Designs:

With the objectives to improve accessibility of bike racks, increase bike storage space utilization, and decrease distance traveled during the bike repair process, our team designed three alternative layouts. Because the team desired to create redesigns that the client finds feasible for implementation, we ensured to communicate our designs and solutions as frequently as possible. Working with the observations our team made, along with the feedback provided by our client, we produced the following three alternative layouts for the Good Karma Bikes facility.

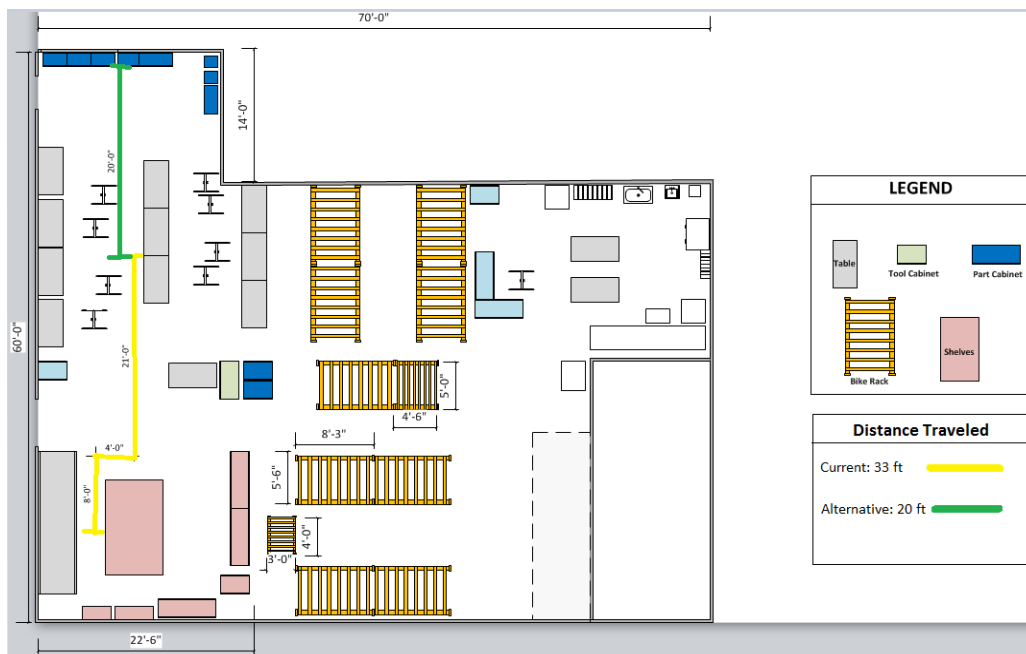
Alternative Layout #1:

The goal for the first alternative layout was to decrease the worker's distance traveled during the bike repairing process. Based on the frequency of workers traveling from the workstation to the cabinets observed from the current state spaghetti diagram, the team decided to move the cabinets closer to the workstation. The upper left area of the facility is essentially wasted space, as it is currently used to store parts that are no longer usable. The proximity of that area is a lot closer to the workstations; therefore, the team feels that the space would be better utilized if the area was replaced by the cabinets and shelves containing the commonly used bike parts. By doing this, the distance traveled from the workstations to the parts would decrease from 33 feet to 20 feet. The new design of the facility is shown below in Figure 5.

Although the distance traveled for a worker walking from the workstation to the spare bike parts would decrease, the new location of parts in alternative layout #1 introduces some considerations. Relocating the parts section to the top of the facility as shown in Figure 5 would cause slight interferences for a customer looking to purchase those used spare parts. Based on the feedback from the team's client, it is not unusual for customers to walk into the facility and browse through the spare parts section in hopes of finding a used bike part that they can use and purchase at a discounted price. Therefore, by moving the parts section to the top of the facility, unaware customers would walk through the main entrance then make a left, walking through the workstations. This poses a lot of potential risk as it would not be safe for customers to be wandering through the workstations where mechanics and volunteers are working with tools and bikes.

As a risk mitigation, our team concluded that if the client really desires to minimize non-value added processes, unnecessary motion created from repeatedly walking from the workstations to parts, it must be made clear where the spare parts are located. As shown in Figure 5, there is an entrance at the top left of the facility. Having something as simple as a sign at both of the entrances would help direct customer flow, reducing the chances of a customer walking through the workstations to reach the spare parts section. With this in mind, this first alternative layout is a rather feasible and easy to implement facility redesign. Specifically, the opportunity cost of implementation would be only one fewer bike fixed by a volunteer. This value was calculated from the average time of a volunteer repairing a bike, which was four hours. Based on the client's experiences, a simply relocation of the parts are would take no more than four hours. If this first alternative layout design were to be implemented the reduced travel time for a worker working on a bike would be 71 hours per year, increasing revenue by \$1700 per year. The calculations for this are shown in Table 8 of the Appendix.

Figure 5 Alternative Layout #1

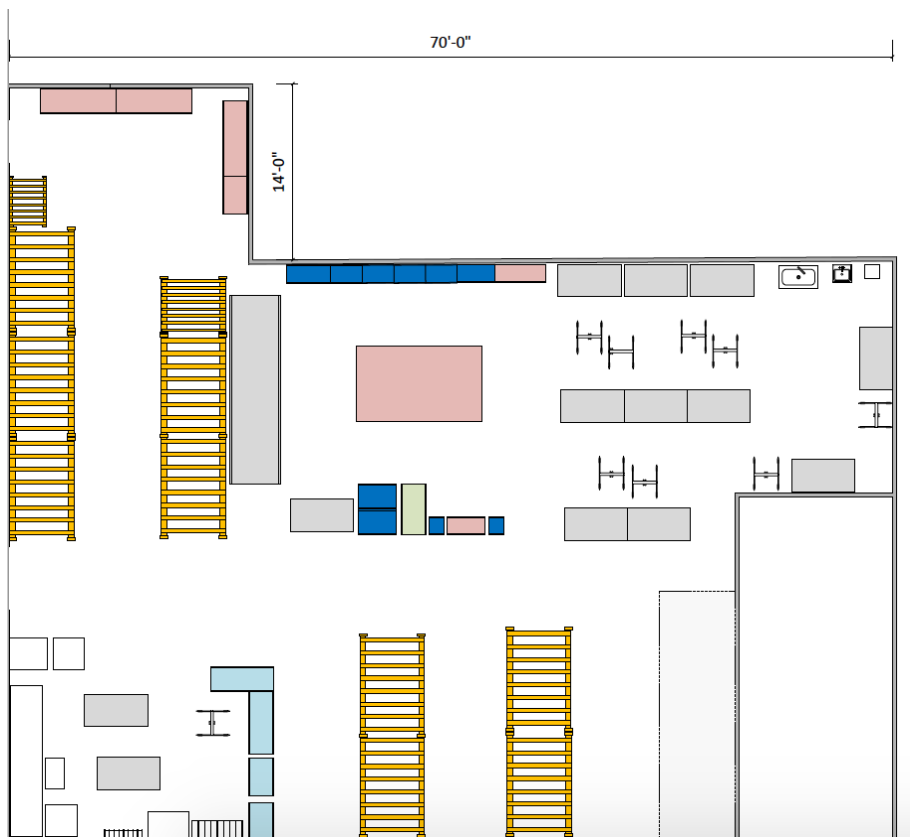


Alternative Layout #2:

The team also developed a second alternative layout in response to Good Karma Bike's consideration of pipelining the compressed air station down to the individual workstations. Based on our conducted online research, the team concluded that such a job would cost the company close to \$800. Therefore, this second alternative layout aims to avoid the cost of implementing a compressed air pipelined system by relocating the workstations to the current rest area location.

As seen in Figure 6, this facility redesign is less conservative and requires the major departments of the facility to be moved around. Because this second alternative layout varies greatly from the current state, the project team developed a 3D model in SketchUp (refer to Figure 15 in Section IV Methods). Based on the team's calculations, redesigning the facility to this second alternative layout would have an opportunity cost of implement of three bikes. This ambitious facility layout also involves moving the cabinets and shelves of parts to the middle of the facility, in order to keep it in proximity to the workstations, as there is a strong relationship between the two departments. In this design the orientation of the bike racks are rearranged to create a less awkward flow of bringing the bikes from the bike rack to the workstation. In terms of the classification of bike racks, the team decided that shop bikes (floor and customer bikes that generate revenue and will be placed in the front retail store) would be stored next to the main entrance. Compared to the current state facility, there is a decrease in the distance traveled when moving bikes into the retail store.

