Doosan Bobcat ZT2 Workstation 13 Process Improvement Final Report

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Executive Summary

The Doosan Bobcat ZT2 Workstation 13 process improvement project aimed to enhance efficiency and ergonomics within the tire installation workstation of the ZT2 assembly line at the Johnson Creek, WI facility. Utilizing the PDCA (Plan-Do-Check-Act) methodology, the project team focused on reducing non-value-added (NVA) waste and addressing operator ergonomics. Key analyses, such as SIPOC, spaghetti diagrams, and root cause assessments, revealed inefficiencies in workspace organization and communication, along with opportunities for ergonomic enhancement.

The proposed solutions were divided into two main categories: workstation organization and ergonomic improvements. Workstation recommendations include enhancing the current 5S practices, introducing daily operator checklists, reorganizing material holding areas, designating specific places for all tools and materials, and implementing visual aids for organization. For ergonomics, solutions such as installing spring-loaded pallets, using pneumatic lift carts, restructuring the current assembly steps for tire installation to be first, and requiring a height adjustment of the current tire pallet were identified and prioritized based on feasibility, cost, and expected impact. The MOST (Maynard's Operation Sequence Technique) analysis revealed that implementing all organizational solutions, rearranging the work instruction steps, and using a spring-loaded pallet was the optimal choice, offering a cycle time reduction of 26.88 seconds (7.83% improvement), an efficiency gain of 7.83% (1-2 unit throughput increase), while minimizing physical strain on operators.

Cost-benefit analysis highlighted the financial viability of the recommendations. For instance, the spring-loaded pallet, with an initial investment of $4,000, is projected to deliver a net gain of $1,988 over ten years through reduced labor costs and enhanced operator safety. To sustain these improvements, the team proposed regular audits, operator training, and enhanced communication strategies, ensuring long-term adherence to new processes. Overall, the project emphasizes the value of implementing incremental changes in fostering lean manufacturing and continuous improvement, reducing operator fatigue, and achieving cost savings for Doosan Bobcat Inc..

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1.0 Problem Definition

1.1 Company Overview

Doosan Bobcat Inc. is a global leader in equipment manufacturing and innovation that was founded in 1947. The company designs, manufactures, and distributes a wide range of company construction equipment, landscaping, and agricultural machinery. Some of their key products include skid-steer loaders, excavators, and zero-turn mowers. One of Doosan Bobcat's manufacturing sites is located in Johnson Creek, WI which is the specific site that our team was working with. At this location, our team focused solely on the tire installation workstation on the ZT2 assembly line.

1.2 Project Motivation

The motivation behind this project was to address efficiency in the ZT2 sub-assembly tire installation workstation to foster continuous improvement towards lean manufacturing. The area of focus for this project was mainly ergonomic improvements related to tire installation and NVA waste reduction. Significant emphasis was placed on implementing small, incremental changes that lead to collective long term improvements.

1.3 Project AIM

The goal of this project was to reduce non-value-added waste in the Bobcat ZT2 mower sub-assembly tire installation workstation by up to 30 minutes per shift through a PDCA methodology to improve overall efficiency and reduce costs. This goal will be achieved by looking at both the ergonomics of the tire installation and the organizational layout of the workstation.

2.0 Project Management

2.1 PDCA Methodology

In order to ensure our project worked towards continuous improvement, we followed the Plan-Do-Check-Act (PDCA) methodology. The Plan phase consists of our current state analyses that allow us to understand the overall ZT2 sub-assembly and our specific workstation. Our Do phase is separated into two sections, one relating to tire ergonomics and the other to the organization of the workstation. This report contains recommendations and implementation plans covering both sections. From there, our Check phase includes ways that Bobcat can evaluate the effectiveness of our recommendations and ensure they are working as intended. Finally, our Act phase contains information on how to sustain the solutions moving forward including common pitfalls and mitigation strategies along with how our recommendations relate to the Doosan Bobcat Production System (DBPS).

2.2 Project Plan

As seen in *Figure 1*, our team created a gantt chart at the start of this project with our plan for the semester. This plan allowed us to stay on track and laid out tasks that follow our methodology.

3.0 Current State Analysis

In order to understand the efficiency and pain points of the current process, our team conducted the following analyses.

3.1 Process Flow

To understand what occurs at workstation 13, our team created a process flow diagram seen in *Figure 2.* This diagram is based off of the work instructions for the workstation and includes the intended cycle times. Our team separated the process into nine overarching categories each containing smaller steps. Creating this process flow allowed us to understand what is supposed to occur at the workstation and compare it to what we observed. It was at this point that our team realized operators were not often following the steps of the work instructions. One key observation is that tire installation is listed as the last step in the process but operators often put them on first.

3.2 SIPOC

To further our understanding of the process, after the process flow our team created a SIPOC diagram, as seen in *Figure 3*, to understand both the supplier and customer needs. This diagram separates and focuses on the suppliers, inputs, process, outputs, and customers of a process. One key takeaway from this analysis includes the method for the replenishment of materials which includes both in-house make parts and purchase parts. There is a separate material supply team that handles most of the replenishment. Another key takeaway is that any parts dropped on the ground during the process are considered defective and must be replaced. This analysis allowed our team to have a comprehensive view of the entire ZT2 sub-assembly process.

3.3 Spaghetti Diagram and Process Map

In order to gain an understanding of any NVA movement in the process, our team created a spaghetti diagram, as seen in *Figure 4*, by observing and tracking operator movement. Through this analysis, we were able to see that there was lots of excess movement that led to longer cycle times, specifically with operators having to walk back and forth between the workbench and the active assembly cart. This was taken into consideration during our pain point identification and when creating our solutions. Once we had the spaghetti diagram drawn, we categorized the movements within a process map, as seen in *Figure 5*, including the time taken for each step. From this analysis, our team learned that the observed cycle time was 5 minutes and 57 seconds. This differs from the projected cycle time via the work instructions that calls for 5 minutes and 28 seconds per assembly. Performing this analysis allowed us to isolate and identify specific inefficiencies in the process.

3.4 Identified Areas of Waste

To continue identifying possible areas of NVA waste, our team performed a TIM WOODS analysis as seen in *Figure 6*. This included looking at the process, identifying any NVA waste, and dividing it into the categories of transportation, inventory, movement, waiting, overproduction, over-processing, defects, and skills. Some highlights from this analysis include limited space for operators to set down tools and materials during assembly, excess and unorganized raw materials on the workbench, excess movement required to obtain necessary tools and materials, and certain steps being completed out of order. This list, although not exhaustive, highlights some of our main focus areas when creating our solutions. This analysis was key in determining the amount of NVA waste currently in the process and how to eliminate it.

3.5 Current State Performance

In order to perform our cost analysis on our future state recommendations, our project champion provided us with other key metrics of the current state. This includes the fact that there is a labor cost of $20/hour for each of the 14 operators working on the line. The current throughput is 15 units/day and our team was to work on the assumption that there are 440 working minutes/day and 250 working days/year.

3.6 Key Issues and Considerations

Once our team had a solid understanding of the current process, our team created an Affinity Diagram (AD), as seen in *Figure 7*, to appropriately organize our findings in an attempt to isolate root causes contributing to process inefficiencies. The AD allowed our team to gather ideas, opinions, and issues related to the process and group them based on their relationship with each other. For our AD, our overarching question was: *What are the key issues and considerations for the ergonomic and process improvement in the ZT2 Station 13?* After a round of silent brainstorming and recording ideas, each "post-it" was sorted into groupings and headers for each group were created. This was an iterative process that was modified based on group consensus. Details on each card can be seen in *Figure 7*, but our team determined the following seven headers to be key issues and considerations for our project:

- Process steps with non-value added (NVA) waste are lowering efficiency.
- The current workstation layout and ergonomics are not optimized.
- Ensure the health and safety of the workstation operators.
- The metrics for efficiency and data acquisition are not properly defined.
- The team does not have a positive communication culture.
- Root causes and issues must be identified.
- There is a poor understanding of the current process.

These results were then used to identify the root causes of the process.

3.7 Root Cause Analysis

As aforementioned, the seven headers from our AD were then put into a Interrelationship Digraph (ID), as seen in *Figure 8*, to separate the root causes from the key issues. A matrix format was used where our team asked the question: *Does this factor influence/cause any other factor?* In the ID, upward arrows indicate a root cause and sideways arrows indicate a key issue. Out of this exercise, it was determined that "The team does not have a positive communication culture" and "There is a poor understanding of the current process" were our two root causes. By understanding what the root causes are, steps can be taken to address them.

