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Evaluating the impact of lean on employee ergonomics, safety, and job satisfaction in manufacturing

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EVALUATING THE IMPACT OF LEAN ON EMPLOYEE ERGONOMICS,
SAFETY, AND JOB SATISFACTION IN MANUFACTURING

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
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in partial fulfillment of the
requirements for the degree of
Master of Science

in

The Department of Mechanical and Industrial Engineering

by
Amanda Morse
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For Meg, who always keeps me grounded.

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ABSTRACT

The goal of this study was to explore the proposed relationship between employee satisfaction, ergonomics, and safety while implementing a Kaizen event. In order to address this goal, two Kaizen events (K1 and K2) were conducted in a heavy equipment manufacturing plant. Before and after both events, levels of employee satisfaction were documented for Kaizen and Non-Kaizen (NK) participants using the Job Diagnostic Survey (JDS). The objective of the first event (K1) was to improve the efficiency of the task of torquing the rear axle bolts in Station #1- skid assembly. The K1 methodology followed a traditional Kaizen structure, enhanced with ergonomic and safety evaluation tools, Rapid Entire Body Assessment (REBA) and Job Hazard Analysis (JHA) respectively. During the event (K1), problem areas caused by the current skid were identified, analyzed, and a new skid was developed and implemented via a prototype. After testing the prototype all skids were replaced for full implementation. Ergonomic and safety was again evaluated. By using this approach to redesign the process, it was possible to improve productivity (83%), while reducing employee safety (from 5 hazards to 1 hazard) and ergonomics (REBA score from 13 to 11). The objective of the second kaizen event (K2) was to improve the efficiency of the manufacturing process for the welding subassembly station. The K2 methodology followed a traditional Kaizen structure, where the team identified the key problems for the welding subassembly station, analyzed the concerns for the material arrival, developed a solution for more consistent material delivery, and implemented a solution. By using Kaizen as a tool to address scheduling and material movement it was possible to improve the manufacturing process efficiency (36%). The JDS evaluation revealed mixed results for the impact of a Kaizen event on job satisfaction- some employee's job satisfaction levels increased when others decreased. The findings also show that some characteristics (Feedback from Agents ($p=0.036$), Experienced Meaningfulness of the Work ($p=0.036$), Growth Satisfaction ($p=0.027$), Satisfaction with Compensation ($p=0.034$), and Motivating Potential Score ($p=0.025$)) were significantly different across participants' groups (e.g. K1, K2 and NK). The events helped to encourage communication and involvement making the new processes more efficient and less frustrating for employees. Findings from this research contribute to a better understanding of the impact of lean on employees' ergonomics, safety, and job satisfaction.

INTRODUCTION

The manufacturing industry typically has a repetitive environment and a lack of employees' involvement. This condition has detrimental effects on productivity, safety, and employee involvement. Long-term success for manufacturers is dependent on improving both the productivity and safety of employees, forcing companies to search for strategies that will address multiple areas at once. Previous studies show that the combination of lean and ergonomics principles provide a reduction in occupational risks through the organization as well as provides increases in both quality and productivity (Bernstein, 2009). The theory for this study is that the use of lean strategies through a Kaizen event as a means to encourage communication between varying departments, companies can experience increases in productivity as well as employee ergonomics, safety, and job satisfaction.

Today industries around the world are experiencing an increasing amount of competition among peer companies and market demands. This results in companies searching for new and better practices for increasing employee involvement and performance, to improve their position in the global market. Many companies are using strategies like lean production (Krafcik, 1988), just-in-time (Abegglen & Stalk, 1985), total quality management (Deming, 1982), and best practices (Shadur, Rodwell, Simmons, & Bamber, 1994) for improved employee involvement and performance. These tactics are used as a means of increasing employee involvement so that the company will experience an increase in quality and productivity (Cotton, 1993). Employee involvement also has an impact on safety by reducing incidents and awareness (Leff, 2011).

Lean is a popular method of process improvement in many industries. Lean manufacturing is producing the most reliable products or services while having the lowest possible operational cost and inventory levels (Evans & Lindsay, 2008; Louis, 1997). While there is not a universal tool or philosophy that works in every project or company, a Kaizen event serves areas in need of rapid improvement well (Feld, 2001). Kaizen, a lean tool, can be used in both a discrete unit of the manufacturing operation as well as the overall process. Kaizen allows for actual hands-on implementation through a team effort of engineers and shop floor personnel. This maximizes ideas in theory with practicality for successful implementation (Walker, 1966). By using lean strategies with ergonomic, safety, and job satisfaction tools both individual work centers and the overall process can benefit. Lean can also be used as a tool for companies to reinforce their safety programs (Leff, 2011). Kaizen events help to encourage communication between varying departments. As a result, companies might experience an increase in both employee satisfaction and productivity (Hackman & Oldham, 1980; Vidal, 2007).

The goal of this research was to demonstrate the proposed relationship between lean and employee satisfaction, ergonomics, and safety. A heavy equipment manufacturing facility served as the test bed for this study. The objective of this study was to explore the impact of a Kaizen event on employee satisfaction, ergonomics, and safety levels in a heavy equipment manufacturing plant. This study focused on the evaluation of the manufacturing and assembly process for a tractor. In order to address the objectives of this study, two Kaizen events were performed. Before the implementation of both Kaizen (K1 and K2) events, levels of employee satisfaction for 15 employees were documented using the Job

Diagnostic Survey (JDS). The objective of the first Kaizen event (K1) was to improve the efficiency for the task of torqueing the rear axle bolts in Station #1. The methodology for the K1 event followed a traditional Kaizen event structure, enhanced with ergonomic and safety evaluation tools, the Rapid Entire Body Assessment (REBA) and Job Hazard Analysis (JHA) methodology respectively. Then a second Kaizen (K2) was performed. The objective of the K2 event was to improve the efficiency of the manufacturing process for a component feeding to final assembly. The methodology for the K2 event followed a traditional Kaizen event structure. Employee satisfaction was again evaluated 30 days after the completion of both K1 and K2 improvement implementations in order to evaluate the impact of the Kaizen events on employee's satisfaction for those involved and not involved.

REVIEW OF LITERATURE

Lean Manufacturing

The origin of lean manufacturing is often sighted in the Toyota Production System (Louis, 1997). The lean manufacturing system is also known as just-in-time management, continuous flow production, or World Class manufacturing. The Japanese manufacturers developed a concept called 'lean management' or 'lean thinking'. By developing new tactics towards the management of manufacturing, the Japanese have raised the bar for product and production performance (Lindberg, Voss, & Blackmon, 1998). This thinking was primarily based on the work done by W. Edwards Deming, who focused on achieving quality. Deming's work had two fundamentals; one, quality could not be achieved through managers doing a mass inspection and two, there should be a focus on improving the whole production process not just the product (Montgomery, 2009). A process includes the activities that go on without a previously established termination, while product refers to time-limited activities (Marras & Karwowski, 2006). As a result of following the Japanese developed manufacturing system, quality is being built into the service or product every step of the way (Montgomery, 2009).

Lean is a management approach for processes improvement as well as a methodology that is focused on reducing cycle time and waste in processes (Louis, 1997). Lean attempts to evaluate a process by comparing the value-added steps versus the non-value-added steps. By identifying every step in the process and throughout the value stream, ways to eliminate or reduce waste can then be better determined. Ultimately, lean uses less in order to do more (Evans & Lindsay, 2008). Lean manufacturing focuses on low-cost, high-quality, and time-sensitive production methods for customer-driven production rather than traditional mass production. Lean manufacturing helps deliver what the customer desires by minimizing waste and time (Loch, Heyden, Wassenhove, Huchzermeier, & Escalle, 2003).