Figure 6 Alternative Layout #2



Alternative Layout #3:

The third alternative layout addresses the client's main concern of finding a solution that would improve the accessibility of bikes. In this alternative layout, the new bike rack designed by the team has been modeled in Solidworks and also physically built (refer to section New Bike Rack

Design). The physically built prototype was used to perform time studies to prove that this new bike rack design would decrease the time it takes to unrack the bikes, essentially improving the accessibility of bikes from the bike rack.

As shown in Figure 7, the new bike racks would be implemented in the similar facility layout as the current state facility. However, the main difference would be the orientation of the new bike racks. The team decided that a U-Shape orientation will improve the accessibility of the bikes even further. This is possible because the U-Shape creates an open space, allowing more space for a worker to unrack the bike and roll the bike out without hitting neighboring bikes. In the previous orientation, the bike racks were back to back, without enough room in between the rows to easily unrack and roll out the bike without hitting the bikes located on the opposing bike rack. From our time studies, this new bike rack would reduce the total bike unrack time from two and a half minutes to thirty seconds. The time studies and test methods will be further discussed in Section IV Methods.

In addition to improving the accessibility of bikes in this third alternative layout, the team also achieved increasing the space utilization of bike racks. In the current state facility layout, the revenue earning section of bike racks (upper middle of the facility), can hold up to 33 bikes without the handlebars touching or bikes laying on each other. With the new bike rack design, the bike capacity is increased to 45 bikes. Increasing the storage space of bikes within the same square footage solves the company's need of finding a solution to increase its space utilization.

The opportunity cost of implementing this third alternative layout would be ten fewer bikes fixed by volunteers, assuming that it would take them eight hours to assemble and build each bike rack. This alternative layout, as shown in Figure 7, would require five new bike racks, each with the capacity of nine bikes. The design of these bike racks, along with the methods in which the team would transfer the knowledge of building them is further discussed through the documentation of the Good Karma Bike Rack Guide. The cost of implementing this redesign would simply be the material and equipment cost for the bike racks, as volunteers would be the ones assembling the new bike racks. Therefore, the total implementation cost would be \$500 for the five new bike racks that would be placed in the bike storage section shown in Figure 7.

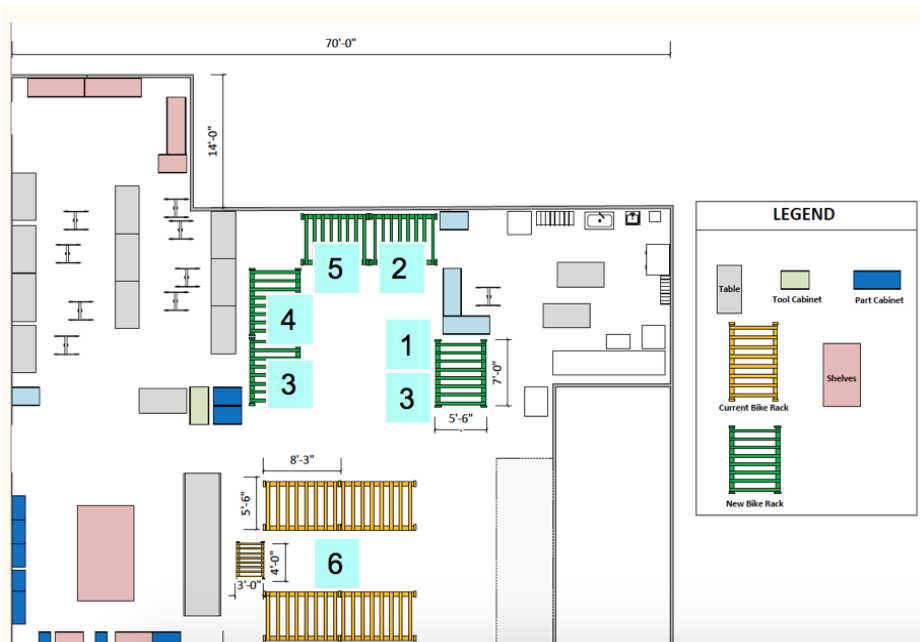
Table 4 below displays the numbers associated with the type of bike stored on the new bike racks. The placement of different types of bikes affects the ease of accessibility and overall workflow. For example, the inner corners of the U-Shape design where the number 4 and 5 are shown pose the potential of those bikes to interfere when unranking. The team decided to place the customer bikes that are ready for pickup on one side because those bikes would not be unracked often. This eliminates the hassle of unranking the quality check bikes stored at that inner corner of the U-Shape orientation. As stated previously, these new bike racks are designed

so the handlebars would not touch, essentially decreasing the time it takes to remove the bike and minimizing the chances of potential damage to surrounding bikes.

Table 4 Alternative Layout #3 Bike Rack Classification Legend

1	Staff
2	Service
3	Floor & Customer
4	Customer (Ready for Pickup)
5	Quality Check
6	Program & Donor

Figure 7 Alternative Layout #3



New Bike Rack Design:

The new design consists of staggering platforms to enable easy access for mechanics and volunteers to load and unload bikes on this rack. As shown in Figure 8, the elevated platforms allow for the handlebars to not impede onto the neighboring bike's space. Furthermore, these elevated platforms are at a four inch height difference from each other to ensure that the handlebars on the raised platforms do not touch or block the bike on the other raised platform

from being stored or unloaded. In addition, these raised platforms are slightly angled (10°) downhill towards the frame of the rack. Gravity causes the bikes to be pressed against the frame while the posts keep the bike inline. The dimensions and performance metrics of this new bike rack design can be seen in Table 5.

The materials used to produce the bike rack are easily obtainable because every part can be purchased at a local hardware store. More importantly, these materials can be easily manufactured that even a volunteer with limited hardware experience can build this bike rack on their own. The new design keeps the horizontal layout but increases the overall height to accommodate for the raised platforms. Increasing the size of the rack vertically does not hinder the amount of space available in the warehouse as the roof of the building is about ten times taller than this new height for the rack. To decrease the amount of space consumption, the length was shortened by a little over a foot long. Even with the decrease in length, the bike rack can hold nine bikes comfortably within their slots as the post are gapped by at least three inches. Overall, this new design for a bike rack can be easily implemented within the warehouse and can be applicable for displaying bikes in the retail store.

Figure 8 New Bike Rack Solidworks Design

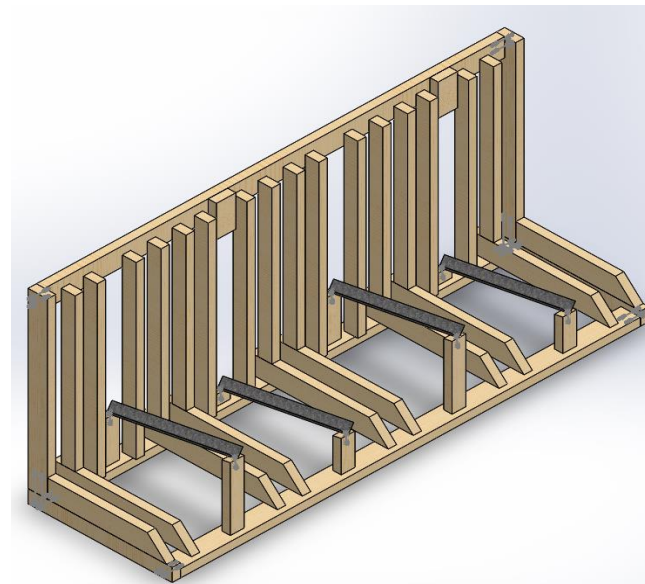


Table 5 New Bike Rack Dimensions and Performance Metrics

Dimensions	
Height	35.5"
Width	26"
Length	86"

Performance Metrics	
Sq Ft (bikes included)	38.5'
Bike Capacity	9 Bikes

Good Karma Bike Rack Guide (See Appendix D):

Figure 9 List of Mandatory Materials

- 2"x4" 96" Whitewood (7)
- #10 x 2-1/2" Wood Screws (12)
- 2"x3" 96" Whitewood (7)
- #10 x 1-1/2" Sheet Metal Screws (8)
- 2"x2" Roof Edge Galvanized Steel (2)
- #8 x 5" Wood Screws (4)
- Gorilla Glue (1)

In order to make the bike rack plausible, these are the minimum quantities for each required material based off the dimensions of each part. Having a set list of materials required for a design makes replication simplistic and easier for the company to buy in bulk. When materials are bought in bulk, discounts are given to the buyer, ultimately saving the company money. In addition, all of these materials can be bought in one location and are highly accessible.