3.8 Addressing the Root Causes

In order to understand how the root causes found in Section 3.7 can be addressed, a Tree Diagram (TD) was created as seen in *Figure 9*. The goal of the tree diagram is to break down complex goals into actionable components by providing a visual representation of the pathway to solve problems. In this project, the tree diagram served as a critical tool to identify the inefficiencies in the tire installation workstation. The TD began with our overall project goal, before branching into our two main root causes identified in the ID. Each root cause was further explored to determine actions that could be taken to address them, which were then broken into specific tasks that could be assigned and implemented. By systematically breaking down these root causes into actionable steps, the tree diagram provided a comprehensive roadmap for addressing these inefficiencies found in the workstation. Twelve assignable tasks were identified that include creating a communication charter, scheduling recurring meetings between operators and management, establishing a communication channel (e.g. MS Teams), tracking process movements and cycles, developing anonymous survey/feedback forms and creating action items based on feedback and follow-up, holding "speak-up" events twice per quarter, hosting workshops, conducting training sessions, creating visual aids for the station, shadowing operators, collecting data on performance, and conducting walkthroughs with stakeholders.

To ensure the most impactful and feasible tasks were implemented first, a prioritization matrix, as seen in *Figure 10*, was developed using the following criteria which were chosen based on the current needs of the company and the scope of the project: Task can be done at low or no cost, task can be done quickly and easily, task improves communication flow between teams/operators/supervisors, task supports achieving at same or higher level, task enhances the work environment and/or employee well-being. Each actionable item was then ranked based on how relevant it is to each criteria. It is important to note that two of the tasks were not included in this analysis (conduct walkthroughs with stakeholders and establish a communication channel). The reason for this is because these tasks were found to already be in place currently therefore, it is important to focus on the remaining actions. The first five tasks should be implemented in the order seen in the prioritization matrix:

1. *Schedule recurring meetings between operators and management*

Regularly scheduled meetings foster communication, build trust, and create a safe space for discussing different issues that may arise. This task is highly beneficial in the success of this workstation as it ensures alignment between stakeholders.

2. *Hold "speak-up" events twice per quarter*

These events are usually company or business unit wide that encourage open dialogue, allowing employees to voice concerns and share ideas without the fear or retaliation. These events empower the workforce, uncover hidden inefficiencies, and foster a collaborative culture.

3. *Create a communication charter*

Developing a communication charter formalizes team expectations, setting a standard for effective and respectful communication. Overtime, this becomes second nature once a positive communication culture is established.

4. *Host workshops*

Workshops provide opportunities for employees to learn hands-on. This is highly important for both the operators and the engineers/supervisors/managers as everyone should be knowledgeable about the workstation they support. This task addresses process understanding issues and equips the teams with knowledge needed to understand and identify issues in the current process.

5. *Shadow operators*

Shadowing operators provide management and stakeholders with a first-hand view of daily tasks, helping identify inefficiencies. This can be done at first to understand the process, and then to understand what issues arise. This task is essential in ensuring continuous process improvement.

Our team believes that operator acceptance is critical to our future state recommendation and these tasks will not only improve efficiency, but also improve team dynamics, support long term success and avoid operator push back. Although the implementation of these tasks were outside the scope of this project due to time constraints, this serves as a guide for the Bobcat team on how to create a more collaborative work environment, enhance process understanding, and work towards achieving the goal of reducing NVA waste.

4.0 Future State Alternatives

Once our team had conducted all of our current state analyses, we moved onto the Do phase of the project which includes our future state recommendations and implementation plans. In order to most effectively tackle our goal of reducing NVA waste while simultaneously reducing the ergonomic stress put on operators, our team split our solutions into two categories: workstation organization and tire installation ergonomics. The first part of this section will cover the workstation organization and the second part will cover the tire installation ergonomics. Both sections are immediately followed by ways to Check the effectiveness of the proposed solutions.

4.1 Workstation Organization Solutions

With regards to the workstation organization, our team came up with the following solutions to address any inefficiencies:

- Update the current 5S practices.
- Implement daily operator checklists.
- Reorganize material holding areas.
- Designate specific places for all tools and materials.
- Implement visual aids for organization.

All five of these solutions will be covered within either the *5S Action Items* or *Workstation Organization* implementation plans.

4.2 Current 5S Practices and Audit

Before diving into our solutions, it is important to note that Bobcat currently implements 5S within their sub-assemblies and runs biweekly 5S Audits. Since Bobcat runs these audits, our team used the official form to determine the current state of their 5S practices, the results of which can be seen in *Figure 11*. Our audit revealed a score of 3.85/5 with the main pain points falling in the sort, set, and shine categories. Our audit showed that the workbench and surrounding area lacked organization, with excess parts, unlabeled fixtures, and misplaced items, while bins, tools, and work instructions had no designated or labeled spots. Cleaning efforts were inconsistent, with incorrect trash labels, insufficient materials, and no long-term solutions. One thing to note is that most standardization and sustainability measures were up to par and thus our implementation plans focus on uplifting the sort, set, and shine categories to reduce NVA waste.

4.3 5S Action Items and Implementation

To address the solutions of *updating the current 5S practices* and *implementing daily operator checklists*, our team created the following implementation plan. The assembly line manager/engineer should:

1. Provide cleaning kits for each workstation and ensure they are consistently stocked and accessible.
2. Based on the most recent 5S audit, remove unnecessary items that clutter the work area.
3. Implement a 5-minute daily checklist for operators to ensure bins, carts, and tools are correctly organized and labeled at the end of each shift.

A possible daily checklist can be seen in *Figure 12*. This checklist includes small actionable tasks for operators to complete at the end of shift to ensure the organizational standards from the current 5S practices are being upheld. If deemed necessary based on identified recurring problem areas in 5S audits, the daily checklist should be updated to incorporate highly detailed prompts for managing issues such as misplaced tools, improperly sorted items, or poorly maintained bins. In order to ensure these steps are implemented successfully, the following contains target completion times for implementation. On Day 1, new cleaning equipment and the daily checklist should be put onto the floor. There should also be a short training for operators on the new standard operating procedures to ensure understanding and necessity of the new implementations. On Day 5, management should check in with the operators on the new implementation status and ask for any identified problems, evaluate operator adherence to the daily checklist, and document any improvements or problem areas. On Day 14, managers should continue with the biweekly audits and compare the audit score to previous audits to track improvements or identify shortcomings. Cleaning equipment such as brooms, dustpans, rags, and cleaning solutions will be additional resources required for a successful execution. By implementing these changes, NVA movement will be reduced as all tools and materials will consistently be in their designated areas and the workspace will be clean.

4.4 Organizational Implementation Plans

To address the solutions of *reorganizing material holding areas, designating specific places for all tools and materials,* and *implementing visual aids for organization*, our team created the following implementation plan. The assembly line manager/engineer should:

1. Remove all bins and labels from the top shelf of the workstation.
2. Place Wheel Lug Nuts (64187-03) bin on the upper left hand side of the workstation as indicated in *Figure 13*.
3. Add in a bin for Torque as diagrammed.
4. Place Torque on the left hand side of the workstation.
5. Replace all labels following the diagram and putting bins onto their corresponding label.
6. Add in a Lug Nut bin to transport (64187-03) to the assembly cart
7. Create color coded tape markings for Lug Nut Staging Bin, Red Staging Bin, Free Workstation Space, Small bin for whiz nuts and eyebolts, and HOC pre-labeled plates
8. Create a label for work instructions to sit on the right hand side of the 1st shelf under the workbench as diagrammed.
9. Once all aforementioned steps are completed, take a photo of the workstation in its ideal state and add it to the workbench for operators to reference.

All of these changes are reflected in *Figure 13* which contains a proposed ideal workbench diagram. The new proposed layout has the bins in a consistent and logical order from left to right and the "small slim bin" for the HOC plates with labels should limit the amount of plates operators label ahead of time. It is important to note that this layout coincides best with our tire solution that involves rearranging the work instructions to install the tires first and then move the cart as all of the necessary equipment for tire installation is located on the left hand side. In order to ensure these steps are implemented successfully, the following contains target completion times for implementation. On Day 1, bins should be moved in accordance with the diagram and aforementioned steps and operators should be informed of the changes. Days 2-7 should be used to evaluate and test the efficiency of the new layout while making sure to check in with operators for feedback. On Day 8, any adjustments based on feedback should be made. Tape for marking locations, new bins, and extra labels are additional resources needed for a successful execution. By implementing this new layout, NVA time will be reduced as there will be less excess movement.

4.5 Evaluating the Effectiveness of the Proposed Workstation Organization

In order to evaluate the effectiveness of these solutions, Bobcat should continue conducting the biweekly audits, use worker feedback forms, and monitor tool retrieval times. In addition, area supervisors should ensure the daily checklist is being filled out and reflected in the workbench and track common issues identified during the audits to isolate trends/root causes. The ideal result from these implementations is that the 5S audit scores should increase from the current state and maintain the improved level. All of these changes will contribute to lowering the NVA time in the current process as the space will be consistently organized and there will be less excess movement required when gathering tools and materials.

4.6 Tire Installation Ergonomic Solutions

Moving on to our ergonomic tire installation solutions, our team initially came up with eight possible solutions. These include requiring operators to adjust the tire pallet to proper lifting height, implementing team lifts, using mobile carts to move tires, implementing a rotating mower assembly stand, using a pneumatic lift cart, using a spring based height pallet for tires, using rail guided carts, and installing tires first and then moving the cart for the rest of the assembly. In order to determine the most feasible solution, our team used another prioritization matrix.