The goal of lean thinking is to differentiate between the activities that add value and those that do not add value, which are therefore waste (Loch, et al., 2003). The Japanese try to eliminate waste, or muda, in all areas of the operation (Schniederjans, 1993). Womack and Jones (Womack & Jones, 2003) state that there are five principles of lean thinking. First, the value of each product or service needs to be established from the customer's perspective. Value is ultimately delivering the correct product, for the price, at the right time (Marras & Karwowski, 2006). There are typically multiple customers because a customer is identified as anyone, internal or external, that requires a product or service to be supplied to them. Second, identify all the steps throughout the value stream in order to highlight waste. This includes all activities and processes that are needed for the product or service to be produced. Waste is identified as anything that contributes to additional costs of a product or service without adding value (Womack & Jones, 2003). Waste is traditionally thought of as activities that don't add value to the final product based on customer requirements. Lean thinking forces the realization that waste is also seen in inefficient production rates, excess inventory, and unnecessary movement of people and products (Loch, et al., 2003). Specifically waste is typically seen in the areas of transportation, inventory, motion, underutilization, defects, over-processing, over-

production, and idle waiting (Kelby, 2012). Third, eliminate waste to make the products flow without interruption. Waste disrupts the flow to complete a product or process. A lean flow is achieved by minimizing bottlenecks and disconnections in the process. These bottlenecks and disconnects are often seen in machines that take longer than needed, poor training and staffing, limited information and direction, delayed arrival of materials, and insufficient quality of materials. As a result of having a lean flow, there is a reduction in lost orders, delays, mistakes, and other wastes. Fourth, only produce what the customer demands. Just-in-time manufacturing is essential to producing only what the customer demands. Fifth, perfection should be pursued by continuous improvements. The right value is created for the customer in a perfect process. Each step in a perfect process is valuable, capable, available, adequate, flexible, and linked by continuous flow. This means that the process creates value for the customer, produces a good result every time, produces the desired output as well as quality every time, and does not cause delays (Womack & Jones, 2003).

Lean manufacturing focuses on providing the customers with what is wanted, at the time wanted. This is achieved by using tools and principles to reduce or eliminate waste while only producing to the customer demands (Evans & Lindsay, 2008). Lean manufacturing is a complete cultural view of the interdependence between five key elements each with a set of lean principles. The key elements are manufacturing flow, organization, process control, metrics, and logistics. Manufacturing flow looks at the physical changes as well as design standards. Organization addresses the identification of individual's roles and functions, training in the new methods, and thorough communication. Process control focuses on monitoring, controlling, stabilizing, and pursuing improvements to the process. Metrics focuses on results-based performance measures, targeted improvement, and the recognition or rewards for teams. Logistics addresses the standardization and defining of operating rules for planning and controlling the material flows. Combined these elements achieve the highest level of performance excellence. As a result, there is a complete coverage for the many issues that could become apparent during a lean manufacturing implementation (Feld, 2001).

Lean concentrates on the processes, not just the results. Benefits from lean are widely seen. The results of lean are often seen through production capacity increases, inventory reductions, labor reductions, lower production costs, and waste reduction (Evans & Lindsay, 2008). There are numerous characteristics of a lean workplace. Often the work area is orderly and clean with standardized 'best' methods. Work standardization stabilizes performance because it reduces variability. Often these standards are developed and presented pictorially so that it is an easy and quick reference. This aids in designing techniques for error and mistake proofing, also known as poka-yoke. The layout of the facility encourages a continuous flow. Customer demands drive production through just-in-time processing, where a 'pull' system is required for getting the product completed (Louis, 1997). Just-in-time manufacturing is a strategy defined as the "successful completion of a product or service at each stage of production activity from vendor to customer just-in-time for its use and at a minimum cost (Schniederjans, 1993)." As a result of just-in-time processing, there are often single pieces or small batches produced that provide continuous workflow, minimal inventory on hand, and quick changeovers (Louis, 1997). Companies that utilize a pull system have superior flexibility and lower cost in on-hand inventory (Schniederjans, 1993). A great lean manufacturing system often utilizes both

Manufacturing Resource Planning (MRP) and kanban in order to optimize just-in-time production for a pull system. MRPII is a computer package that “is designed to launch, realign, and cancel purchase and manufacturing orders predicated upon projected demand (Louis, 1997, p.5).” MRPII aligns the master production schedule for customer orders to drive what purchases and production orders need to be launched, realigned, or canceled. The kanban technique, stocking using containers as a means to make production systems respond to the actual need for refilling instead of predictions, is a common way to optimize a pull system. The customer often experiences short time delays for the order-to-ship cycle. Customer satisfaction increases, as does the quality of the product they receive, as a result of defect prevention built into the processes. A lean work environment has better preventative maintenance and team-based continuous improvement (Louis, 1997).

Lean manufacturing is enhanced through the use of tools like Kaizen and Value Stream Mapping (Womack & Jones, 2003). When a team works together to identify the current state of a process, both business and manufacturing waste occurring throughout the processes are easily addressed (Kluck, 2003).

Kaizen

Kaizen is a Japanese word, meaning ‘gradual and orderly continuous improvement’ or incremental improvement (Louis, 1997). The root meaning of Kaizen can be broken down into two parts; ‘kai’ meaning change and ‘zen’ mean for the good. Just-in-time manufacturing was the foundation for this philosophy of improvement, which the Japanese referred to as Kaizen. Kaizen is an overall philosophy for the organization’s business activities and employees. This philosophy promotes improvements for better quality in all areas of business such as; cost, meeting delivery schedules, employee safety and skill development, supplier relations, new product development, and productivity (Evans & Lindsay, 2008). Kaizen is a methodology for continuous improvement in constant pursuit of perfection. The main goal of Kaizen is to identify and eliminate muda (Askin & Goldberg, 2002).

Kaizen focuses on “small, gradual, and frequent improvements over the long term with minimum financial investment and with participation by everyone in the organization (Evans & Lindsay, 2008).” Kaizen is a team approach to quickly breaking down and improving a process so that it is more efficient. By this definition any activity that addresses improvement is a Kaizen event. Operating practices, total involvement, and training are all needed for a successful Kaizen program. Operating practices open up new opportunities for improvement as a result of waste, inefficiency, and poor quality. Total involvement and training of all levels of an organization allow the tools and techniques of Kaizen to become embedded in the company culture. A Kaizen event is a short-term improvement event that focuses on the redesign of a certain process or a smaller portion with the goal of improving cost, quality, or delivery (Evans & Lindsay, 2008). Kaizen seeks to “simplify, combine, and eliminate” in order to improve processes and products (Askin & Goldberg, 2002).

There are many ways to optimize Kaizen event implementations. It is suggested that conventional ideas should be set aside and team members should think about how to do something rather than why it is impossible. Team members should also be encouraged to question current practices without making excuses (Tapping, 2007).

Kaizen helps to train people in basic tools for quality improvement. As a result of integrating Kaizen with the company culture, employees continually look for improvements in their own job areas. By having a process approach to improvement, better communication is seen between workers and managers (Evans & Lindsay, 2008). Askin and Goldberg (2002, p.355) state, "The golden rule of Kaizen is to utilize everyone's knowledge to identify and implement improvements quickly and without significant costs." Successful Kaizen events help build momentum and employee morale, which will lead to successful future events. This encourages employees to maintain changes while also seeking new opportunities for improvement (Askin & Goldberg, 2002).

In the literature and in practice, the number of steps and structure of a Kaizen event varies. Some companies have a coordinator for Kaizen improvement events. This coordinator directs the process steps so that all events can easily be compared. When using Kaizen for improvement it is necessary to first select the specific area for improvement. From there the exact area causing trouble should be determined so that all efforts are focused and concentrated. This will serve as the overall focus of the Kaizen event. Areas to focus on could include improving the quality of products, improving product yield, or decreasing lead-time. A team of multidisciplinary members should then be selected. Six to twelve employees, including a trained facilitator, supervisors, engineers, and line workers, form the team for the event. This team will gather for a Kaizen event to brainstorm and suggest ideas to rapidly improve the problem area (Askin & Goldberg, 2002). Kaizen events typically follow five structured steps over a three to five day period: 1) identify the problem, 2) analyze the problem, 3) develop a solution, 4) implement a solution, and 5) evaluate the results. To identify the problem it is important to establish the current state of the process. There are many techniques to help establish the current state. One technique is value stream mapping, where a flow-chart processes is used to map out the key steps in the process under evaluation. Value Stream Mapping is a technique used to create a "one page picture" (Kluck, 2003) of all the activities that occur through the company from when a customer places an order until the item is received. It is a way to follow a product's production path from beginning to end, and draw a visual representation of every process in the material and information flows (Rother & Shook, 2003). Value Stream Maps serve as a way to document the processes used to produce and ship a product by evaluating the Value-Added processes and the Non-Value-Added (waste) processes (Feld, 2001). The ultimate goal is to depict material and information flows both across and throughout all the Value- Adding processes that are necessary to produce and ship the product to the customer (Jones & Womack, 2002). Another technique is to question the current method through the "five whys" approach, where the leader will ask the team why five times as a means of finding the root cause or motivation for each action. The current state of the process and problem should be analyzed and evaluated from all stakeholders' perspectives. Brainstorming possible improvements is a great way to develop a possible solution. It is important to make sure the solution is realistic and feasible. Often the solution is proposed to the team prior to implementation. Finally, the results should be evaluated using same technique as the current state in order to properly compare the success or failure (Askin & Goldberg, 2002).