Figure 10 List of Required Equipment

- Steel Shear



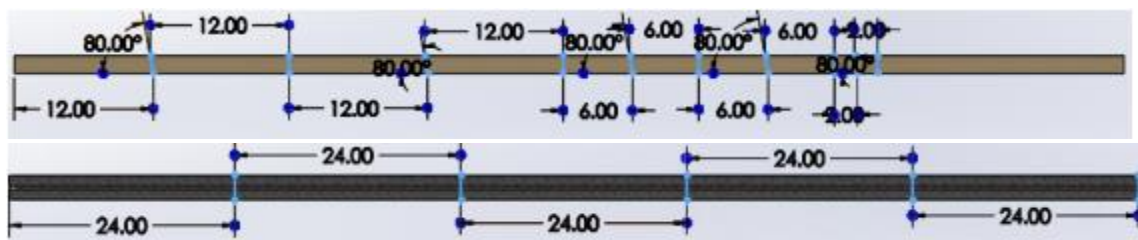
- Power Drill



The bike guide lists all the necessary equipment in order to complete the new design. Pictures are included in the document for volunteers who are not familiar with using hardware tools.

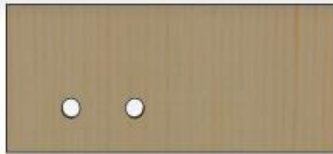
Therefore, a volunteer can easily identify the proper tool to use during the assembly of the racks through referencing the picture. The only specialty tool that is required for the job is a compound miter saw in order to cut angles for the raiser.

Figure 11 Cut Diagrams



To ensure the right dimensions are being cut for each part, it is important for the builder to draw cut lines to identify the proper location for a cut. Figure 11 displays where the lines are located on a stock material and label any angles that need to be cut. Lastly, the cut diagrams show how each piece of purchased material is being used for specific parts. Therefore, there are no extra materials being purchased.

Figure 12 Assembly Procedures



2) With a power drill, drill two holes 1.25" apart from each other at a height of .75" from the ground up with a drill bit that is a smaller diameter size of the #10 x 2-1/2" wood screw. Repeat for each corner of the frame.



3) With a power drill, screw the #10 x 2-1/2" wood screws into the already drilled holes. Repeat for each corner of the frame.



4) Like the base frame, lay the top plank (83" length) on the ground with the two side frame planks (33" length) and glue together to form the top frame of the bike rack.

5) Repeat steps 2 & 3 for inserting the screws into the top frame making for extra security.

Figure 12 above shows the proper step-by-step instructions provided in the bike guide on how to assemble the newly designed bike rack. Each step is equipped with a picture for the builder to reference in order to minimize any confusion while assembling the parts together. In addition, tools and part names are referenced in the assembly instructions. The tools are identified in the Equipment Required section and the names of the parts are provided by a bill of materials next to an exploded view of the new bike rack design at the beginning of the Assembling Bike Rack Procedure section. Therefore, the builder can clearly decipher the instructions, resulting in minimal errors and redoes.

New Bike Rack Storage Process within Bike Rack Guide:

In order to maximize the efficiency of the new bike rack design, Good Karma Bike's employees and volunteers must change their bike storing ways and comply with the following storage process laid out in Figure 13. Currently, bikes are being jammed in any available open gap causing handlebars to scrape frames and tangle with neighboring bikes. The following process limits these problematic occurrences and provides a smooth transition of a bike being on a rack to off a rack and vice versa. Alternating pedals prevent the pedals from latching onto any nearby bike's pedal or spokes. Storing wide handlebar bikes on the ground eliminates the tangling of handlebars upon retrieval. Having the bikes on the ground be stored rear-wheel first allows a bike to be easily squeezed in between two existing stored bikes without any hassle with handlebars. To unload a specific bike, the gaps holding the bike in place create extra room to lean over neighboring bikes in order to form a wide gap for a bike to go through. Simply lifting the front wheel of the bike by grabbing the stem to take the bike out would prevent a bundling of handlebars and scraping of frames.

Figure 13 New Bike Rack Storage Process

Storing

**Bike Stored On Ground Level
Go Rear Wheel In First**



Store Wide Handlebar Bikes on Ground



Alternate Pedals



Unracking

Create Gap To Un-Rack Middle Bike



Fully Lift Bike Out

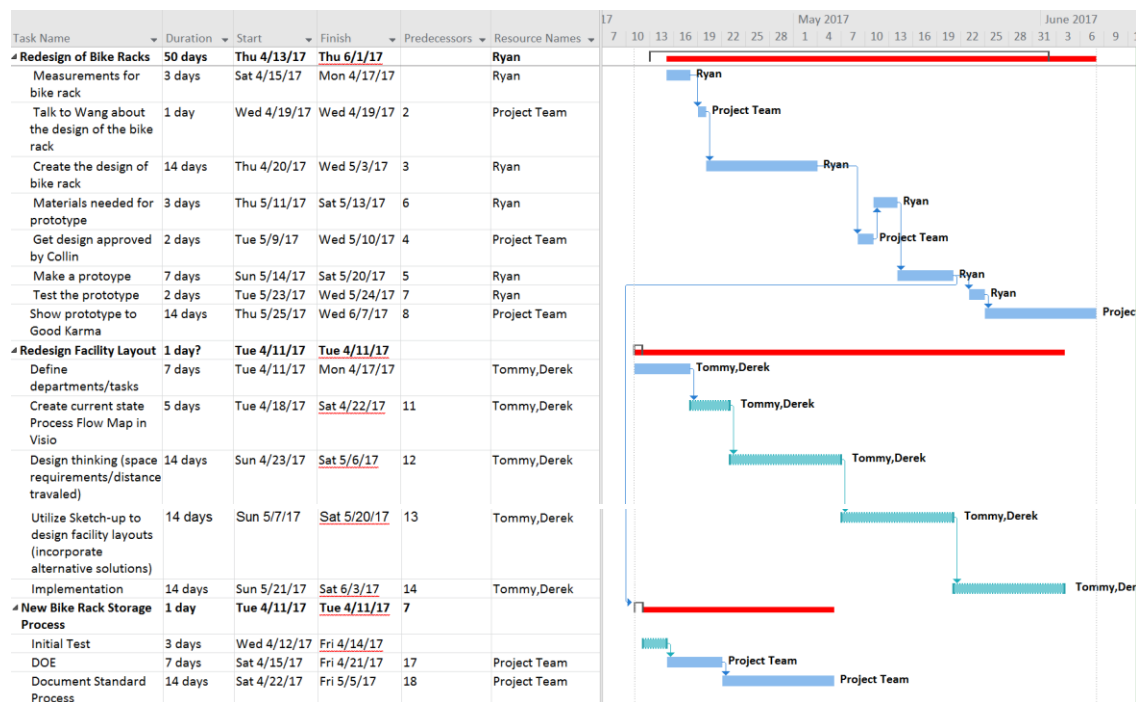


IV. Methods

Microsoft Project:

At the initial stages of the project, the team decided to develop a Gantt Chart to help keep us accountable to the project deliverables. By assigning weekly deadlines, the team was able to continuously push the project forward towards solutions that would resolve our client's needs and issues. As seen in Figure 14, Microsoft Project made it simple for team members to know what action items are in need of completion and when they should be completed. Using the tool allowed our team to function accordingly, minimizing the risk of miscommunication regarding the project deliverables.

Figure 14 Gantt Chart



Microsoft Visio:

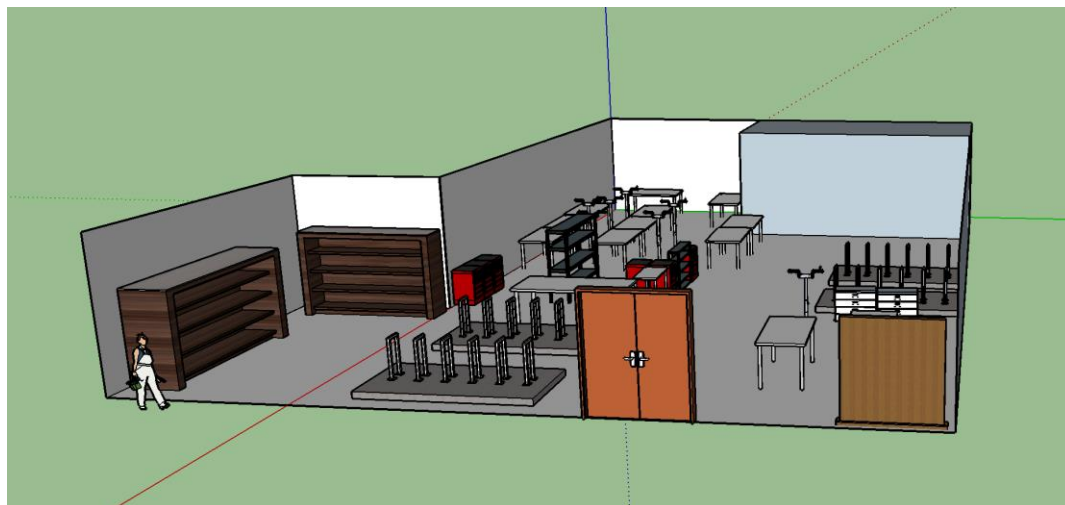
Microsoft Visio was used to develop the alternative facility layouts. As seen in Section III Design, this tool was vital in the creation of the three different alternative layouts. Using the dimensions our team measured within the facility, we were able to input the actual dimensions for the facility space, workstations, cabinets, tables, bike racks, etc. into Visio. By doing so, the team was able to create alternative layouts that were properly scaled. Therefore, the changes implemented in the alternative layouts accounted for the proper dimensions and space requirements. Additionally, Visio works well as a visual tool, showing the orientation and

location of the various objects placed in the facility. This allows for the creation of proper pathways and spacing for the desired flow of operations.