4.7 Ergonomic Solutions Prioritization Matrix

Using the eight solutions identified above, our team used a prioritization matrix to determine the best possible solutions. We used the following criteria when evaluating the solutions: Can be implemented at no or low cost, can be implemented quickly and easily, the solution significantly reduces ergonomic stress from heavy lifting, the solution supports achieving at same or higher levels, and the solution requires minimal additional training. The prioritization matrix, as seen in *Figure 14*, gave us these four solutions are the best recommendations:

1. Install tires first, then move cart
2. Use a spring loaded pallet for the tires
3. Use a pneumatic lift cart
4. Require manual tire pallet height adjustment to proper lifting height

Given that the solutions all vary in cost and time to implement, in order to ensure we are handing over a comprehensive list of possibilities we have created implementation plans for each of the top four solutions. In section 5.3 Recommended Implementations, our team will go over what solutions we believe will be most effective on both a short and long term basis.

4.8 Solution 1 - "Install Tires First Then Move Cart" Implementation

Current work instructions state that tire installation should be the last step at workstation 13. By altering the work instructions to have tire installation precede the rest of the assembly steps and by adding a step to move the cart closer to the workbench after the tire installation, time spent lifting the heavy tires and NVA movement would be reduced. The new proposed locations for the assembly cart can be seen in *Figure 15*. To implement this solution, the assembly line manager/engineer should:

1. Update the work instructions to specify that operators should complete tire installation first at position 1 in *Figure 15*.
2. Add floor tape 3'4" closer towards station 14 from current stop as seen in *Figure 15.*
3. Update the work instructions to specify that operators should move cart to position 2 after the tires have been installed to complete the rest of the assembly.

In order to ensure these steps are implemented successfully, the following contains target completion times for implementation. On Day 1, the work instructions should be updated and floor tape should be placed in the new desired positions. Operators should be trained on the new standard operating procedures. Days 2-4 should be used to evaluate the efficiency of the new procedure. On Day 5, operator feedback should be taken and any necessary adjustments should be made. This solution, although not eliminating the heavy lifting, will limit the amount of time spent lifting the tires as the cart will now be placed directly in front of the tire pallet. In addition, NVA time will be reduced as operators will now be stationed directly in front of the workbench during the rest of the assembly. This will allow for quicker access to tools and materials and limit the excess movement that was identified during the current state analysis. This solution can be implemented immediately at low to no cost.

4.9 Solution 2 - "Spring Loaded Pallet" Implementation

The current workspace utilizes a movable height pallet for stacking the tires which are separated by the unit's model and tire size. As the tire stack reduces in height, there is no compensation for the stack height loss raising major concerns in the ergonomics. This is to be tackled by replacing the current pallet with a spring based height pallet, which would adjust its height with accordance to the load atop. The spring-based pallet should feature dual progressive-rate springs calibrated for a 353lbs total load capacity. To implement this solution, the assembly area manager/engineer and a pallet installation/calibration team will be involved. The steps to complete are as follows:

1. The existing pallets are to be emptied and safely moved out of the assembly area for disposal or further processing of its constituent materials..
2. Using tape, temporarily mark down the place (roughly around the same place as the previous pallets), where the new spring based height pallet is to go into.
3. Place new spring pallets into designated space. Upon replacing the spring pallets into their designated spots, remove the tape.
4. Install corner guides and anti-slip surfaces on the platform for tire stack alignment.
5. Calibrate the dual progressive-rate springs to maintain the following height specifications:
    a. No load height: 44 inches (top working height)
    b. Full load height: 27 inches (bottom working height)
    c. Initial spring rate (K1): 20 lbs/inch
    d. Final spring rate (K2): 30 lbs/inch
6. Update the workplace safety instructions regarding calibration of the spring pallet, including spring compression guidelines and maximum load warnings.
7. Update the work instructions with the new standard operating procedures for operators. This includes the order of which the tires should be grabbed. In order to keep the pallet as balanced as possible,operators should grab the tires in sequence of rows to ensure that the pallet is raised properly to the desired height.
8. Install safety locks to secure spring movement when accessing the final tire of each layer.
9. Engage EHS team to validate the ergonomic design and conduct risk assessment of the spring-loaded pallet system before implementation.

10. Update work instructions or safety manuals on how to identify and mitigate any common issues that may arise. This includes minor repairs if machinery is notably unbalanced and instructions on how to deal with related risks and injuries.
11. Train operators on new standard operating procedures including proper loading/unloading sequences, safe handling techniques, and emergency procedures, emphasizing how it will improve efficiency and reduce physical stress on them.
12. Establish a periodical maintenance period to ensure safety standards are met and the longevity of the pallet is maintained.

In order to ensure these steps are implemented successfully, the following contains target completion times for implementation. Days 1-3 should be used to conduct a detailed ergonomic assessment and identify the optimal spring type and configuration. Days 4-7 should be used to develop detailed calibration procedures and training materials. Days 7-10 should be used to calibrate and install the new pallets and update the work instructions. Day 15, or after the pallet has been installed, should be used to train operators on the new spring pallet system. On Day 21, or one week after implementation, feedback from operators should be taken to evaluate the performance and identify any shortcomings. On Day 28, or one week after the initial feedback, management should check in on the maintenance of the new spring pallet looking for any possible issues. Some possible additional resources needed besides the pallet itself include floor tape, anti-slip mats, corner guides and height indicators, spring calibration tools, and load testing equipment. This solution, although not eliminating stress from heavy lifting, would reduce the amount of stress put on the operator's back as the top layer of tires will sit at roughly 40” which is within the optimal heavy lifting height power zone thus reducing the possibility of back strain. Initial cost calculations and time saving analysis for this solution will be shown in following sections.

4.10 Solution 3 - “Pneumatic Lift Cart” Implementation

Currently, operators must lift each tire in order to add it to the assembly and thus to reduce the ergonomic stress on operators, we recommend the purchase of a pneumatic lift cart. With the cart, operators can match the heights of the cart and tire pallet and roll/stack the tires (~4-6) onto the cart. This step can be completed at any point throughout the assembly process, even when the assembly cart is in another location. Once the tires are on the cart, operators can raise the cart to match the height of the active assembly and roll them onto the in-progress mower. By doing so, ergonomic stress from heavy lifting is heavily reduced and the pneumatic carts capacity for more than two tires will decrease the added time spent loading the tires. To implement this solution, management and the assembly line manager/engineer should:

1. Order a pneumatic lift cart.
2. Mark off and dedicate space next to the tire pallets for the storage of the new cart when not in use.
3. Update work instructions to reflect the use of the new cart. This includes its capacity (~4-6 tires), instructions for adjusting the height, and the standard operating procedure.
    a. SOP: Align the height of the pneumatic cart and tire pallet, load 4-6 tires onto cart, move cart to active assembly, align the height of the pneumatic cart and the active assembly cart, roll tire onto the mower, repeat on the other side.
4. Train operators on the new standard operating procedure emphasizing how it will reduce physical stress.
5. Schedule a periodical maintenance period to ensure safety standards are met and the longevity of the pallet is maintained.

In order to ensure these steps are implemented successfully, the following contains target completion times for implementation. On Day 1 after receiving the cart, mark off using tape the area for the pneumatic cart when not in use and put the cart on the floor. On Day 2, updated work instructions should be put on the floor and operators should be trained on the new standard operating procedure. On Day 7, or one week after implementation, a feedback survey should be conducted to evaluate the performance and identify any shortcomings. Around Day 12, the assembly line manager should check in on the maintenance of the pneumatic cart looking for any possible issues. Aside from the pneumatic cart itself, the only other resource needed is floor tape. This solution will provide the greatest ergonomic reduction as if used properly it can essentially eliminate all heavy lifting through the rolling techniques. One downfall is there are possibilities for a slower cycle time specifically for tire installation step, but if accompanied with the new proposed assembly locations and making tire installation the first step, that excess time would be offset. Initial cost calculations and time saving analysis for this solution will be shown in following sections.

4.11 Solution 4 - “Required Pallet Height Adjustment” Implementation

The current workspace utilizes a movable height pallet for stacking the tires which are separated by the unit’s model and tire size. As the tire stack reduces in height, there is no compensation for the stack height loss raising major concerns in the ergonomics. This is to be tackled by placing a visual height indicator beside the tire pallet to mark the ideal height of the tire pallet that corresponds with where the top layer of tires should be placed. Operators would then be required to adjust the tire pallet’s height manually as necessary so that the indicator is consistent even with the top layer. The ideal height for appropriate weight lifting is between 2 feet and 4 feet vertically from ground level (around 40”). To implement this solution, the assembly line manager/engineer should:

1. Place a visual indicator (e.g., tape) marking the ergonomically ideal pallet height beside the pallet. The indicator would align with the top tire in the stack.
2. Update the work instructions on how it is required that the top tire be aligned with the height indicator.
3. Train operators on new standard operating procedures emphasizing how it will improve efficiency and reduce physical stress.
4. Schedule a periodical maintenance period to ensure safety standards are met and longevity of the pallet is maintained.