Ergonomics

Historically machines were designed and then an appropriate operator was found, as opposed to designing the machine to fit the human's needs (Bernstein, 2009). The work of Frederick Winslow Taylor to scientifically study the workers as a means to increase their efficiency helped the field of ergonomics start to rise. Taylor pioneered many principles that are still used today for task analysis such as work design as well as time and motion studies. World War I and II significantly influenced the development and study of Human Factors and Ergonomics (HFE). World War I forced attention toward the human capacity. During World War II it had become apparent that people could no longer be selected to work for a machine. This forced a change in philosophy and a realization that equipment needed to be designed in order to optimize human capabilities as well as avoid human limitations (Meister, 1999).

Ergonomics is a method that utilizes a widespread and multidisciplinary approach toward process improvement. Ergonomics takes into account both productivity and human aspects (Marras & Karwowski, 2006). One of the main goals of ergonomics is to increase the overall efficiency by improving the interaction between humans and all other parts of the system (Lee, 2005). Human factors and ergonomics strive to design equipment that optimize human capabilities and minimize human limitations (Meister, 1999). The continuous improvements that come from ergonomic initiatives often lead to the reduction of waste and non-value added time in processes (Zeng, Shi, & Lou, 2007).

Human factors and ergonomics play a key role for risk reduction when used to address multiple risks and continuous improvement. Ergonomics programs usually have a progression of results that are seen through smaller human factors projects. The results of human factors programs are first seen by tackling major ergonomic injuries, then minor ergonomic injuries, then productivity and quality performance improvements, and finally quality of work life improvements (Marras & Karwowski, 2006). This progression as depicted by Marras and Karwowski (Marras & Karwowski, 2006) can be seen in Figure 1.



Figure 1: Progression of the results of ergonomics projects (Marras & Karwowski, 2006).

When using ergonomics in the manufacturing industry, it is important to keep a practical approach. This is easily achieved with employee involvement and commitment from management. Ergonomic changes are more practical when using a participatory ergonomics approach. Employee involvement through participatory ergonomics helps to address basic factors in the problem, since the employee actually doing the job typically has invaluable insight toward possible improvements. By involving employees throughout the process the workers gain a sense of empowerment and ownership over the new changes

(Marras & Karwowski, 2006). Many companies encourage employees to take an active role in continuous improvement efforts through the use of ergonomics. These actions make employees more aware of their working environments and more involved in the improvement process.

Studies have shown that the most prosperous ergonomics programs identify low-cost solutions that yield substantial benefits. These benefits are seen in the reduction of injuries, workers compensation costs, and absenteeism. Benefits are also seen in increased employee morale, productivity, and quality of the products. These valuable results are reached and maintained through mutual effort toward a shared goal (United States General Accounting Office, 1997).

Similar to the lean process, successful ergonomics programs follow an established set of steps. The main steps are; identifying the problem, analyzing the problem, develop a solution, implementation of the solution, and evaluation of the results. When identifying the problem the work location should be evaluated for the physical aspects as well as the work methods, flow of products, and tool maintenance. The analysis of the problem should include the key goals and critical characteristics for the solution. When developing a solution many methods can be used such as brainstorming, group discussions, sketches, models, and complete mock up tests. For optimum implementation everyone should be adaptable and open to changing the plan if needed (Marras & Karwowski, 2006).

There are often numerous ways to tackle an ergonomics problem. This is because of the differences in company culture and awareness, technology level, and the resources available. Ergonomic programs are most successful when the problem has been carefully analyzed to optimize the changes that need to be made (Marras & Karwowski, 2006). Problems are often presented for ergonomic intervention when tasks must be completed under strained conditions. When work conditions are less-than-optimum employees often must increase their effort to complete a task or maintain efficiency. When effort is increased so does the risk for errors, accidents, and injuries (Nicholson & Ridd, 1988).

Many ergonomics programs encouraging safety and health improvements are a result of action-oriented or participatory ergonomics, where employees have an active role in the problem solving process. The most successful programs focus on the local issues and available resources in that specific environment (Kawakami & Kogi, 2001). Active involvement from employees utilizes the invaluable knowledge and ingenuity of workers and leads to an improved workplace and products (Marras & Karwowski, 2006).

After reviewing various ergonomic programs, Marras and Karwowski noted a set of success factors as well as common flaws (Marras & Karwowski, 2006). They were then able to establish that the success factors that contribute to a prosperous ergonomics program typically fall into four categories; meet business needs, avoid common traps, create a strong purpose, and maintain the program. They were able to develop a list of sixteen key factors that fall into the four categories, seen in Figure 2 (Marras & Karwowski, 2006). The success factors for an effective ergonomics program are to 1) emphasize business objectives, 2) avoid too many low-value/high-cost solutions, 3) ensure that ergonomics projects are evaluated quantitatively, 4) maintain a tabulation of the cost of projects, 5) use resources efficiently (the self-help/skilled-help/expert-help strategy), 6) identify and overcome barriers, 7) training should be supported by suitable infrastructure, 8) avoid using “ergo-babble,” 9) clearly define the purpose of your ergonomics program, 10) plan the stages of the ergonomics culture change, 11) create a strategic plan, 12) understand the

differences between an ergonomics program and the practice of ergonomics, 13) create a tactical plan, 14) ensure that there are regular quantitative evaluation of the overall ergonomics program, 15) do not wait for top management to push the program down, and 16) maintain political support (Marras & Karwowski, 2006).

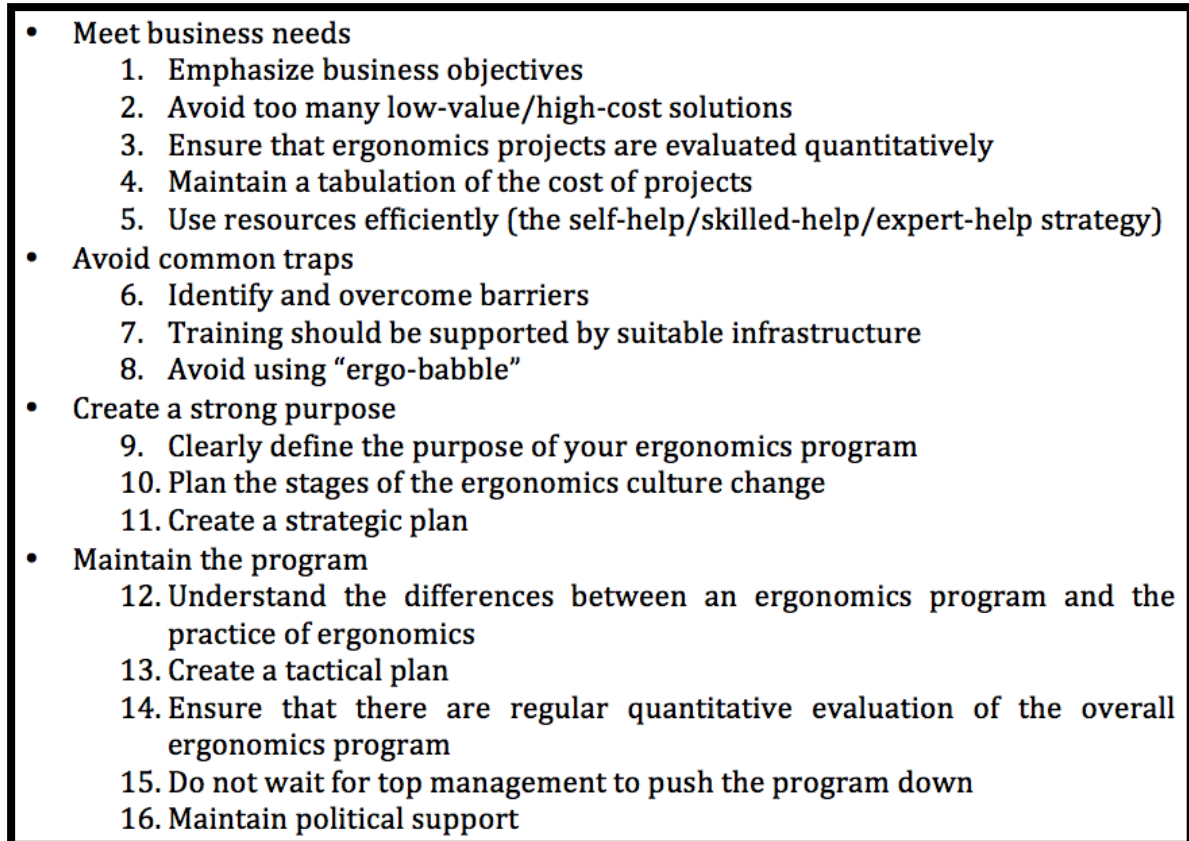
- 
- **Meet business needs**
 1. Emphasize business objectives
 2. Avoid too many low-value/high-cost solutions
 3. Ensure that ergonomics projects are evaluated quantitatively
 4. Maintain a tabulation of the cost of projects
 5. Use resources efficiently (the self-help/skilled-help/expert-help strategy)
 - **Avoid common traps**
 6. Identify and overcome barriers
 7. Training should be supported by suitable infrastructure
 8. Avoid using “ergo-babble”
 - **Create a strong purpose**
 9. Clearly define the purpose of your ergonomics program
 10. Plan the stages of the ergonomics culture change
 11. Create a strategic plan
 - **Maintain the program**
 12. Understand the differences between an ergonomics program and the practice of ergonomics
 13. Create a tactical plan
 14. Ensure that there are regular quantitative evaluation of the overall ergonomics program
 15. Do not wait for top management to push the program down
 16. Maintain political support

Figure 2: Success factors for an effective ergonomics program (Marras & Karwowski, 2006).