SketchUp:

SketchUp provides a realistic visualization of the facility through its 3D modeling capabilities. The team utilized this tool for the second alternative layout (refer to Figure 15), as it was the most different from the current state facility. By doing so, the client was able to properly visualize our recommendations and changes made in this second alternative layout design. Without this tool, key details such as space requirements for the flow of employee movements may be overlooked. Specifically, because this alternative facility design moved the workstation department to a different location, the SketchUp model with the correct dimensions allows the team and client to see if relocation was actually feasible. Overall, this tool allowed us to provide a better visual representation of the drastic changes displayed in the second alternative layout design to the client.

Figure 15 SketchUp for Alternative Layout #2



Solidworks:

This 3-D modeling software was used to bring the bike rack design to life. Given specific dimensions, Solidworks generated a visual of each individual part and arranged all of the parts in a way to see the final bike rack assembly before any production. Furthermore, the software created an engineering drawing consisting of a labeled exploded view and a bill of materials listing the name of the parts, location, and quantity. The simplicity and capability of the program puts an engineering designer's vision into a reality.

Prototype Testing:

Throughout the build process the prototype opened up the flaws in the original designs, forcing us to create alterations from the original idea. The evolution of the bike rack design can be seen in Figure 16 displayed below. At first, the rack was supposed to fit as many bikes as possible within the current state rack's length. The gaps in between the bikes were too narrow, making the pedal gaps the change in the design. Additionally, the poles were angled, causing the forks to hit them, resulting in the bike to topple over. Changing the pole to a simple vertical direction concludes the alterations made to the design while testing. The finished bike rack, painted in Good Karma Bikes company colors, is portrayed in Figure 17.

Figure 16 Evolution of Bike Rack Design

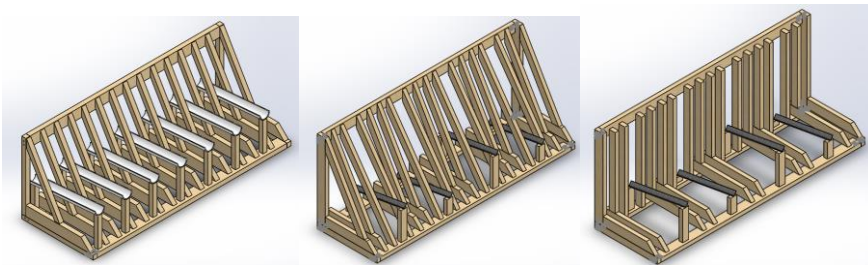


Figure 17 Finished Bike Rack Prototype



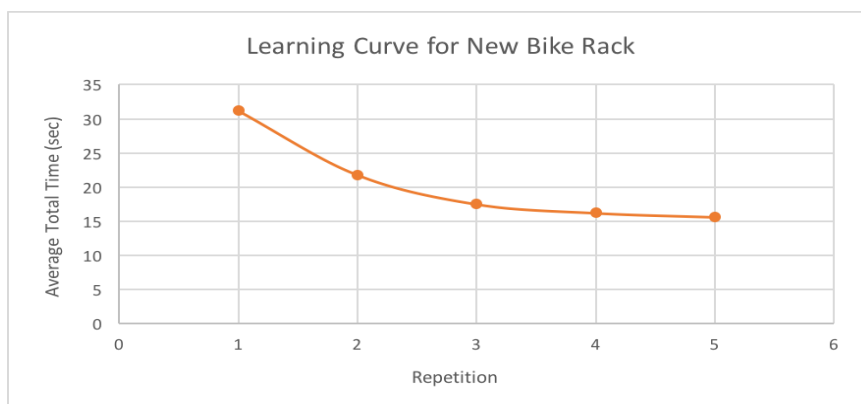
Time Studies and Learning Curve:

After the construction of the prototype bike rack, the project team performed time studies to quantify the improvements made for bike accessibility. The goal of these time studies was to produce a learning curve, effectively showing potential for additional time savings as workers familiarize using the new bike racks. The team set the bikes up as shown in Figure 18 to perform both unrack and load motions. Time studies were then gathered from five samples, who were friends of the project team who have never used the bike rack before. Each sample did five repetitions of unranking and racking the bikes on randomly assigned bikes. The averages of their total time were taken and the learning curve shown in Figure 19 was graphed.

Figure 18 Bike Rack Setup for Time Studies



Figure 19 Learning Curve for Bike Rack Process



V. Results

Alternative Facility Layouts Findings:

The first alternative layout leads to a reduction of 13 feet in traveled distance for a worker walking from a workstation to retrieve bike parts from the parts department. This results in 71 hours of travel time reduced per year, which translates to a \$1700 increase in revenue. Although this decreases the travel distance, moving the parts to the upper left portion of the facility poses safety issues regarding customers walking through the workstations to find used bike parts to purchase. However, as stated previously, the team will mitigate this risk by clarifying that the second entrance at the top left of the facility to be used for customers potentially looking to purchase used bike parts. The second alternative layout provides a way for workers to repair bikes closer to the air compress station. This layout relocates the workstation to the current rest area to avoid the costs associated with pipelining the compressed air station. As mentioned previously, this alternative layout requires major departments of the facility to be relocated. Finally, the third alternative layout implements the new bike racks designed by the team. These bike racks would hold bikes that generate revenue for the company, such as the staff, service, shop, and quality bikes. The current state facility has a max bike capacity of 33 bikes if they were placed so the handles don't touch. In this third alternative layout design, the five new bike racks would replace those original bike racks in a U-Shape orientation, increasing the overall bike capacity to 45 bikes with a reduction of two minutes for the accessibility of the bikes. A summary of the performance metrics, financial benefits, and opportunity cost of implementation for the three alternative layouts are shown in Table 6 below.

Table 6 Summarized Comparison for Alternative Layouts

	Alternative Layout #1	Alternative Layout #2	Alternative Layout #3
Performance Metrics	<i>Distance Traveled:</i> Decreased to 20 ft from workstation to cabinet Travel time reduced: 71 hours per year	N/A	Space Utilization: Improved from 33 bikes to 45 bikes Productivity: Improved by decreasing rack time from 2.5 mins to 30 secs

Financial Benefits	Increase revenue by: \$1700 per year	Cost savings: Compressed air piping system \$799	Low Implementation Cost: Material Cost: \$275 Equipment Cost: \$200
Opportunity Cost for Implementation	1 fewer bike fixed by volunteer	3 fewer bikes fixed by volunteer	10 fewer bikes fixed by volunteer (assumed 8 hours to assemble a new bike rack)

Multi-Criteria Decision Analysis:

The team created a Multi-Criteria Decision Analysis (MCDA), shown in Figure 20, to choose an alternative layout based on what the client finds important. Based on the concerns our client voiced, the team assigned weights the criterias appropriately. As shown, the criteria space impact and accessibility were weighted the highest at 5 to represent the two most important criterias. As industrial engineers who aim to eliminate non-value added activities such as wasted motion, the team would have liked to also heavily weigh the distance traveled criteria. However, based on feedback from the client and discussions from mechanics and volunteers, they do not mind the amount of distance they typical travel around the current state facility. Therefore, the team assigned this criteria with a weight of 3. The ease of implementation is rather important to changing around a layout because the simpler the task, the lower the opportunity cost and the less labor force and required time they would need to perform the changeover.

After scoring each individual alternative layout on the criterias, the team concluded that the third alternative layout would be the best option for a facility redesign of Good Karma Bikes. This makes sense because the changeover for this third alternative layout is minimal, as the facility redesign requires only the implementation of the five new bike racks. These new bike racks are rather inexpensive to make at \$60 per rack. Additionally with the bike rack guide provided by the team, the process of assembling and building the new bike racks should not be too difficult and time consuming. With the simple implementation of this third alternative facility layout, Good Karma Bikes can achieve an increase in space utilization of bikes in addition to improving the accessibility of the bikes.