In order to ensure these steps are implemented successfully, the following contains target completion times for implementation. On Day 1, the work instructions should be updated to include a required pallet height adjustment step before tire installation and a visual height indicator should be put onto the floor next to the tire pallets. On Day 2, the updated work instructions should be put in the workbench and a training session with operators should be held to inform them of the new standard operating procedure. On Day 9, or one week after implementation, a feedback survey should be conducted to evaluate the performance and identify shortcomings. The only additional resource needed for this solution is some sort of visual height indicator, such as tape. This solution, although not eliminating the heavy lifting, would limit the amount of stress on the operator as the tires will now be placed at the optimal height for heavy lifting. This solution would also reduce NVA movement if accompanied with Solution 1 that contains the proposed new locations for tire installation and the rest of the assembly. This solution can be implemented immediately at low to no cost.

4.12 Evaluating the Effectiveness of the Ergonomic Solutions

In order to evaluate the effectiveness of our proposed ergonomic solutions, management should monitor the cycle times per operator and the annual health reports of the operators. Workflow efficiency and operator adherence to the new order of the work instructions post-implementation should be observed. Feedback from operators will be one of the key indicators on how effectively the solutions are working. The ideal results will contain no injuries as a result of heavy lifting and possibly a 1-2 unit increase in overall throughput per shift depending on the solution. The calculations for increased efficiency and lower cycle times will be shown in the following sections.

5.0 Cost Saving Metrics & Results

5.1 MOST Analysis

A MOST (Maynard's Operation Sequence Technique) analysis was conducted to evaluate and optimize the tire installation process at workstation 13. This systematic work measurement technique focuses on the movement of objects and provides standardized time values for workplace activities.

5.1.1 Current State Analysis

The existing process consists of 53 total activities, broken down into 22 operations, 23 transport movements, and 8 storage activities, resulting in a cycle time of 357 seconds. The primary movements identified through MOST analysis include basic arm movements, basic grasping actions, precision placements, and longer reaching movements. The analysis revealed significant time spent on walking between work zones and repeated tool retrieval patterns.

5.1.2 Solutions Analysis and Results

Our team used the MOST analysis to evaluate the four potential solutions as seen in *Figure 16*. The first solution involved modifying the assembly sequence, which optimized general move sequences, reduced transport indexes through improved layout, and maintained necessary tool use sequences. The second solution built upon the first by incorporating a spring-loaded pallet, introducing controlled move sequences and equipment operation elements. The third solution implemented a pneumatic lift system, incorporating tool use sequences for controls and modified move patterns for cart interaction. The fourth solution focused on manual height adjustment, modifying reach and grasp indexes while adjusting placement sequences for improved ergonomics. All solutions showed cycle time improvements, ranging from 21.6 to 26.88 seconds. In addition to the cycle time improvements, this reduction allows for efficiency gains for each solution as seen in *Figure 17*. The average efficiency gain for all solutions is 7.13% which allows for a 1-2 unit throughput increase per day. Both the new cycle time and efficiency calculations were performed with the assumption that both the 5S practice update and organizational layout changes were implemented.

5.2 Estimated Costs

The projected associated costs of the spring based pallet and pneumatic lift cart solutions can be seen in *Figure 18*. The pneumatic lift cart calls for an initial investment of around $1,600 and using this metric, our team calculated that it would have projected annual labor savings of $522.40 for the first year and return of investment of $3,623 over ten years. With regard to the spring-loaded pallet solution, despite having the highest initial investment of $4,000, this solution emerges as the optimal choice of the two investment solutions when considering both operational efficiency and long-term benefits. While it shares the same cycle time improvement as the modified assembly sequence (26.88 seconds saved per cycle, 7.83% efficiency gain), it provides crucial additional advantages. The solution eliminates repeated lifting strain on operators, maintains consistent ergonomic working heights throughout the shift, and requires minimal operator intervention to maintain optimal working conditions. These ergonomic improvements reduce the risk of work-related injuries and operator fatigue, potentially decreasing downtime and injury-related costs. With projected annual labor savings of $598.81 for the first year and return of investment of $1988 over ten years, the solution pays for itself while providing lasting improvements to both efficiency and workplace safety.

5.3 Recommended Implementations

There have been many possible solutions to addressing the NVA waste and ergonomic stress stated throughout this report in order to provide Bobcat with a variety of options, but there are certain solutions that stand out to our team as more effective than others. With regard to the 5S actions items and workbench organization, our team believes that these solutions should be immediately implemented as they will reduce NVA movements and decrease the overall cycle time for the process. In addition to these solutions, ergonomic solution 1 - installing the tires first and then moving the cart, should be immediately implemented. Using this sequence instead of what is currently stated in the work instructions will improve the flow of the process and reduce the repetitive NVA movement that currently occurs with operators walking back and forth from the workbench to the active assembly cart. This solution can be implemented at no additional cost and not only reduces the NVA time but also the stress put on the operator while carrying the tires because the required walking distance has been lowered.

Looking at more of a long term solution, the MOST analysis demonstrates that modifying the assembly sequence while incorporating spring-loaded pallets provides the optimal improvement, reducing cycle time by 26.88 seconds (7.83%). The sequence model indicates this solution effectively balances movement minimization with ergonomic benefits through mechanical assistance. Our team also believes that between the two investment solutions, the spring-based pallet would be more widely accepted by operators as the pneumatic lift cart may be considered tedious. Overall, all of the proposed solutions provide different benefits, but given the company culture and requirements for implementation, the aforementioned solutions stand out as the most effective.

6.0 Sustainability Moving Forward

6.1 Mitigating Future Process Deviations

It is just as important to implement solution troubleshooting procedures as it is to implement solutions. In order to get ahead of possible process deviations, our team compiled a list of probable deviations and relevant mitigative procedures. This list is as follows:

- Operator non-compliance
- Wear and tear on the mechanism
- Over-reliance on the machine
- Machinery maintenance

Operators are the key stakeholders within every solution and their buy-in to the proposed solutions is critical for success. In order to ensure operators are aware of the benefits of the solutions, management could hold regular training and safety meetings emphasizing the importance of following protocols for operator ergonomic safety. Operator feedback should be gathered and taken into account and it should be clear to the operators that their opinions are being taken into consideration. Wear and tear on the mechanism is another probable process deviation. In order to mitigate this, regular preventative maintenance should be scheduled ahead of time and repair training sessions should be held for operators and management alike to get ahead of possible system failures. When it comes to over-reliance on the machine, operator training on new machinery should include physical demonstrations of appropriate practices to help standardize the implementation. This deviation adheres to all solutions but especially the pneumatic lift cart as that solution contains the biggest changes from current standard operating procedures. Regarding machinery maintenance, the spring pallet and pneumatic lift cart have higher initial costs associated and there are more possibilities for necessary part replacements. To mitigate, our team recommends implementing a spare parts inventory system and a maintenance record system to help identify trends and have replacement parts available so as to not delay production.

6.2 Engineering Considerations

While determining our proposed solution, our team took many different engineering considerations into account. For starters, from a business and ethical perspective, it is essential that our solutions cater to operator safety within the workplace while being cost effective, accessible, and reliable. Operators are the party that will be most affected by any process changes and thus their safety and input is paramount. From a workforce-management perspective, it is important to maintain proper communication between operators and management to make sure operator well-being is being considered and prioritized and to make sure that standard operating procedures are understood and followed. This will not only bring significant benefits to the production rate and the business but also an enhancement to the job experience for operators. As a result of this consideration, all of our solutions contain either operator feedback surveys or training emphasizing the benefits of following the new standard operating procedures which will enhance company culture. In addition, Bobcat adheres to certain ISO standards and so it was crucial that our solutions could easily be implemented in accordance with said standards and the management system manual.

6.3 Kaizen Relation

When coming up with solutions for this project, it was key that they all adhered to the Doosan Bobcat Production System (DBPS) as do all current processes within the facility. The DBPS has a goal of developing the highest quality products, at the lowest cost, with the shortest lead time by systematically and continuously eliminating waste. This is achieved by looking at all processes through 5 major categories of fundamentals, just-in-time, operator stability, securing quality, and continuous improvement. Each category has associated modules that go more in depth. Of the 19 modules, our specific solutions most coincide with health and safety, 5S, visual management, and rapid improvement. Given the adherence of our solutions to the DBPS and the fact that there is an existing company culture of the idea that small changes can lead to big improvements, our team believes our project will be readily accepted and successful at Bobcat.