The literature and practice showcase several ergonomic evaluation tools to measure ergonomic programs and improvements. Ergonomic tools are used to measure and assess employees working conditions. There are many different ergonomic evaluation tools that are used to gather information on employee ergonomics. Marras and Karwowski (2006) provide an ergonomics program checklist that is a great aid in assessing both new and existing interventions that focus on ergonomics improvements, seen in Figure 3 (Marras & Karwowski, 2006).

In practice, companies might use tools developed by ergonomists such as the Rapid Entire Body Assessment (REBA), seen in Figure 4 (Hignett & McAtamney, 2000), which is based on the Rapid Upper Body Assessment (RULA) (McAtamney & Nigel Corlett, 1993). The REBA is often used to assess spinal and upper-extremity work-related postures. The current study used the REBA method since the RULA method focuses primarily on the upper-extremities and is not the best option to assess the lower back and whole body. The REBA system examines postures by measuring the body angles as well as evaluating the

Ergonomics Program Checklist		
	Yes	No
1. Program Goals	<input type="checkbox"/>	<input type="checkbox"/>
2. Management Commitment	<input type="checkbox"/>	<input type="checkbox"/>
3. Communication Plan	<input type="checkbox"/>	<input type="checkbox"/>
4. Program Resources Identified and Allocated	<input type="checkbox"/>	<input type="checkbox"/>
5. Formal or Informal Employee Involvement	<input type="checkbox"/>	<input type="checkbox"/>
6. Employee Training	<input type="checkbox"/>	<input type="checkbox"/>
7. Supervisor and Management Training	<input type="checkbox"/>	<input type="checkbox"/>
8. Risk Prioritization Protocol	<input type="checkbox"/>	<input type="checkbox"/>
9. Risk Assessment Plan	<input type="checkbox"/>	<input type="checkbox"/>
10. Solution Development Plan	<input type="checkbox"/>	<input type="checkbox"/>
11. Employee Participation in Solution Ideas	<input type="checkbox"/>	<input type="checkbox"/>
12. Follow-through on Identified Solutions	<input type="checkbox"/>	<input type="checkbox"/>
13. Program Evaluation Plan	<input type="checkbox"/>	<input type="checkbox"/>

Figure 3: Ergonomic Program Checklist (Marras & Karwowski, 2006).

load or force, repetitiveness of movements, and the frequency of those position changes. The postures are grouped into ranges for the neck, trunk, upper and lower arms, legs, and wrists. Each of the posture ranges is then correlated with a score that progressively increases with the distance from the given neutral position. Score A is determined from the sum of the posture scores for the trunk, neck, and legs as well as the determined Load/Force score. Score B is determined from the sum of the posture scores for the upper arms, lower arms, and wrists as well as the coupling score for each hand. The final REBA score is equal to the sum of the given table value for the combination of Score A and Score B and the activity score. The final REBA score tells the evaluator the severity of the ergonomic posture and thus the priority that needs to be placed for process improvement. The REBA scores range from less than 1 to greater than 11; 1 = negligible risk, 2 or 3 = low risk, change may be needed, 4 to 7 = medium risk, further investigation, change soon, 8 to 10 = high risk, investigate and implement change, 11+ = very high risk, implement change (Hignett & McAtamney, 2000).

The REBA was formulated by Hignett and McAtamney (2000) after an analysis of the reliability of body part coding of over 600 different postures throughout the health care, manufacturing, and electricity industries that was conducted by a team of health care professionals that included occupational therapists, physical therapists, nurses, and ergonomists. The REBA serves as both a reliable and valid tool. The reliability was established by first having three ergonomists/physiotherapists independently code the 144 posture combinations. Next the professionals dissolved any conflicting scores. The group then determined the needed risk scores for loading, coupling, as well as activity, which would then generate the final REBA score of a value from 1 to 15. Second, two teams of health care professionals that included occupational therapists, physical therapists, nurses, and ergonomists were assembled to review the body part coding of over 600 different postures throughout the health care, manufacturing, and electricity industries (Hignett & McAtamney, 2000). This provides strong face validity for the REBA method. The

REBA Employee Assessment Worksheet

based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

 Step 1a: Adjust...
 If neck is twisted: +1
 If neck is side bending: +1
Neck Score

Step 2: Locate Trunk Position

 Step 2a: Adjust...
 If trunk is twisted: +1
 If trunk is side bending: +1
Trunk Score

Step 3: Legs

 Step 3a: Adjust...
 If leg is twisted: +1
 If leg is side bending: +1
Leg Score

Step 4: Look-up Posture Score in Table A
 Using values from steps 1-3 above, locate score in Table A

Step 5: Add Force/Load Score
 If load < 11 lbs: +0
 If load 11 to 22 lbs: +1
 If load > 22 lbs: +2
 Adjust: If shock or rapid build up of force: add +1
Force/Load Score

Step 6: Score A, Find Row in Table C
 Add values from steps 4 & 5 to obtain Score A.
 Find Row in Table C.

Scoring:
 1 = negligible risk
 2 or 3 = low risk, change may be needed
 4 to 7 = medium risk, further investigation, change soon
 8 to 10 = high risk, investigate and implement change
 11+ = very high risk, implement change

SCORES

Table A

	Neck		
	1	2	3
Legs	1	2	3
Trunk Posture Score	1	2	3

Table B

	Lower Arm	
	1	2
Wrist	1	2
Upper Arm Score	1	2

Table C

Score A	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	4	5	6	7	7	7	7
2	1	2	2	3	4	5	6	7	7	8	8	8
3	2	3	3	4	5	6	7	7	8	8	8	8
4	3	4	4	5	6	7	8	8	9	9	9	9
5	4	4	5	6	7	8	8	9	9	9	9	9
6	5	5	6	7	8	9	9	10	10	10	10	10
7	6	6	7	8	9	9	10	10	11	11	11	11
8	7	7	8	9	9	10	10	11	11	11	11	11
9	8	8	9	10	10	11	11	11	12	12	12	12
10	9	9	10	11	11	11	12	12	12	12	12	12
11	10	10	11	12	12	12	12	12	12	12	12	12
12	11	11	12	12	12	12	12	12	12	12	12	12

Table C Score + **Activity Score** = **Final REBA Score**

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

 Step 7a: Adjust...
 If shoulder is raised: +1
 If upper arm is abducted: +1
 If arm is supported or person is leaning: -1
Upper Arm Score

Step 8: Locate Lower Arm Position:

Lower Arm Score

Step 9: Locate Wrist Position:

 Step 9a: Adjust...
 If wrist is bent from midline or twisted: Add +1
Wrist Score

Step 10: Look-up Posture Score in Table B
 Using values from steps 7-9 above, locate score in Table B

Step 11: Add Coupling Score
 Well fitting Handle and mid rang power grip: good: +0
 Acceptable but not ideal hand hold or coupling acceptable with another body part: fair: +1
 Hand hold not acceptable but possible: poor: +2
 No handles, awkward, unsafe with any body part: unacceptable: +3
Coupling Score

Step 12: Score B, Find Column in Table C
 Add values from steps 10 & 11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.