Figure 20 Multi-Criteria Decision Analysis

Decision Factors		Layout #1	Layout #2	Layout #3
Criteria	Wt.	1	2	3
Ease of Implementation	4.0	5	3	4
Cost of Implementation	3.0	4	5	3
Space Impact	5.0	3	3	4
Distance Travelled	3.0	4	5	3
Accessability	5.0	3	4	5
Weighted Scores		74.0	77.0	79.0

Cost Analysis Results:

Material Cost

- (7) 2"x4" 96" Whitewood (\$3.16ea)
- (12) #10 x 2-1/2" Wood Screws (\$.18ea)
- (7) 2"x3" 96" Whitewood (\$2.21ea)
- (8) #10 x 1-1/2" Sheet Metal Screws (\$.16ea)
- (2) 2"x2" Roof Edge Galvanized (\$4.91ea)
- (4) #8 x 5" Wood Screws (\$.20ea)
- (1) Gorilla Glue (\$7.97)

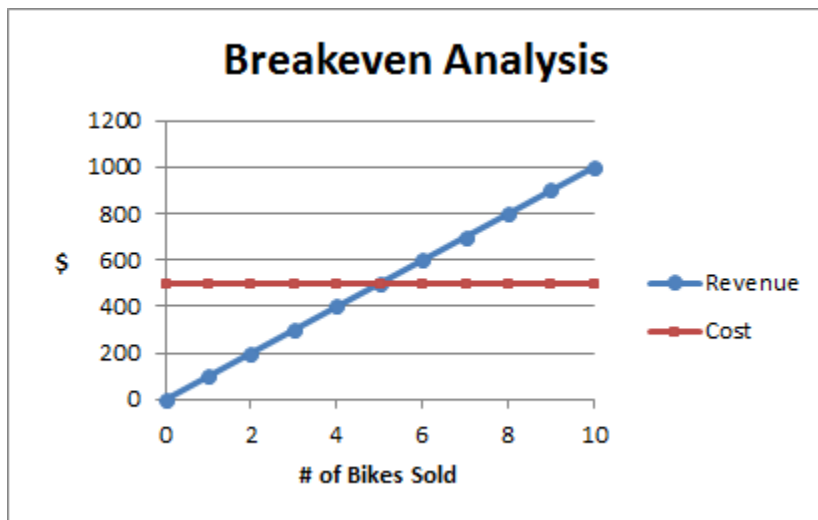
Total Cost of Bike Rack = \$60

Equipment Cost

- Cheap Compound Miter Saw (\$100)
- Steel Shears (\$60)
- Power Drill (\$40)
- Total Equipment Cost= \$200**

The breakpoint period to build 5 bike racks were to sell 5 bikes as Good Karma Bikes made a commission of about \$100 per bike sold. This is shown in the graph displayed in Figure 21 below.

Figure 21 Breakeven Analysis for 5 Bike Racks



As shown in Figure 22, the assumptions made when calculating the financial impact of the new bike racks. Based on the data provided by the client, the average number of bikes sold in a month is 60 and the cycle time is 4 hours. The number of times each bike gets unracked is 4 times. Finally, the average profit for each bike that Good Karma Bikes sells is \$100.

Based on the mock time studies completed by the team, the time saved each time when unracking a bike is 2 minutes. Therefore, total time saved is $60 \times 4 \times 2 = 480$ minutes per month, which is 8 hours. This is equivalent to the cycle time for 2 bikes, which translates to \$200 increase in revenue per month and \$2400 per year.

Figure 22 Increased Revenue with New Bike Racks

Assumptions:			
# of bikes per month	60	Cycle time per bike (hrs)	4
# of times unrack	4	Profit per bike	\$ 100.0
Time saved (minutes)	2	Increased throughput (# of bikes)	2
Total time saved per month (min)	480	Increased Revenue per month	\$ 200.0
Total time saved per month (hrs)	8	Increased Revenue per year	\$ 2,400.0

VI. Conclusion

Good Karma Bikes presented a problem to the project team concerning their storage capacity within the warehouse. The project's problem statement is as follows: Due to a recent increase in customers, GKB is forcing each incoming bike into any open space in a rack due to limited capacity. Limited space between bikes causes difficulty with moving the bikes in and out of the racks. In addition, volunteers and mechanics have to repeatedly retrieve parts and tools, wasting value added service time. Both of these situations inhibit productivity and decrease bike throughput entering the retail store. The team's main objective was to reduce the total production time of servicing the bikes to increase throughput of bike reaching the retail store in order to meet a future increase in demand. In order to accomplish this, the objectives were to perform time studies, conduct a facility redesign, and analyze the workflow process in order to come up with suggested implementations. Throughout the project, the team followed a Gantt Chart to complete tasks on time and used many Industrial Engineering tools. Halfway through the project duration, the team was informed that the warehouse layout was already rearranged forcing us to quickly change our current state. The project team took multiple visits to the warehouse floor in order to fully understand the bike service process of the customer, donation, and programmed bikes. While there, the project team took time studies of the assembly process, gained knowledge of the process from the mechanics, and noted many areas in need of improvement. Through the analysis phase of the project, the team used SketchUp software and Microsoft Visio to model a facility redesign and Solidworks to model an ideal bike rack to expand their capacity to meet the future demand. The project team came up with multiple suggestions in conclusion:

- Build 5 of the new bike racks
- Arrange the bike racks in a U-shape pattern

Throughout the project, the team learned a great deal through a hands-on experience working with a local company. The team encountered an unforeseen obstacle and learned how to change direction quickly and handle the new situation presented. For the project team, visiting the facility and having a hands on experience within the workplace was very beneficial in understanding the whole process from the incoming bike to the repaired finished product. During the visits, interaction with the workers provided inside knowledge that helped direct the project to where the most improvements could be made. The project team learned how to take the data collected and use it in SketchUp and Visio layouts in order to design a new ideal state for the company. Next time, the team would like to have collected more data earlier on in the process. The sooner the data collection began, the more our performance metrics would portray the improvements made by our designs. Overall, working with Good Karma Bikes was a pleasure and our team hopes to see our designs be implemented in the near future.

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APPENDICES

Appendix A. Bike Rack Designs

Figure 23 Smith Bicycle Parking and Storage Rack

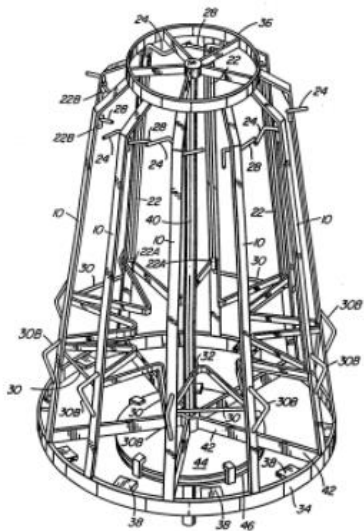
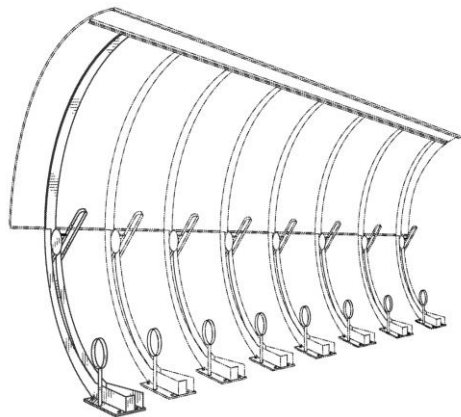