6.4 Going Forward

All of our proposed solutions adhere to and comply with Bobcat's current operational philosophies. Our team believes that if Bobcat implements our recommended solution as stated in section 5.3, there will be a significant reduction in NVA waste and in ergonomic stress put on the operator. Solutions related to 5S practices and the workstation organization will reduce the current NVA time in the assembly and if found to be successful, the daily checklist could easily be applied throughout the entire facility. Solutions related to tire installation will reduce the ergonomic stress put on operators and for other lines with similar ergonomic issues, our solutions could be manipulated to be implemented in other areas. Overall, all of our solutions work towards continuous improvement through small steps and will show improvements through cycle time reductions and efficiency gains.

Appendix

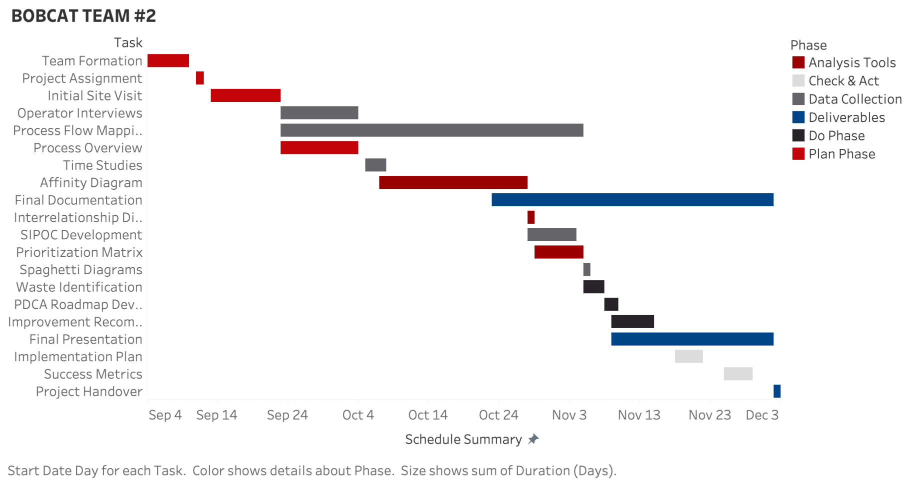

Figure 1: Gantt Chart of Overall Project Plan

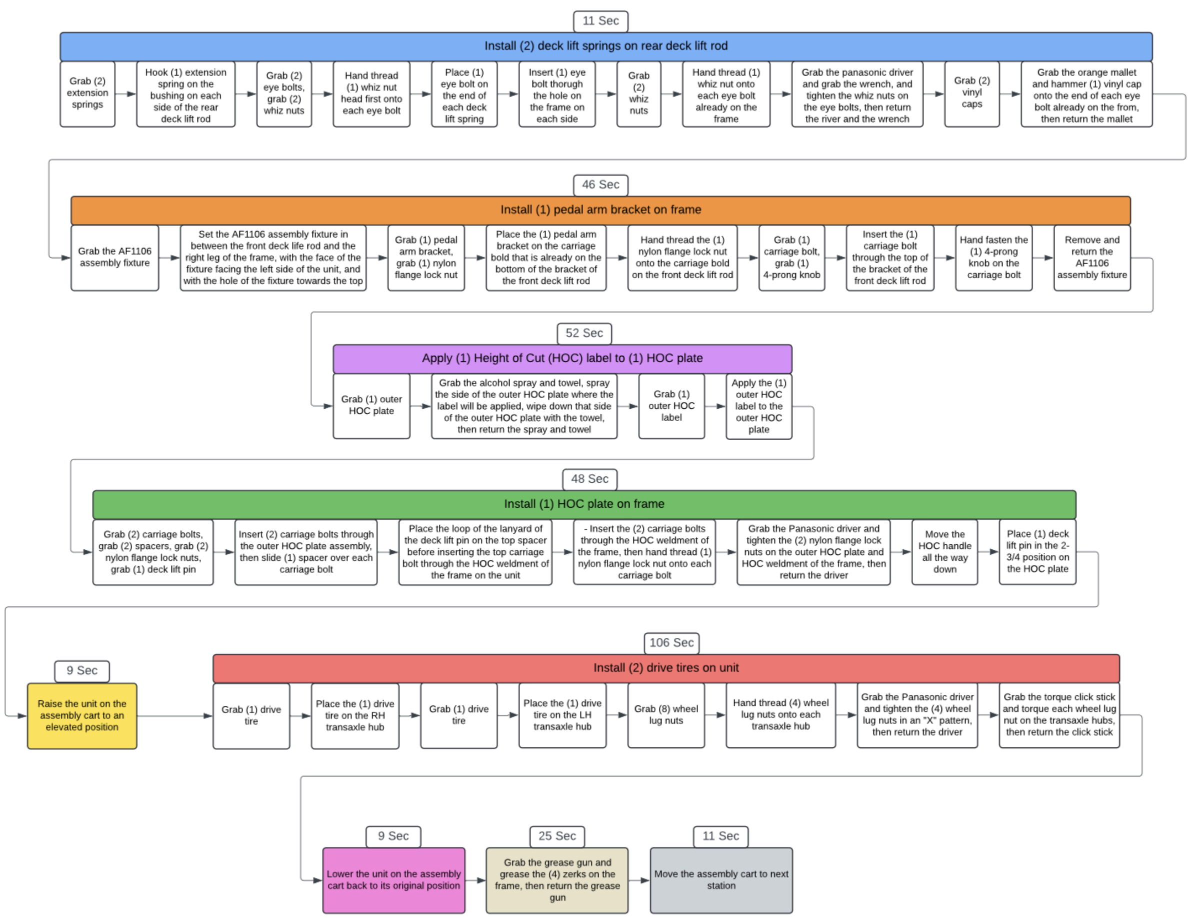

Figure 2: ZT2 Workstation 13 Process Flow Diagram

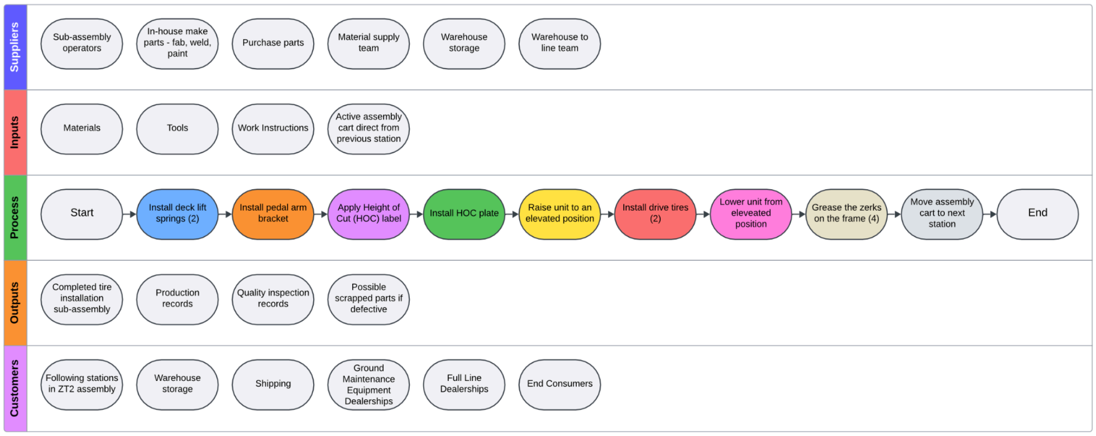

Figure 3: SIPOC Diagram of ZT2 Workstation 13

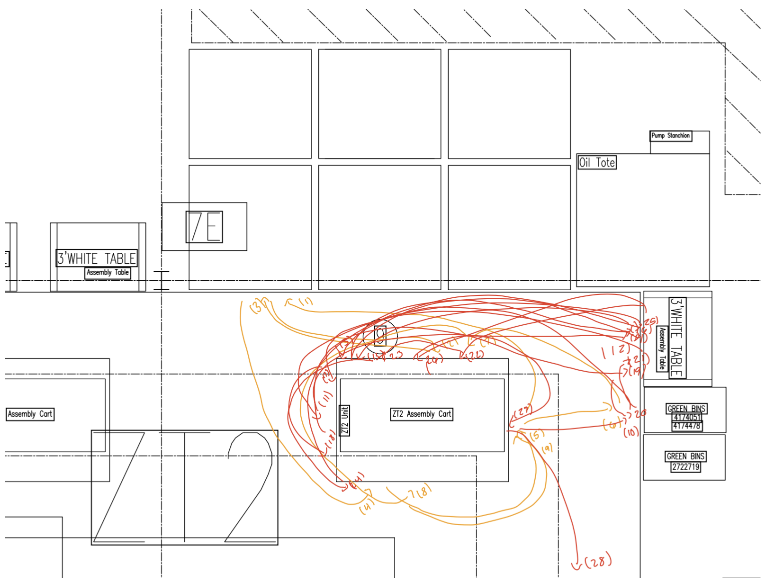

Figure 4: Spaghetti Diagram

#	Activity	Operation	Transport	Inspect	Wait	Store	Time (Min)
1	Raise cart to elevated position	X					0:14
2	Grab lug nuts from work station					X	0:02
3	Walk to tire palette		X				0:06
4	Walk back to mower		X				0:03
5	Place tire 1 on mower	X					0:02
6	Hand screw tire lug nuts	X					0:27
7	walk to tire palete		x				0:04
8	Walk to place tire 2 on mower		x				0:03
9	Place tire 2	x					0:02
10	Place tire lug nuts	x					0:25
11	walk to move cart		x				0:03
12	move cart closer		x				0:03
13	Grab panasonic driver					x	0:01
14	walk to cart with panasonic driver		x				0:01
15	Use panasonic driver to screw on lug nuts	x					0:10
16	Walk to other side of cart		x				0:04
17	Use panasonic driver to screw on lug nuts	x					0:11
18	Walk to workstation/drop off driver		x				0:03
19	Lower cart	x					0:09
20	Grab tool/parts basket					x	0:01
21	Walk to back side of mower		x				0:03
22	Find AF1106 plastic part					x	0:07
23	Grab and place AF1106 plastic part	x					0:05
24	Place loop of lanyard for HOC plate	x					0:02
25	Install springs (substep 1-8)	x					0:45
26	Grab and place pedal arm bracket	x					0:07
27	Install HOC plate (substep 2,4)	x					0:25
28	Walk to get panasonic driver		x				0:03
29	Walk back to cart with driver		x				0:02
30	Screw pedal arm	x					0:05
31	Return AF1106 plastic part	x					0:01
32	Install HOC plat (substep 5)	x					0:05
33	Return panasonic driver		x				0:02
34	Grab panasonic driver					x	0:01
35	Walk back with panasonic driver		x				0:02
36	Tighten whiz nuts	x					0:12
37	Return panasonic driver		x				0:02
38	Walk back to car		x				0:03
39	Install pedal arm (substep 6,7,8)	x					0:10
40	Find Vinyl Caps					x	0:02
41	Use orange mallet to install caps	x					0:10
42	Walk back to workstation		x				0:02
43	Set up for next cart (grab pieces)					x	0:28
44	Grab grease gun					x	0:01
45	Walk to cart with grease gun		x				0:02
46	grease 2/4 parts	x					0:06
47	Walk to other side of cart		x				0:02
48	Grease other two parts	x					0:05
49	Walk back to workstation		x				0:02