Step 13: Activity Score
 +1 1 or more body parts are held for longer than 1 minute (static)
 +1 Repeated small range actions (more than 4x per minute)
 +1 Action causes rapid large range changes in postures or unstable base

Task name: _____ Reviewer: _____ Date: ____/____/____
 This tool is provided without warranty. The author has provided this tool as a simple means for applying the concepts provided in REBA. © 2004 Hignett Consulting, Inc. provided by Practical Ergonomics
 rbarker@ergosmart.com (816) 444-1667

Figure 4: Rapid Entire Body Assessment (REBA) (Hignett & McAtamney, 2000).

REBA evaluation tool is widely used in many industries (Stanton, Hedge, Brookhuis, Salas, & Hendrick, 2004). Therefore the REBA serves as a valid and reliable evaluation tool when analyzing the measure of spinal and upper-extremity work-related postures. It is believed that for this case study and the postures that were evaluated the REBA method has sufficient content validity. The REBA method is designed to evaluate specific and repeatable tasks and is best when used in industries, like manufacturing, that the employees routinely perform job tasks by repeatable methods and procedures (Vieira & Kumar, 2004). To correctly use the REBA method each employee should be photographed while performing daily tasks by an independent evaluator from the front, back, left and right. The photographs should then be used to calculate the values for the body angles (Hignett & McAtamney, 2000).

The REBA evaluation tool was selected for the current study since previous research showed the effectiveness when used for whole body analysis in repetitive jobs like manufacturing. The REBA is widely used in practice and research (Dempsey, McGorry, & Maynard, 2005). The University of Southern Florida, College of Public Health website provides the REBA as a valid and reliable tool to use when evaluating the whole body ergonomics (Bernard, 2007) much like the current study. Success was reported when using the REBA to evaluate complaints of operators in video display terminals (Pillastrini et al.,

2007). An evaluation of manual handling practices in a supermarket found that the REBA method would be more useful if applied to a situation where specific ergonomic changes are implemented to decrease the risk from work-related injuries (Coyle, 2005). Coyle (2005) also found that the REBA was ideal if a quantitative value is needed for re-assessment after implementing ergonomic modification to determine the effectiveness. Similar advantages and disadvantages for the REBA method were found when current techniques for evaluating physical exposure to work-related risks (Li & Buckle, 1999). Since the REBA method worked best with photographing employees, the independent ergonomic evaluator was needed for a shorter period of time. The current study required the evaluation of a specific and repeatable manufacturing task, which is the type of situation that is best suited for the REBA methodology. As opposed to other ergonomic evaluation tools, the REBA evaluation tool provided the ability to analyze the whole body. A whole body evaluation was critical for the standing activity in the current study.

Safety

Safety in manufacturing facilities is vital for all levels of the organization. The overall safety of a system is important to all participants, especially when there is an increased risk of accidents occurring. These accidents within a system can cause damages to property, the environment, or people (Appicharla, 2006). Today the United States Department of Labor is placing more and more of an emphasis on safety in the workplace. The Occupational Safety & Health Administration (OSHA) is leading the way for employee safety and health. OSHA has established some core elements that are needed for ongoing positive safety programs. These core elements include; “management leadership and employee participation, hazard identification and assessment, hazard prevention and control, information and training, and evaluation of the program effectiveness (Occupational Safety and Health Administration, 2012).” Companies recognize the value that is added to their business from a positive safety and health environment. A strong safety environment is likely to experience a reduction in work related injuries, more efficient work methods, lower workers’ compensation costs, as well as an increase in worker productivity (Occupational Safety and Health Administration, 2002). Safety in the work place is implemented through Voluntary Protection Programs (VPP) as well as hazard detection processes (Occupational Safety and Health Administration, 2012).

Work-related injuries are prevented or reduced when companies evaluate current workplace operations, determine proper procedures, and provide training to all employees. OSHA notes that a best practice to determine and establish the correct work procedure is by conducting a Job Hazard Analysis (Occupational Safety and Health Administration, 2012). The Job Hazard Analysis (JHA), also known as Job Safety Analysis (JSA), for the work environment in question should be conducted independently by a safety professional or risk manager because they have invaluable knowledge towards identifying and preventing occupational hazard and work-related risks (National Safety Council, 2009; Swartz, 2001). The most used source for the JHA format is the National Safety Council’s (NCS) form, seen in Figure 5, this form has been modified over the years from the original version (National Safety Council, 1964). The JHA has become an established building block for safety programs. The JHA helps to identify the standard hazards in a work environment and steps to mitigate the safety gaps (Swartz, 2001). The JHA as a tool provides a solid framework for

using the JHA as a process for a safer work environment. OSHA notes that the JHA can be conducted in many jobs but that it is ideal for “jobs with the highest injury or illness rate, jobs with the potential to cause severe or disabling injuries or illness (even if there is no history of previous accidents), jobs in which one simple human error could lead to a severe accident or injury, jobs that are new to your operation or have undergone changes in processes or procedures, and jobs complex enough to require written instruction (Occupational Safety and Health Administration, 2002).”

<i>Job Title:</i>	<i>Job Location:</i>	<i>Analyst</i>	<i>Date</i>
<i>Task #</i>	<i>Task Description:</i>		
<i>Hazard Type:</i>	<i>Hazard Description:</i>		
<i>Consequence:</i>	<i>Hazard Controls:</i>		
<i>Rational or Comment:</i>			

Figure 5: Job Hazard Analysis (JHA) (National Safety Council, 2009; Occupational Safety and Health Administration, 2002).

The JHA was formulated and seen in the fifth edition of *Accident Prevention Manual for Industrial Operations* (National Safety Council, 1964). The first step in using the JHA is to involve the employees. By involving employees with a unique understanding of the job a quality analysis can better be conducted and potential oversights will be minimized. Second, the accident history should be reviewed since they are indicators of gaps in the current safety environment. Third, a job review should be conducted with the employees so that all parties can brainstorm for ideas to eliminate or minimize the current hazards that are recognized. Fourth, the job hazards should be listed, ranked, and priorities established. Fifth, the steps or tasks for the work environment should be documented and reviewed to

discuss uncontrolled hazards with recommended solutions. Some key questions to ask during this process include; what can potentially go wrong, what would the consequences be, what are the other contributing factors, and what is the likeliness this hazard will occur (Occupational Safety and Health Administration, 2002)?.

The JHA evaluation tool is widely used in many industries for hazard identification, employee training, and incident investigation. When filling out the JHA form it is important to identify the OSHA recognized hazards and description, shown in Figure 6. The JHA has served as both a reliable and valid tool for evaluating safety hazards in a work environment for many years (Occupational Safety and Health Administration, 2002). It is believed that for this case study and the workplace safety that was evaluated the JHA provides sufficient validity.

Common Hazards and Descriptions					
Hazards	Hazard Descriptions				
Chemical (Toxic)	A chemical that exposes a person by absorption through the skin, inhalation, or through the blood stream that causes illness, disease, or death. The amount of chemical exposure is critical in determining hazardous effects. Check Material Safety Data Sheets (MSDS), and/or OSHA 1910.1000 for chemical hazard information.	Electrical (Fire)	Use of electrical power that results in electrical overheating or arcing to the point of combustion or ignition of flammables, or electrical component damage.	Mechanical Failure	Self explanatory; typically occurs when devices exceed designed capacity or are inadequately maintained.
		Electrical (Static/ESD)	The moving or rubbing of wool, nylon, other synthetic fibers, and even flowing liquids can generate static electricity. This creates an excess or deficiency of electrons on the surface of material that discharges (spark) to the ground resulting in the ignition of flammables or damage to electronics or the body's nervous system.	Mechanical	Skin, muscle, or body part exposed to crushing, caught-between, cutting, tearing, shearing items or equipment.
				Noise	Noise levels (>85 dBA 8 hr TWA) that result in hearing damage or inability to communicate safety-critical information.
Chemical (Flammable)	A chemical that, when exposed to a heat ignition source, results in combustion. Typically, the lower a chemical's flash point and boiling point, the more flammable the chemical. Check MSDS for flammability information.	Electrical (Loss of Power)	Safety-critical equipment failure as a result of loss of power.	Radiation (Ionizing)	Alpha, Beta, Gamma, neutral particles, and X-rays that cause injury (tissue damage) by ionization of cellular components.
		Ergonomics (Strain)	Damage of tissue due to overexertion (sprains and strains) or repetitive motion.	Radiation (Non-ionizing)	Ultraviolet, visible light, infrared, and microwaves that cause injury to tissue by thermal or photochemical means.
Chemical (Corrosive)	A chemical that, when it comes into contact with skin, metal, or other materials, damages the materials. Acids and bases are examples of corrosives.	Ergonomics (Human Error)	A system design, procedure, or equipment that is error-provocative. (A switch goes up to turn something off).	Struck By (Mass Acceleration)	Accelerated mass that strikes the body causing injury or death. (Examples are falling objects and projectiles.)
Explosion (Chemical Reaction)	Self explanatory.	Excavation (Collapse)	Soil collapse in a trench or excavation as a result of improper or inadequate shoring. Soil type is critical in determining the hazard likelihood.	Struck Against	Injury to a body part as a result of coming into contact of a surface in which action was initiated by the person. (An example is when a screwdriver slips.)
Explosion (Over Pressurization)	Sudden and violent release of a large amount of gas/energy due to a significant pressure difference such as rupture in a boiler or compressed gas cylinder.	Fall (Slip, Trip)	Conditions that result in falls (impacts) from height or traditional walking surfaces (such as slippery floors, poor housekeeping, uneven walking surfaces, exposed ledges, etc.)	Temperature Extreme (Heat/Cold)	Temperatures that result in heat stress, exhaustion, or metabolic slow down such as hypothermia.
Electrical (Shock/ Short Circuit)	Contact with exposed conductors or a device that is incorrectly or inadvertently grounded, such as when a metal ladder comes into contact with power lines. 60Hz alternating current (common house current) is very dangerous because it can stop the heart.	Fire/Heat	Temperatures that can cause burns to the skin or damage to other organs. Fires require a heat source, fuel, and oxygen.	Visibility	Lack of lighting or obstructed vision that results in an error or other hazard.
		Mechanical/ Vibration/ Chaffing/ Fatigue)	Vibration that can cause damage to nerve endings, or material fatigue that results in a safety-critical failure. (Examples are abraded slings and ropes, weakened hoses and belts.)	Weather Phenomena (Snow/Rain/ Wind/Ice)	Self explanatory.