Figure 24 Selzer and Bellomo Arc Shaped Bike Rack



Appendix B. Time Studies

Table 7 Learning Curve for New Bike Rack

Repetition	Average time (secs)
1	31.2
2	21.8

3	17.5
4	16.2
5	15.6

Appendix C. Financial Impact

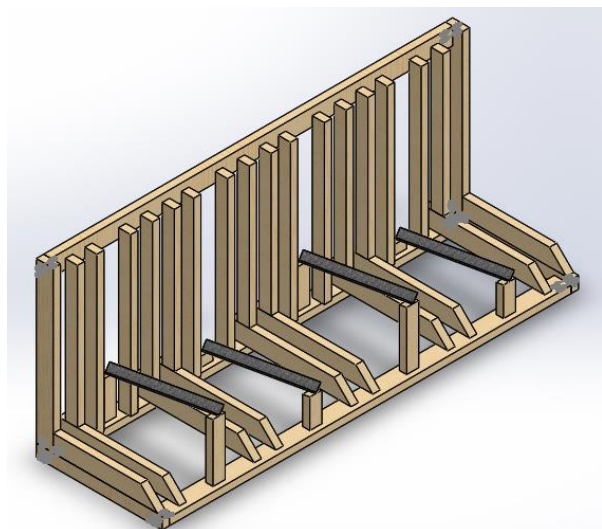
Table 8 Alternative #1

Distance saved per trip × # of times traveled ÷ # of hours observed	$40 \times 5 \div 2 = 100$ (ft) - Distance saved per hour
Working hours per week × Efficiency × # of Staff and Volunteers	$30 \times 0.8 \times 6 = 14400$ (ft) = 2.73 (mi) - Distance reduced per week (mi)
Distance reduced per week (mi) ÷ 2 (mph)	$2.73 \div 2 = 1.36$ (hrs) - Time saved per week
Time saved per week (hrs) × 52	$1.36 \times 52 = 70.91$ (hrs)
Time saved per year ÷ Cycle time per bike	$70.91 \div 4 = 17.72 \approx 18$ (bikes)
# of bikes × Profit per bike	$17.72 \times \$100 = \$1772 \approx \$1800$

Appendix D. Good Karma Bike Rack Guide



Good Karma Bike Rack Guide



Materials Required: (Quantity)

- 2"x4" 96" Whitewood (7)
- #10 x 2-1/2" Wood Screws (12)
- 2"x3" 96" Whitewood (7)
- #10 x 1-1/2" Sheet Metal Screws (8)
- 2"x2" Roof Edge Galvanized Steel (2)
- #8 x 5" Wood Screws (4)
- Gorilla Glue (1)

With Paint:

- 2 for 1 Paint & Primer Gloss White Spray Paint (3)
- 2 for 1 Paint & Primer Gloss Green Spray Paint (2)
- Blue Painter's Tape (1)

Equipment Required:

- Cheap Compound Miter Saw



- Steel Shear

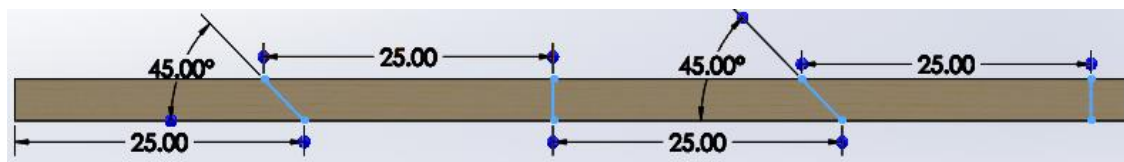
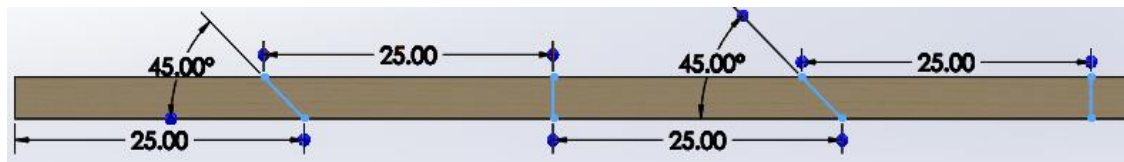
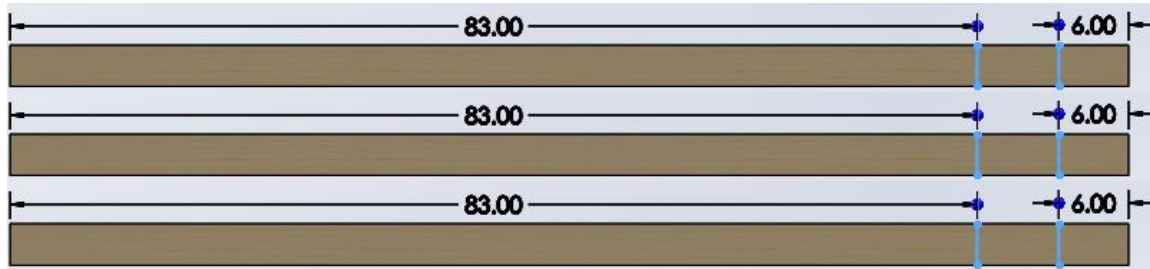


- Power Drill



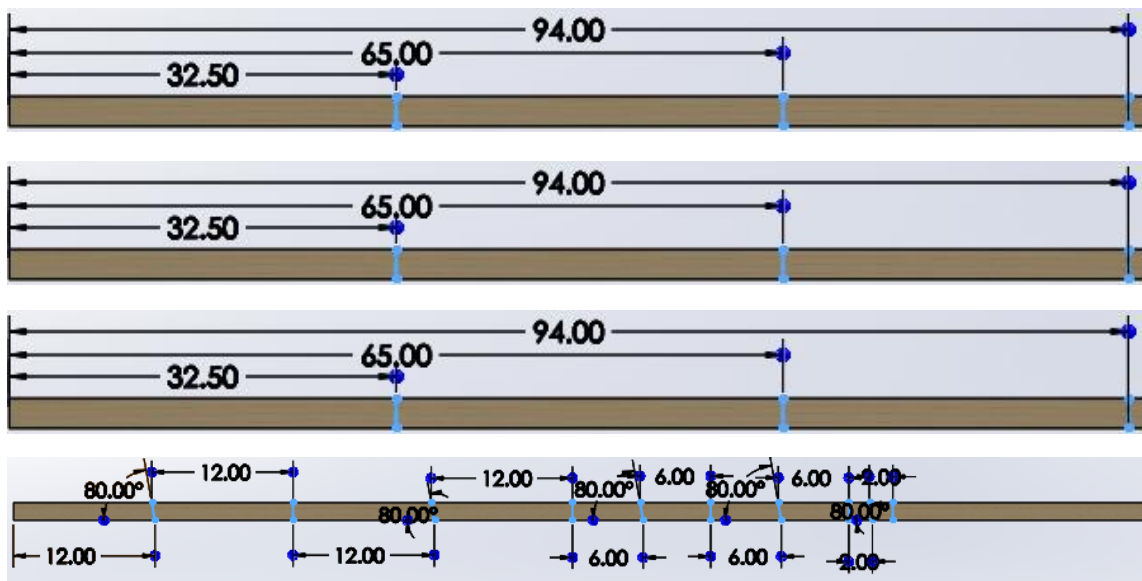
Cut Diagram: (Compound Saw = Wood, Steel Shear = Metal)

- 2"x4" 96" Whitewood (7)

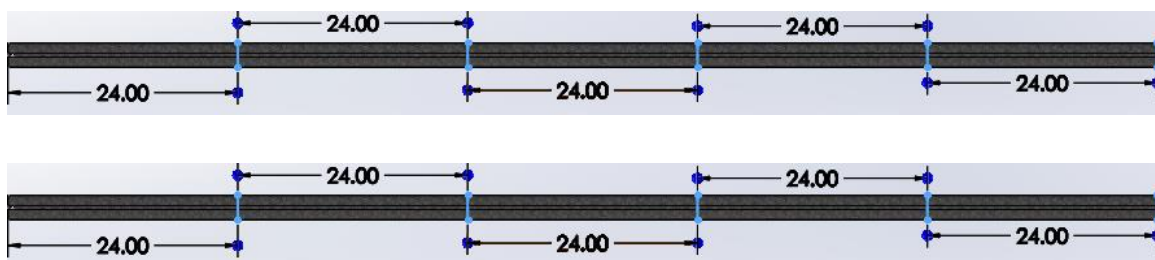


- 2"x3" 96" Whitewood (7) *Angle cuts are the 2" side





- 2"x2" Roof Edge Galvanized Steel (2) *Length about 121"