50	Walk back to cart		x				0:03
51	Install HOC plate (substeps 6,7)	x					0:06
52	Walk to drag cart		x				0:02
53	Move cart to work station 14		x				0:10

Activity	Qty	Time
Operation	22	
Transport	23	
Inspect	0	
Wait	0	
Store	8	
Totals	53	5:57

Figure 5: Spaghetti Diagram Process Map

Transportation	There are not many good spaces for operators to set tools and materials down during the process, leading to consistent transportation of tools between the workbench and the active assembly area.
Inventory	There are excess raw materials on the workbench. Workbench is unorganized with no standardized placements/volumes.
Movement	There is excess walking needed to obtain the required materials and tools as well as no standardization of the order to grab materials. There is excess motion and lifting involved when installing tires. This is ergonomically unsatisfactory as the tires are heavy. The spring installation step in the process sometimes takes operators multiple tries.
Waiting	The operator must wait for the next station to be complete before they can move their finished product. The operator must wait for the prior station to be complete before they can commence their work. This includes the quality checks performed in the immediate preceding workstation.
Overproduction	Certain steps in the sub-assembly, specifically applying the HOC labels, are done ahead of time rather than during each assembly as stated in the work instructions. This leads to numerous HOC plates sitting on the workstation that may have to be scrapped if label information changes before installation. There is a possibility of bottlenecks due to early production if any workstation within the entire sub-assembly encounters a setback.
Over-processing	No current over-processing waste as all quality checks are performed outside of workstation 13 and every current step in process is needed to meet customer and company requirements.
Defects	Low defect data for parts specific to workstation 13. Any hardware that hits the floor must be scrapped due to debris.
Skills	The work instructions are not followed. Although there is a set framework, training for new operators is done at the current operators discretion so there are possibilities for a lack of standardization.

Figure 6: TIM WOODS Analysis

Figure 7: Affinity Diagram

Issue/Problem Statement: **What are the root causes and issues leading to NVA waste on the ZT2 Station 13**

Pairwise Assessment: **Does this factor cause/influence any other factor?**

Created by: Melia Moyer, Jessica Zhang, Arya Raut, Praharshith Jamalapuram, Ana Petereit Cruz

Factor #	Factor	1	2	3	4	5	6	7	Out	In	Total	Decision
1	Process steps with non-value-added (NVA) waste are lowering efficiency.		←		←	←	↑	←	1	4	5	**Key Issue**
2	The current workstation ergonomics and layout is not optimized	↑		↑		←	←		2	2	4	
3	Ensure and regulate the health and safety of the workstation operators		←			←	←	←	0	4	4	**Key Issue**
4	Efficiency metrics & data acquisition are not properly defined	↑				←	↑	←	2	2	4	
5	Team does not have a positive communication culture	↑	↑	↑	↑		↑	↑	6	0	6	**Root Cause**
6	Root causes and issues cannot be identified	←	↑	↑	←	←		←	2	4	6	**Key Issue**
7	Poor understanding of the current process	↑		↑	↑	←	↑		4	1	5	**Root Cause**