Figure 6: Standard job hazards descriptions (National Safety Council, 2009).

The JHA is widely used in practice and research (Caseley, Guerra, & Froome, 2006). Safety analysis involves establishing the best practice for the needed job task as well as reducing the possible hazards associated with the work content and environment (Swartz, 2001). The JHA helps provide a new approach to finding hazards for nurses in an emergency care facility (Ramsay et al., 2006). Glenn (2011) noted that there are significant benefits when using a JHA process and procedures correctly. Rozenfeld, Sacks, Rosenfeld, and Baum (2010) provided an example for using the JHA not only as “an efficient proactive measure for safety risk assessment used in industrial manufacturing settings” but as the base for adaptation to a safety assessment for the construction environment.

The use of JHA is an established practice in the safety field and was used in the current study. Prior to this study, the participating factory used the JHA evaluations, as a normal procedure, to identify and establish correct working procedures and reduce potential hazards. JHA historical records were easily obtainable to review for possible indicators of past and current safety gaps. The current study selected the JHA tool since previous research showed the effectiveness when used for a manufacturing setting and the availability of historical data from the participating factory. Independent safety

professional at the manufacturing facility conducted a JHA and then reviewed the assessment with employees to better engage them in determining and establishing the optimum working procedures.

Employee Satisfaction

Employee job satisfaction is defined as the level of satisfaction that an employee extracts from an assigned task. Job satisfaction is important because it may be linked to motivation and capacity of employees (Stahl, 2004). Employee job satisfaction is comprised of feelings, beliefs, and behaviors (Brief & Weiss, 2002; Weiss, 2002). Ultimately the goal of any organization is to perform at a high level. Employee satisfaction typically is a result not a goal (Kelleher, 2010). Employees that perform at a high level often become frustrated if there are less engaged workers around them receiving the same benefits. As a result the high performing employee will question the judgment and strategic goals of an employer who does not address the difference in performance (Kelleher, 2010). Studies have shown that when companies allow poor performance to become the acceptable average the engagement and satisfaction of other employees decreases (Kelleher, 2010).

There are many factors that influence employee satisfaction levels such as management styles and company culture as well as employee involvement, empowerment, and independence (Vidal, 2007). These influences can be broken down into two main components, environmental and individual factors.

Environmental factors influencing satisfaction stem from the physical strains of the job or communication issues (Rowe, 1987). Ergonomic enhancements can help reduce or eliminate physical strains. This in turn influences employee satisfaction because of the contributions to employee health and safety. It has been proven that healthy people are able to perform and work better (Marras & Karwowski, 2006). Communication with management and the tasks required significantly influence worker satisfaction. Employees can be over-loaded and under-loaded with communication. Overwhelming feelings occur when the rate and complexity of communicated content increase and employees receive too much information at once. This causes some things to unprocessed or processed incorrectly. Communication under-loading occurs when employees are not given enough information. When workers are unsuccessful in processing information or are given insufficient direction they are more likely to become dissatisfied, aggravated, and unhappy. These this are detrimental to job moral and satisfaction (Farace, Monge, & Russell, 1977). Management and workforce communication plays a key role in the way employees perceive their superiors and thus influences the employees' satisfaction. Nonverbal communication such as facial expressions, eye contact, and body movement are critical to a well-balanced relationship between management and the workforce. Some even believe that nonverbal communication is more important than what is actually said because individuals that dislike their supervisor or management are typically not as open to communication and are less motivated (Burgoon, Buller, & Woodall, 1996).

Individual factors influencing satisfaction stem from mood and emotion, genetics, and personality of the employee. An employee's positive and negative moods and emotions influence overall job satisfaction (Brief & Roberson, 1989; Fisher, 2000; Weiss, Nicholas, & Daus, 1999). When employees suppress negative emotions there is a decrease in job satisfaction (Côté & Morgan, 2002). How individuals deal with emotions depends on two

models, emotional dissonance and social interaction model. Emotional dissonance concerns the balance between public displays of emotions and internal emotions. The social interaction model demonstrates the relationship that other employees' emotions influence a workers attitude and thus job satisfaction (Brief & Roberson, 1989). Genetics is believed to directly contribute to job satisfaction through an individual's need for challenge and achievement (Rowe, 1987). Research also suggests that personality influences job satisfaction through positive and negative affectivity. An individual's affectivity relates to how they perceive job circumstances like the environment and pay. Employees who are high in positive affectivity are often more satisfied in their life and job (Brief & Weiss, 2002).

The literature offers several tools to evaluate employees' job satisfaction such as the Job Diagnostic Survey (JDS). The goals of the Hackman-Oldham Job Diagnostic Survey (JDS) are to gain firsthand experience of the job characteristics in the approach to job design and to gain personal feedback about the motivating potential of the present and/or past job critical characteristics (Hackman & Oldham, 1980). JDS is an instrument that was designed to evaluate key job characteristics. Furthermore, The JDS was designed to be used both in the diagnosis of jobs prior to their redesign, and in research and evaluation activities aimed at assessing the effects of redesigned jobs on workers (Hackman & Oldham, 1980). Yale University developed the JDS tool for a study of jobs and the way people react to them. It is used to "determine how jobs can be better designed, by obtaining information about how people react to different kinds of jobs (Hackman & Oldham, 1980)." This survey measures numerous job characteristics, employee psychological state, employee satisfaction with both job and work content, and the employee needs. The JDS is designed with the intention that the actual employee in the job completes it, not someone outside evaluating. If it is not the actual employee completing the survey the proper tool to use is the Job Rating Form (JRF).

JDS consists of eight sections that are designed to evaluate five core job characteristics; skill variety, task identity, task significance, autonomy, and feedback (Hackman & Oldham, 1980).

1. Skill Variety- looks at how much diversity is needed in that job complete the required tasks.
2. Task Identity- evaluates how much of the work for that job requires completing a whole or identifiable task.
3. Task Significance- examines the amount of the job that has a considerable impact on other people's lives or work.
4. Autonomy- looks at the amount of freedom, independence, and discretion for the job scheduling and processes that is given to the employee that will be completing the work.
5. Feedback- evaluates the amount of information the employee receives about the results of completed work.

These core job characteristics make up the three critical psychological states; meaningfulness of work, responsibility for outcomes, and knowledge of results. All of these things combine to form the level of internal work motivation. Hackman and Oldham visually depict these five job characteristics that foster the three psychological states as seen in Figure 7.