Assembling Bike Rack Procedure: *Sand & Paint parts before assembly

Engineering Drawing Identifying the Name and Quantity of Parts

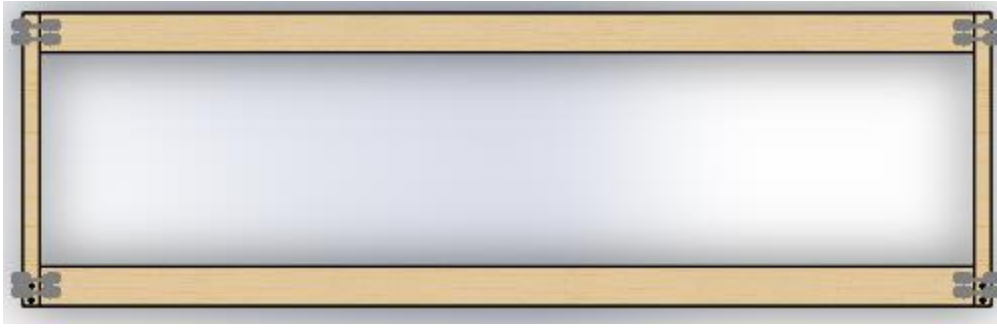
ITEM NO.	DESCRIPTION	QTY.
1	BASE PLANK	2
2	TOP & BOTTOM PLANK	2
3	PHILLIPS #10X2-1/2" WOOD SCREW	12
4	GROUND POST	8
5	ROOF EDGE GALVANIZED 2x2"	4
6	TALL RAISER	2
7	LOWER TALL RAISER	2
8	SMALL RAISER	2
9	LOWER SMALL RAISER	2
10	SIDE FRAME PLANK	2
11	TOP PLANK	1
12	END POST	2
13	LONG POLE	8
14	SHORT POLE	8
15	PHILLIPS #10 1-1/2" SHEET METAL SCREW	8
16	SPACER	2
17	PHILLIPS #10X5" WOOD SCREW	4

UNLESS OTHERWISE SPECIFIED:
 DIMENSIONS ARE IN INCHES
 FINISHES:
 FRA-CRIP HAZ 15"
 FIBER PLASTIC FORMAL 101
 FIBER PLASTIC FORMAL 1000

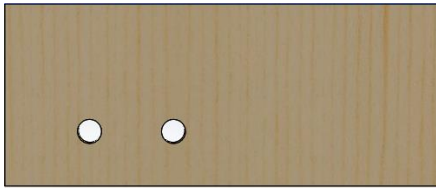
DATE: 5/23/17

CAL POLY
 SAN LUIS OBISPO

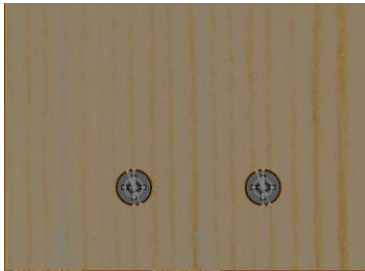
MATERIAL: WHITE WOOD
 DRAWN BY: RYAN OGAN
 TITLE: BIKE RACK FOR GOOD KARMA BIKES
 DATE: 5/23/17
 SHEET 1 OF 1
 SCALE: 1/8" = 1'-0"
 REV: SEE A



1) Laying the pieces of wood on the ground, form a rectangular base by gluing the top & bottom planks (83" length) to the corner of the 3" side of the base plank (26" length). Wait about 15 minutes to have the glue set.



2) With a power drill, drill two holes 1.25" apart from each other at a height of .75" from the ground up with a drill bit that is a smaller diameter size of the #10 x 2-1/2" wood screw. Repeat for each corner of the frame.

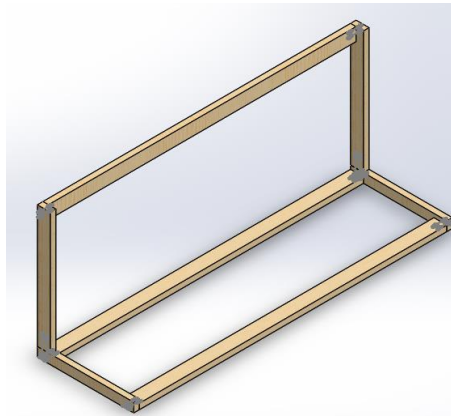


3) With a power drill, screw the #10 x 2-1/2" wood screws into the already drilled holes. Repeat for each corner of the frame.



4) Like the base frame, lay the top plank (83" length) on the ground with the two side frame planks (33" length) and glue together to form the top frame of the bike rack.

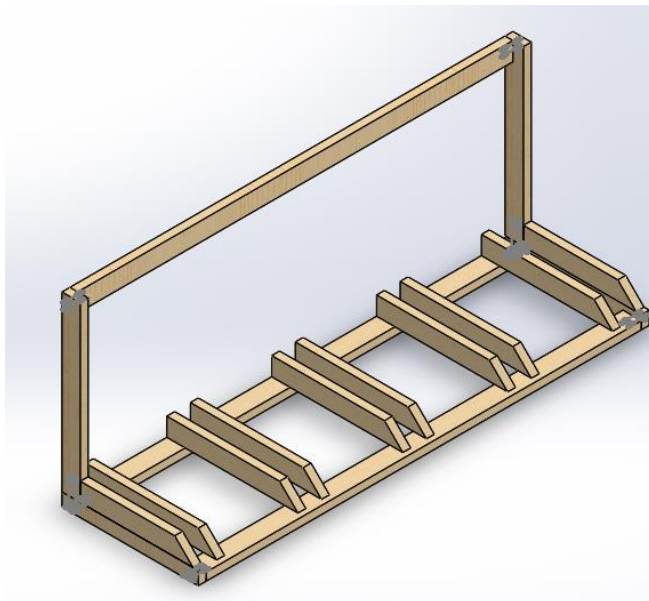
5) Repeat steps 2 & 3 for inserting the screws into the top frame making for extra security.



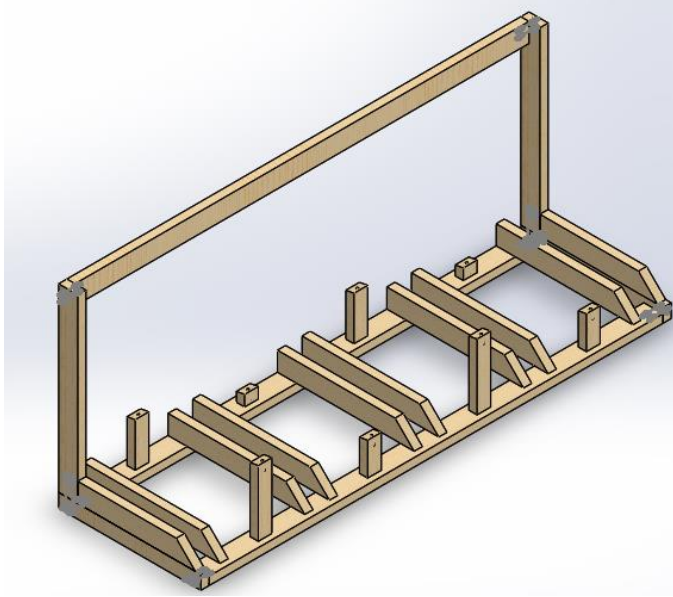
6) To attach the top frame to the bottom frame, glue the top frame to the corner of the bottom frame as shown above. Let the glue sit for 30 minutes or until it is secure before continuing.



7) Carefully lay the top frame over to the ground and drill two holes in between the previous wood screws with a drill bit that is a smaller diameter size of the #8 x 5" wood screw as seen above.

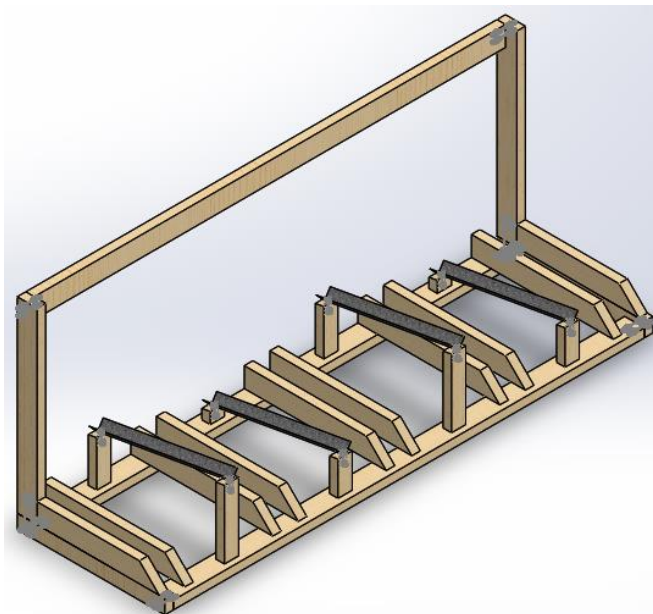


8) Glue the ground posts (25" length) and the end posts (21.50" length) to the base of the frame. The two end posts go on the end of the frame whereas the ground posts are spaced out periodically. The small gaps are 3" wide and the large gaps are 14" wide.