Figure 8: Root Cause Analysis

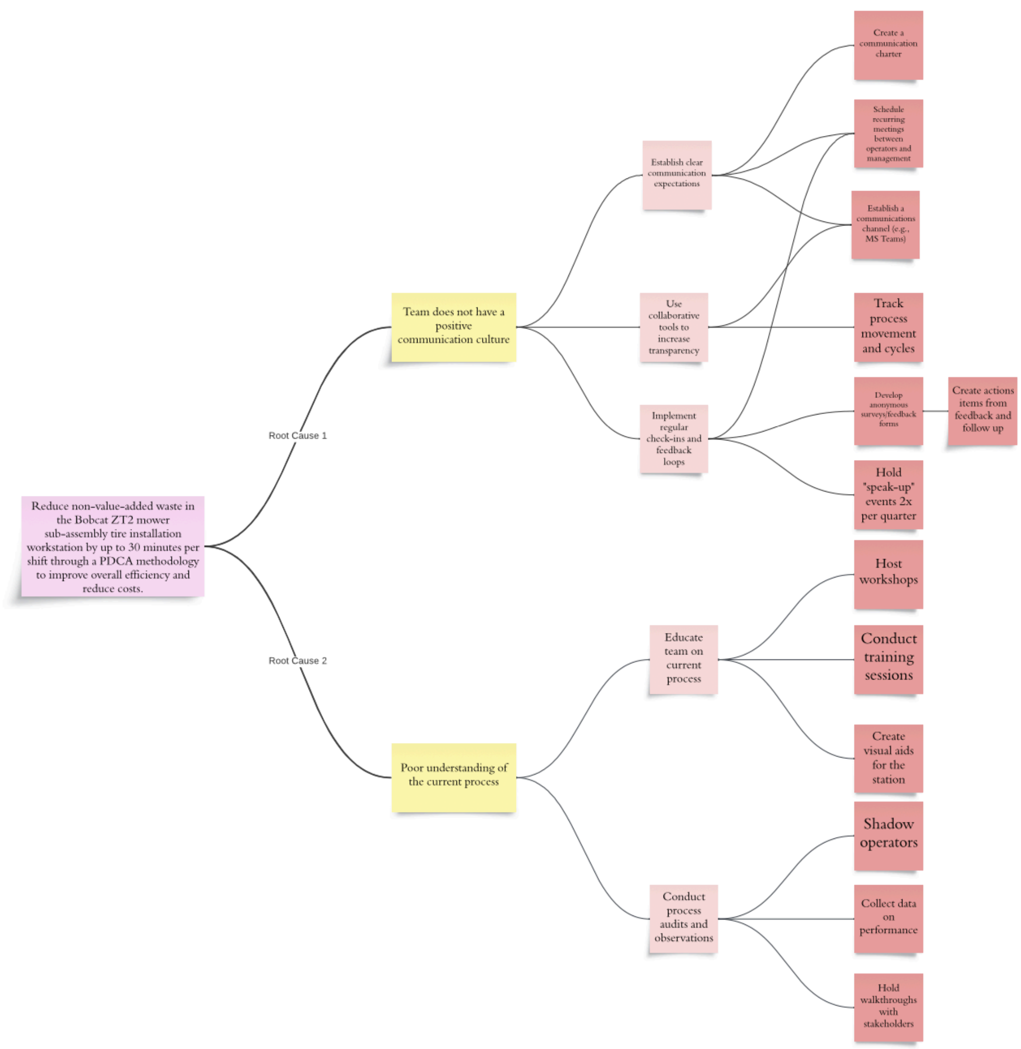

Figure 9: Tree Diagram

Options	Criteria 1: Can be done at no or low cost			Criteria 2: Can be done quickly and easily			Criteria 3: Task improves communication flow between			Criteria 4: Task supports achieving at same or higher levels			Criteria 5: Task enhances the work environment or employee			Total Across Criterion	Top Choices
	Total Ranking Scores Across All Criteria																
	Rank	Weight Value	Weighted Rank	Rank	Weight Value	Weighted Rank	Rank	Weight Value	Weighted Rank	Rank	Weight Value	Weighted Rank	Rank	Weight Value	Weighted Rank		
(A) Create a communication charter	9	1.25	11.25	9	0.55	4.95	10	1.2	12	1	1.05	1.05	1	0.95	0.95	30.20	3
(B) Schedule reccuring meetings between operators and management	10	1.25	12.5	8	0.55	4.4	8	1.2	9.6	2	1.05	2.1	5	0.95	4.75	33.35	1
(C) Collect data on performance	5	1.25	6.25	3	0.55	1.65	1	1.2	1.2	7	1.05	7.35	3	0.95	2.85	19.30	9
(D) Track process movement and cycles	6	1.25	7.5	5	0.55	2.75	2	1.2	2.4	4	1.05	4.2	2	0.95	1.9	18.75	10
(E) Develop anonymous feedback forms	7	1.25	8.75	6	0.55	3.3	7	1.2	8.4	3	1.05	3.15	6	0.95	5.7	29.30	6
(F) Hold "speak up" events 2x per quarter	1	1.25	1.25	1	0.55	0.55	9	1.2	10.8	8	1.05	8.4	10	0.95	9.5	30.50	2
(G) Host workshops	2	1.25	2.5	2	0.55	1.1	6	1.2	7.2	10	1.05	10.5	9	0.95	8.55	29.85	4
(H) Conduct training sessions	3	1.25	3.75	4	0.55	2.2	4	1.2	4.8	9	1.05	9.45	7	0.95	6.65	26.85	7
(I) Create visual aids for the station	4	1.25	5	7	0.55	3.85	2	1.2	2.4	6	1.05	6.3	8	0.95	7.6	25.15	8
(J) Shadow operators	8	1.25	10	10	0.55	5.5	4	1.2	4.8	5	1.05	5.25	4	0.95	3.8	29.35	5

Objective: What action items identified from our tree diagram will help our project be successful?

Figure 10: Prioritization Matrix #1

5S Audit Form **Rev. 10/03/2024**

Bobcat

Auditor Name: UW-Madison Bobcat Team 2 | **Line:** ZT2 | **Station:** 13 | **Date:** 11/18/24

Sort: Eliminate what is unneeded and decide what is needed		1 (6+) ITEMS	2 (4-5) ITEMS	3 (2-3) ITEMS	4 (1) ITEM	5 (0) NONE	SCORE	EVIDENCE
Workbench	1) Extra/missing tooling/fixtures 2) Any unnecessary items 3) Excess subassemblies or inventory			X			3	Excess subparts and nuts, no place for them
Surrounding Area	1) Out of date standard work 2) Obsolete one point lessons (OPLs) 3) Unlabeled fixtures/jigs			X			3	Unlabeled bins
	1) Excess Inventory 2) Unnecessary Items	X					1	Misplaced boxes Extra containers
	1) Uneeded personal items (lunchbags, phone chargers)					X	5	
							12 /20	

Set: Define a specific location for every item needed		1 (6+) ITEMS	2 (4-5) ITEMS	3 (2-3) ITEMS	4 (1) ITEM	5 (0) NONE	SCORE	EVIDENCE
Pegboards, Shelves, & Bins	1) Bins or shelves missing their labels? 2) Any tools not have a clearly labeled place?			X			3	Bins with no labels No labeled place for certain tools
Make Parts	1) Any make parts not having a kanban card? 2) Are any part locations missing labels?		X				2	Missing labels Grease, Panasonic, screw
SWI's	1) Standard work instruction (SWI) locations not labeled? 2) Are any SWIs missing labels or revision levels/dates ? 3) All fixtures and jigs are called out in the SWIs				X		4	No set spot for standard WI
Purchase parts, tools, & WIP locations	1) Do any stools, gas carts, battery charger stands, not have properly labeled home locations? 2) Purchased parts (tires, seats, hoses, etc) missing properly labeled home locations? 3) Any WIP machines/carts not in defined locations?			X			3	Grease gun and Panasonic have no properly labeled home
							12 /20	

Shine: Keep the workplace clean and eliminate abnormalities		1 (6+) ITEMS	2 (4-5) ITEMS	3 (2-3) ITEMS	4 (1) ITEM	5 (0) NONE	SCORE	EVIDENCE
Floor & Workstations	1) Are all labels on bins / floor legible? 2) Are the following areas free of dust/debris - Shelves, workbench, floor - Guard railing, part carts, WIP carts		X				2	Trash label is wrong Multiple areas needs to be swept/cleaned
Shipping Containers	1) Any damaged pallets/shipping containers present?					X	5	
Garbage & Broom boards	1) Any mising/extra items on the broom boards? 2) Clean and empty garbage cans 3) Red oily rag bins emptied daily?			X			3	The garbage was full Lack of items on board
Corrective Action	1) Have contamination and dirt causes (leaks, dust) been identified and treated?				X		4	Aware of dirt/dust but no long
							14 /20	

Standardize: Create a visually managed workplace		1 (6+) ITEMS	2 (4-5) ITEMS	3 (2-3) ITEMS	4 (1) ITEM	5 (0) NONE	SCORE	EVIDENCE
Color Coding	1) Colored floor tape and other visual management follows Bobcat color coding standard					X	5	
Checklists	1) 5S checklist is up to date with a revision level/date 2) 5S checklist is properly filled out					X	5	
Locations & tools	1) Is there an area for empty bin return? 2) Are we using tools not called out in the SWI?				X		4	No area for bin
Operator	1) Have the 5S activities been completed in this area for the last month?					X	5	
							19 /20	

Sustain: Sustain improvements and make further company wide improvements		1 (6+) ITEMS	2 (4-5) ITEMS	3 (2-3) ITEMS	4 (1) ITEM	5 (0) NONE	SCORE	EVIDENCE
EOD 5S - 10 min	1) The last 10 minutes of each shift are utilized for 5S 2) Checklist items are completed and checked off					X	5	
5S Audit	1) Weekly audits are occuring on the line 2) Completed audits are posted to the SQDC board					X	5	
Action Items	1) Audit action items are being completed in this area with clear owners					X	5	
Process Improvements	1) Are there any items missing from the 5S audit process that you would improve?					X	5	
							20 /20	

(Sum of points/100) x 5 = 5S Score ex. (85/100) x 5 = 4.25	77 /100
TOTAL SCORE	3.85 /5

Figure 11: 5S Process Audit

Daily Checklist					
	Monday	Tuesday	Wednesday	Thursday	Friday
Are all tools in their designated places?	☐	☐	☐	☐	☐
Are all materials/parts in their designated places?	☐	☐	☐	☐	☐
Is the workbench free of excess materials?	☐	☐	☐	☐	☐
Is the workstation area clean (swept and wiped down)?	☐	☐	☐	☐	☐
Is all waste (e.g., scrap, packaging) properly disposed of?	☐	☐	☐	☐	☐
Comments:					