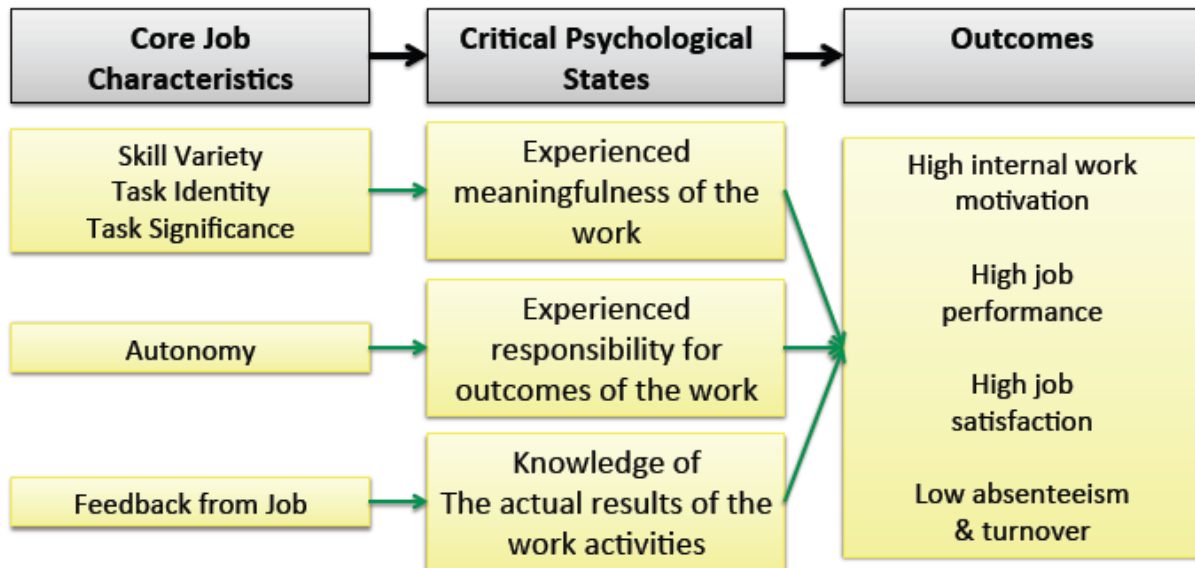


Figure 7: Job characteristic that foster the three psychological states (Hackman & Oldham, 1980).

After the JDS is completed it is scored to obtain values for the job characteristics, experienced psychological states, affective outcomes, context satisfactions, and individual growth need strength. Following the model of job characteristic that foster the three psychological states, the scores for the five characteristics are then combined into a single index, motivating potential score, which helps to better depict the overall potential a job has to foster internal work motivation and all three of the critical psychological states. The motivating potential score (MPS) is determined by the formula seen in Figure 8 (Hackman & Oldham, 1980). This equation depicts the importance of both autonomy and feedback since a low score on either will reduce the overall MPS of the job. The MPS is determined in this way because for successful outcomes, using the model of job characteristic that foster the three psychological states, both experienced responsibility as well as knowledge of the results is required.

$$MPS = \frac{\text{Skill Variety} + \text{Task Identity} + \text{Task Significance}}{3} \times \text{Autonomy} \times \text{Job Feedback}$$

Figure 8: Motivating Potential Score (MPS) (Hackman & Oldham, 1980).

The results for the JDS are divided into 21 categories. The categories, seen in Figure 9, are Skill Variety, Task Identity, Task Significance, Autonomy, Feedback from the Job Itself, Feedback from Agents, Dealing with Others, Experienced Meaningfulness of the Work, Experienced Responsibility for the Work, Knowledge of Results, General Satisfaction, Internal Work Motivation, Growth Satisfaction, Satisfaction with Job Security, Satisfaction with Compensation, Satisfaction with Co-Workers, Satisfaction with Supervision, "Would Like" Format, "Job Choice" Format, Combined Growth Need Strength Score, and Motivating Potential Score (MPS) (Hackman & Oldham, 1980). The employee evaluation results from

JDS Category	
I. Job Characteristics	
	A. Skill Variety
	B. Task Identity
	C. Task Significance
	D. Autonomy
	E. Feedback from the Job Itself
	F. Feedback from Agents
	G. Dealing with Others
II. Experienced Psychological States	
	A. Experienced Meaningfulness of the Work
	B. Experienced Responsibility for the Work
	C. Knowledge of Results
III. Affective Outcomes	
	A. General Satisfaction
	B. Internal Work Motivation
	C. Growth Satisfaction
IV. Context Satisfaction	
	A. Satisfaction with Job Security
	B. Satisfaction with Compensation (Pay)
	C. Satisfaction with Co-Workers
	D. Satisfaction with Supervision
V. Individual Growth Need Strength	
	A. "Would Like" Format
	B. "Job Choice" Format
	C. Combined Growth Need Strength Score
VI. Motivating Potential Score	
	MPS

Figure 9: JDS Evaluated Categories (Hackman & Oldham, 1980).

the JDS scoring should then be compared with the norms for that job family, which are provided by Hackman & Oldham (Hackman & Oldham, 1980). Hackman and Oldham (1980, p.81) reported that the JDS “yields scores for each job characteristic, ranging from a low of 1 to a high of 7. Following the above formula, this means that the lowest possible MPS for a job is 1 and the highest possible is 343.” There are three key factors that influence if people

will respond positively to jobs with a high MPS value, 1) knowledge and skill, 2) growth and strength, and 3) “context” satisfactions. These factors should be moderated when implementing job changes to maximize positive responses. The moderators of the relationship between job characteristics and internal motivation can be seen in Figure 10.

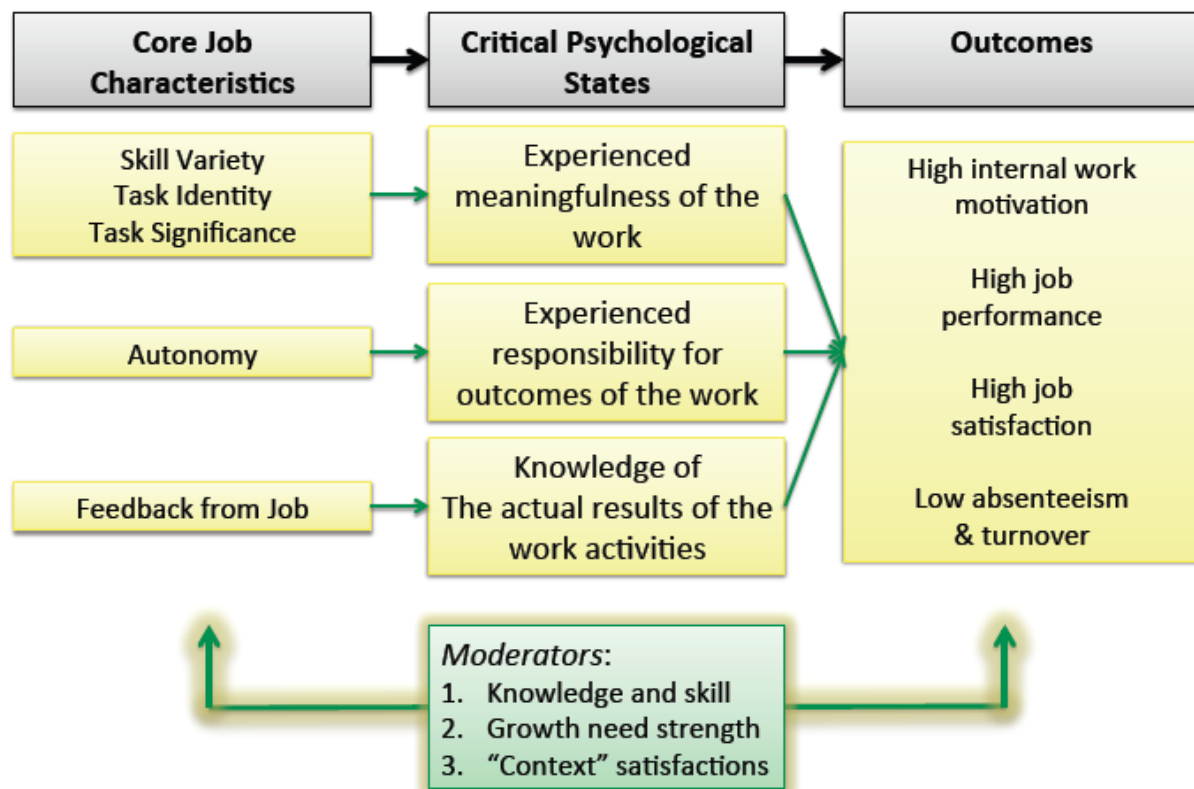


Figure 10: Moderators of the relationship between the job characteristics and internal motivation (Hackman & Oldham, 1980).