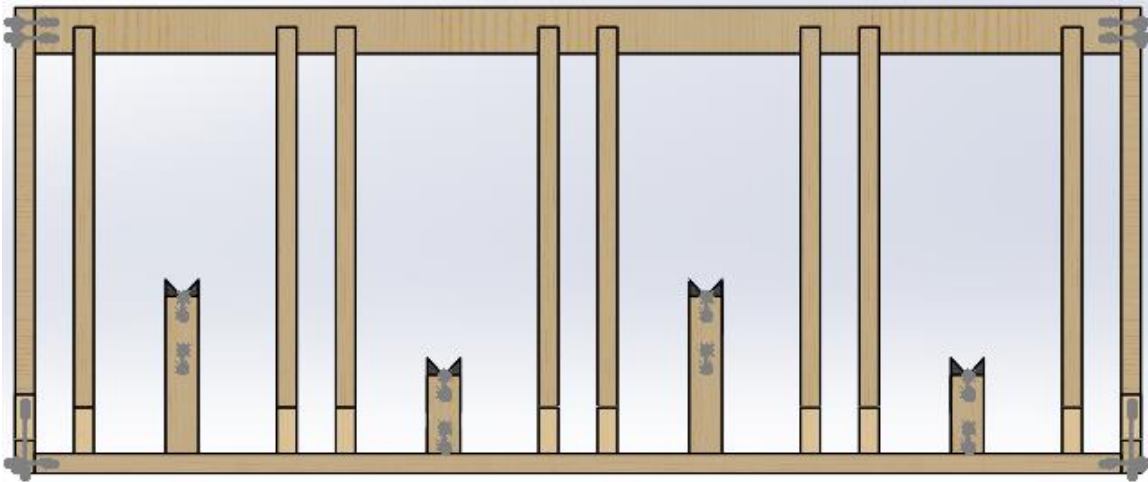
9) Glue down the raisers in the middle of the 14" gaps and an inch off the outside edge of the bottom frame. Make sure that the angled slopes are going downhill towards the top frame. The raisers are paired up like 12" with 6" and 8" with 2". The first dimension being the furthest away from the top frame.

10) Glue two of the 24" roof edge galvanized steel together for extra strength

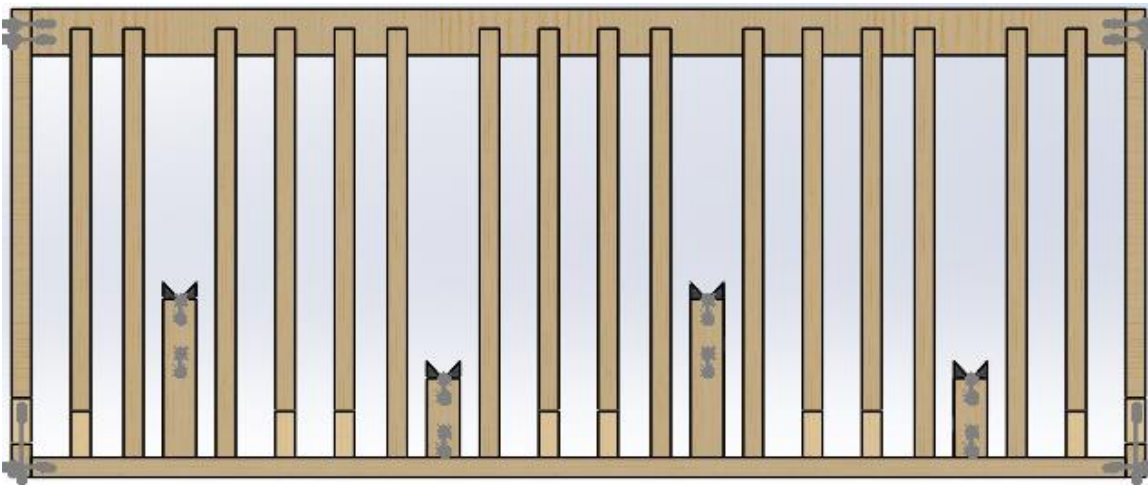


11) Place the reinforced roof edge galvanized steel on the raiser. Then drill a hole with a smaller diameter than the #10 x 1-1/2" sheet metal screw and an inch from the edge of the raiser.

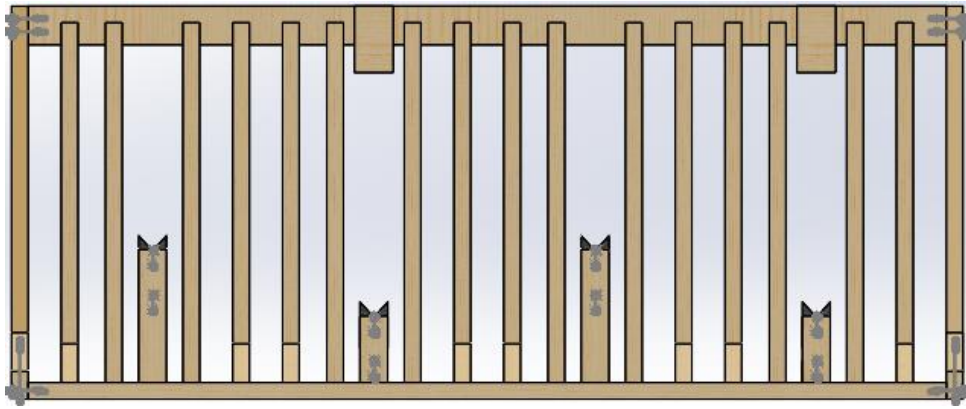
Afterwards, use a power drill to screw in the sheet metal screws on both ends of the roof edge galvanized steel.



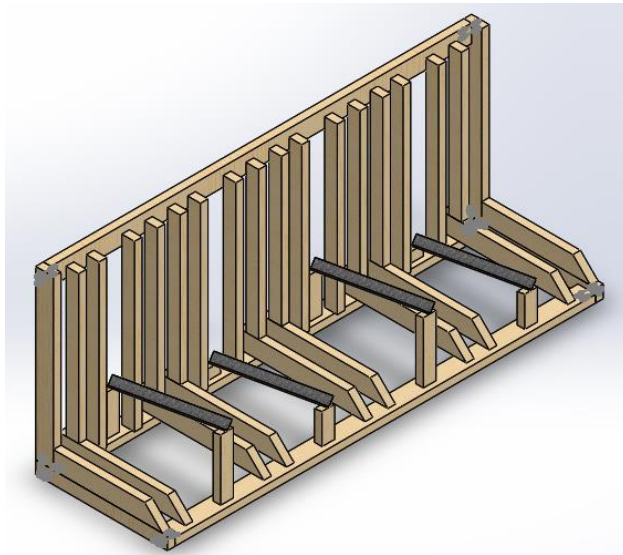
12) Glue the short poles (29") on top of the ground post as shown above.



13) The long poles are separated .5" away from the risers on both sides. The long poles are glued to the top plank and the base plank. The best way to have the right dimension is to find the widest bike tire and place it on the platform in order to have the poles snug against it.



14) Line up the 6" blocks at the edge of the top of the poles and glue them onto the top plank in between the poles of the small raisers (8 1/2" combination). Location is shown above.

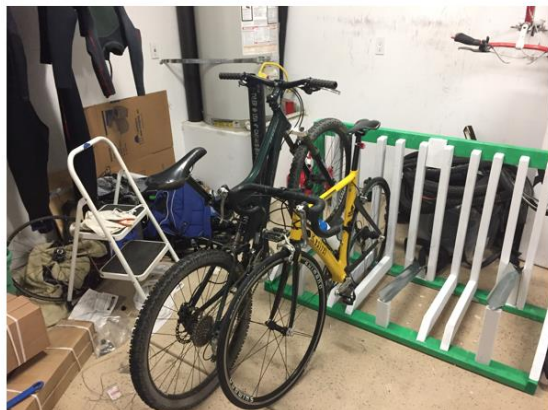


15) Scrap off any excess glue showing on the rack with a knife or scrapper and the bike rack is complete

Bike Storage Procedure:

Storing

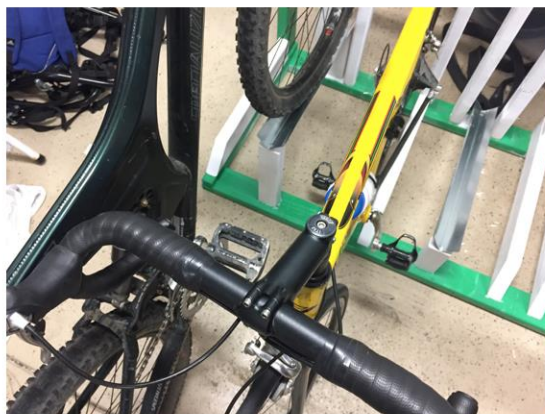
**Bike Stored On Ground Level
Go Rear Wheel In First**



Store Wide Handlebar Bikes on Ground



Alternate Pedals



Unracking

Create Gap To Un-Rack Middle Bike



Fully Lift Bike Out