Figure 12: Daily End-of-shift Operator 5S Checklist

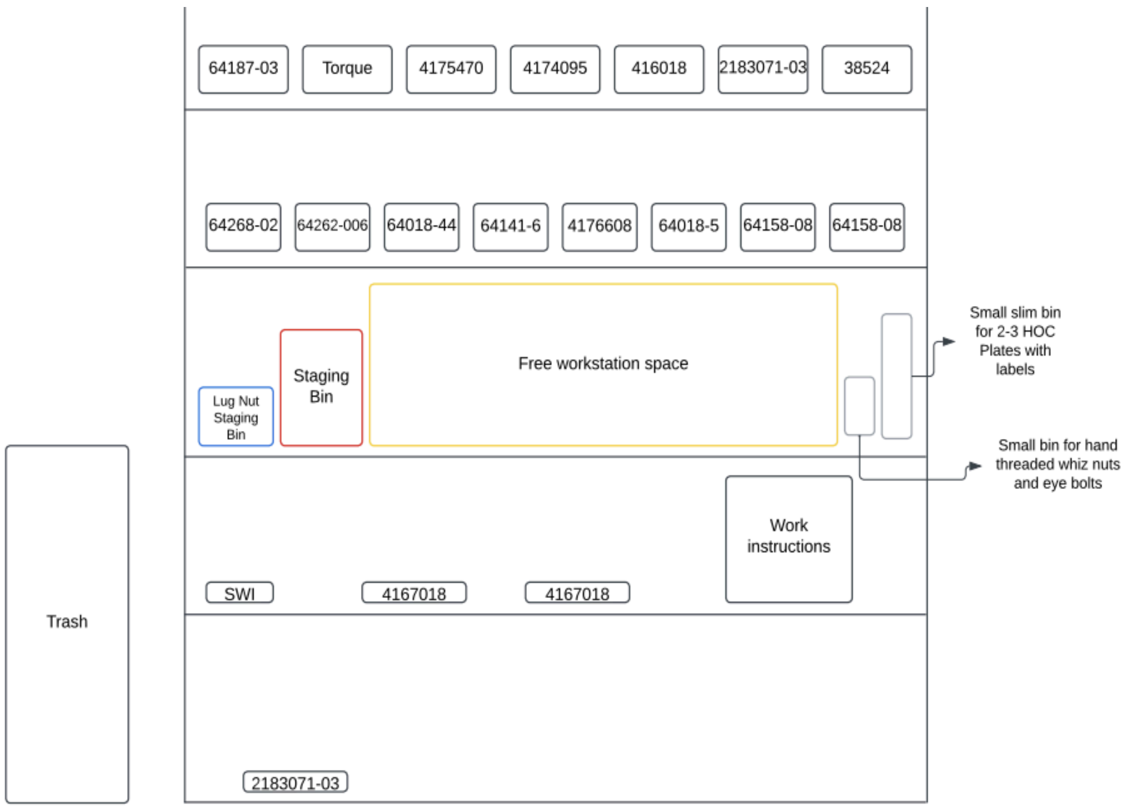

Figure 13: Proposed Workbench Diagram

Options	Total Ranking Scores Across All Criteria															
	Criteria 1: Can be implemented at no or low cost			Criteria 2: Can be implemented quickly and easily			Criteria 3: Solution significantly reduces ergonomic stress from			Criteria 4: Solution supports achieving at same or higher levels			Criteria 5: Solution requires minimal additional training			Total Across Criterion	Top Choices
	Rank	Weight Value	Weighted Rank	Rank	Weight Value	Weighted Rank	Rank	Weight Value	Weighted Rank	Rank	Weight Value	Weighted Rank	Rank	Weight Value	Weighted Rank		
(A) Require operators to adjust tire pallet to proper lifting height	7	1.35	9.45	7	0.85	5.95	2	1.55	3.1	3	0.95	2.85	6	0.3	1.8	23.15	4
(B) Implement team lifts of tires (2 operators)	4	1.35	5.4	6	0.85	5.1	1	1.55	1.55	1	0.95	0.95	8	0.3	2.4	15.40	7
(C) Use mobile carts to move tires	6	1.35	8.1	5	0.85	4.25	2	1.55	3.1	2	0.95	1.9	5	0.3	1.5	18.85	6
(D) Implement a rotating mower assembly stand	3	1.35	4.05	2	0.85	1.7	6	1.55	9.3	4	0.95	3.8	2	0.3	0.6	19.45	5
(E) Use a pneumatic lift cart	2	1.35	2.7	3	0.85	2.55	7	1.55	10.85	7	0.95	6.65	3	0.3	0.9	23.65	3
(F) Use a spring based height pallet for tires	5	1.35	6.75	4	0.85	3.4	8	1.55	12.4	6	0.95	5.7	4	0.3	1.2	29.45	2
(G) Use rail guided carts	1	1.35	1.35	1	0.85	0.85	4	1.55	6.2	5	0.95	4.75	1	0.3	0.3	13.45	8
(H) Install tires first, then move cart again for the rest of the assembly	8	1.35	10.8	8	0.85	6.8	5	1.55	7.75	8	0.95	7.6	6	0.3	1.8	34.75	1

Objective: What ergonomic solution for tire installation is best suited for Bobcat ZT2 Workstation 13?

Figure 14: Prioritization Matrix 2: Ergonomic Solutions

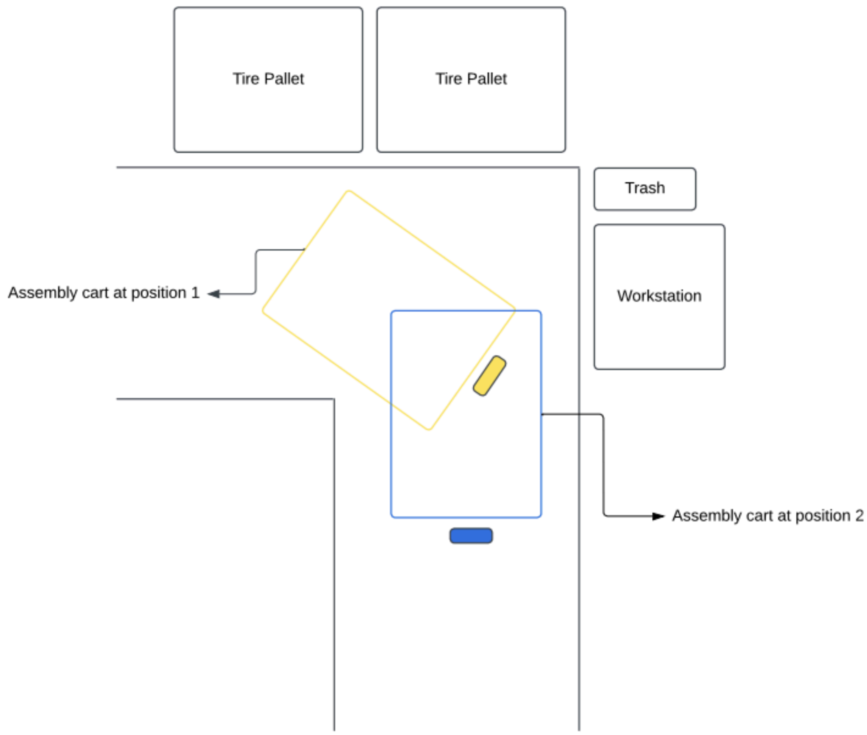

Figure 15: Proposed Workstation Floor Layout

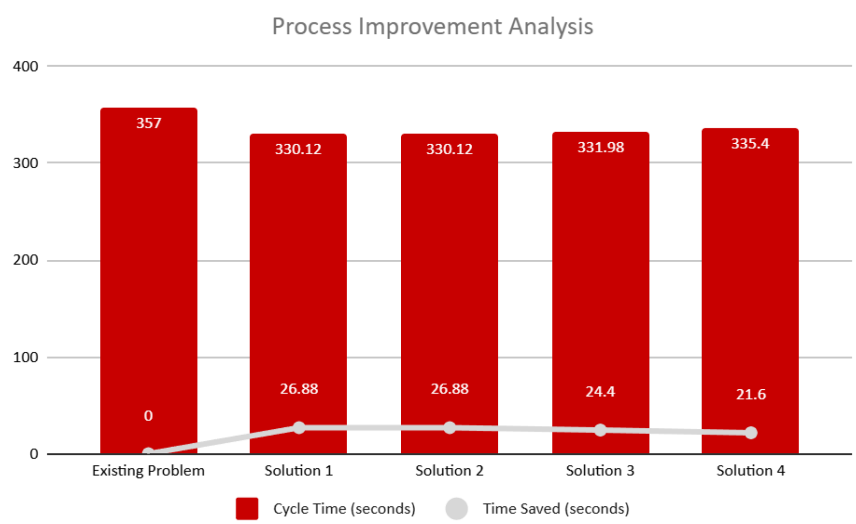

Figure 16: Cycle Time Reduction per Solution via MOST Analysis

Scenario	Cycle Time (seconds)	Time Saved (seconds)	Efficiency
Existing Problem	357	0	0
Solution 1	330.12	26.88	7.831
Solution 2	330.12	26.88	7.834
Solution 3	331.98	24.4	6.83
Solution 4	335.4	21.6	6.054
Averages for solutions	331.905	24.94	7.13725

Figure 17: Efficiency Gain Per Solution

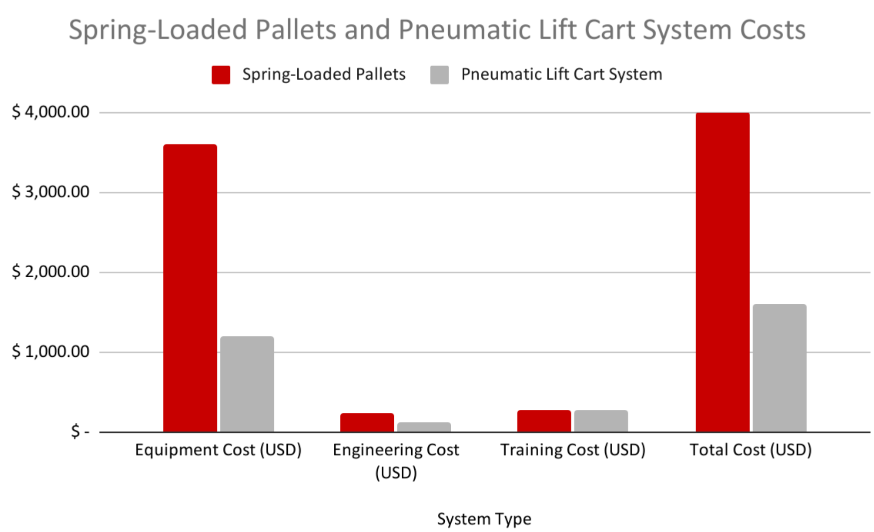

Figure 18: Associated Costs of New Equipment