Relationship between Lean, Ergonomics, Safety, and Job Satisfaction

The impacts of Lean strategies have been explored from ergonomics, safety and job satisfaction perspectives in a topical manner. The literature presents different successful and unsuccessful lean strategies as well as their impact on these factors, but only one or few factors are addressed at a time. This implies that there is not one single study that explores the impact of lean strategies on all three factors; ergonomics, safety and job satisfaction. Furthermore, some previous studies show conflicting relationships between lean and ergonomics, safety, and job satisfaction. Previous literature seems to be mostly divided with enthusiasm and criticism of the effects of workplace implementation of lean and ergonomics. The controversy surrounding the relationship between different improvement initiatives creates the need for further study and evaluation. The current research seeks to better understand the impact on employee satisfaction from lean improvements implemented via a kaizen event (K2) or a kaizen event integrated with ergonomics and safety for a single process improvement framework (K1). A single process

improvement framework would allow for companies to see benefits in multiple areas and aid the company culture for continuous improvement.

Some previous research suggests that there are negative effects on employee satisfaction, ergonomics, and safety after the implementation of lean principles. Parker's (2003) 3-year field study showed that the employees involved in lean implementation working in assembly lines had a reduction in organizational commitment and self-efficacy and thus increased job depression. The analysis also showed that negative effects seen from lean production were somewhat linked to decreases in perceived work characteristics such as job autonomy, skill utilization, and participation in decision making (Parker, 2003). Boswell, Boudreau, and Tichy (2005) examined the relationship between employee job change and job satisfaction. The research found that after a voluntary job change the employee job satisfaction levels immediately increased but were followed by a decrease. Anderson-Connolly, Grunberg, Greenberg, & Moore (2002) examined the relationship for workplace transformation with the well being of employees in a manufacturing company for the dimensions of intensity, autonomy, team-work, skilling, and computing. Their data showed that some components were harmful while others were beneficial to the employees (Anderson-Connolly, et al., 2002). Vidal's (2007) study on lean production, worker empowerment, and job satisfaction also yielded mixed results. The research found that workers could be satisfied in a traditional Lean manufacturing environment and that an increase in employee involvement was not always related to an increase in satisfaction (Vidal, 2007). Some research, such as Glendon (2008), suggests minimal contributions from ergonomics to the safety culture of a company.

Other previous research suggests that there are positive effects on employee satisfaction after the implementation of lean principles. Lean environments offer a culture that pursues perfection through continuous improvement (Evans & Lindsay, 2008). Lean often focuses on reducing waste in a process. Waste is traditionally thought of as scrap and rework. Lean thinking forces the understanding that waste is also seen in poor quality, inefficient production rates, excess inventory, and unnecessary movement of people and products (Loch, et al., 2003). Waste is often seen in machines that take longer than needed, poor training and staffing, limited information and direction, delayed arrival of materials, and insufficient quality of materials. As a result of having a lean flow, there is a drop in lost orders, delays, mistakes, and other wastes. When a company produces a product with better quality there is often less rework. Employees then experience less frustrations related to their work and are happier (Kelleher, 2010).

Lean manufacturing uses Kaizen for accelerated process improvement. Kaizen events strive to find a low-cost high-impact solution (Smith, 2002). Ergonomics evaluations may help enhance and motivate shop floor personnel during Kaizen events. The integration of ergonomics into a Kaizen event establishes that the goal is to personally improve each employee's work experience and conditions through better productivity (Smith, 2002). The research done by Bentley and Tappin (2010) shows that ergonomics can play an important role in process improvement when certain aspects of human performance are essential for better system design and implementation.

The use of Kaizen as a tool to integrate ergonomics and lean principles, can improve the outcome of continuous process improvement projects (Marras & Karwowski, 2006). Lean and ergonomics principles function together as a tool to better understand both the work process and the worker. When using an integrated approach it allows wastes in

human performance to be measured and accounted for by looking at unnecessary movements, unusual or restrictive movements, and cognitive processes (Kelby, 2012). Human factors and ergonomics are important factors to consider in the manufacturing industry because of the impacts related to safety in the work environment. Ergonomics plays a key role for risk reduction when addressing multiple risks on the human body and coupled with continual improvement. When ergonomic measures are implemented system wide in manufacturing facilities the company culture shifts to view ergonomics as a key source of process improvement. Ergonomics provides realistic measures toward preventing occupational injuries and illnesses by analyzing things like workload, excessive stress, human error, and poor organization (Kawakami & Kogi, 2005). Ergonomics is an integral part for better system design because it serves as a preventive method for safety and health (Fadier & De la Garza, 2006).

Successful results for both productivity and safety have been seen when integrating lean strategies with ergonomics and safety. The link between lean and ergonomics is also seen when assessing risks in a process. These risks are often referred to as hazards and play a key role in a company's safety culture. The application of ergonomics leads to benefits in health, safety, and efficiency for both the worker and the work process (Nicholson & Ridd, 1988). Ergonomics principles play a significant role in occupational health and safety practices. In the manufacturing industry ergonomic injuries mainly result from overexertion and repetitive motion, being struck by an object, being struck against an object, being caught, or falling (Nicholson & Ridd, 1988). Ergonomic injuries include sprains, strains, and tears, cuts or lacerations, bruises or contusions, and fractures just to name a few (Nicholson & Ridd, 1988). Many manufacturing jobs have numerous physical limitations and barriers that restrict productivity. When these issues are addressed and are reduced or eliminated, there is improved productivity as well as benefits for the workers body (Smith, 2002). Since the goal of ergonomics is to reduce injuries and illnesses, rather than saving company money, it is difficult to evaluate as linked to Lean unless the productivity and product quality are considered. Employees make the largest contribution to quality, productivity, and cost. When implementing lean strategies with ergonomics and safety it is possible to better reduce or eliminated the wastes that result from the human element as well as reduce or eliminate possible injuries. By analyzing both the work process and the worker there is a reduction in the potential for accidents and injuries in the workplace (Nicholson & Ridd, 1988). This approach allows for organizations to view the workers as an asset and then designing the workplace and job to best fit their needs (Bernstein, 2009). The use of Kaizen as a tool to integrate ergonomics and lean often results in improved production, quality, and safety. The productivity gains are typically more durable and can translate into time savings proving the benefits of lean and ergonomics. When managing risks by recognizing ergonomic issues many of the hassles and blocks to productivity can be reduced or eliminated. The benefits of linking lean and ergonomics are more pronounced when the ergonomic evaluations identify specific task factors like forceful exertion, awkward postures, and high rates of repetition (Kelby, 2012).

Previous studies reported success when evaluating improvements from integrating lean strategies with ergonomics, safety, or job satisfaction principles through Kaizen events. Smith (2002) reported success when evaluating an air conditioning component manufacturing facility for ergonomic improvements through a Kaizen approach. Ikuma and Nahmens (2011) reported the success of an integrated lean and ergonomics approach in

their evaluation of modular home building's processes. Walder, Karlin, and Kerk (2007) reported a reduction in waste, a more flexible process, and improved productivity from fatigue reduction in utilizing material handling assist devices when combining process improvement techniques and ergonomics. Hafey (2009) demonstrated that lean tools, such as kaizen, are as beneficial for the health and safety of employees as they are for the company. When ergonomics principles are applied toward health and safety the benefits are also seen in increased efficiency and better employee morale (Nicholson & Ridd, 1988). Companies like Humantech that specialize in ergonomics training and education for organizations are now offering seminars like "lean ergonomics" to address the optimization that can be seen by linking lean with ergonomics (Humantech, 2003). Humantech (2011) reported numerous industrial companies that have linked ergonomics with lean for continuous improvement. Toyota, Honda, and Honeywell have all documented reductions in wasted motion and non-value added time after ergonomic improvements (Humantech, 2011). This shows that there are productivity gains as a result of lean and ergonomics programs. By using lean without ergonomics there is less effectiveness and sustainability because there is a missing link found in the human centered approach of human factors. Integrating lean and ergonomics is beneficial since ergonomics designs the job to fit the worker, the workers can complete the job easier. The largest waste that is identified by considering ergonomics is motion. Motion contributes to both external and internal productivity levels of the employee. By integrating ergonomics with lean there is a better evaluation of an employee's ability to safely have a higher output (Kelby, 2012). An evaluation of employee strategic alignment at a wood manufacturing found that employees with more knowledge about the lean strategies being implemented tended to show higher levels of commitment, job satisfaction, and trust. The results also showed that there was a lower level of employee cynicism for those with a more knowledge about the lean strategies and engagement in the activities. This indicates that when implementing change initiatives the company should "strive to increase employees interest in and knowledge of the new initiative (Gagnon & Michael, 2003)."

When using any improvement tool it is important to have employee involvement as well as commitment from management. Process changes are more practical when using a participatory approach, where employees have an active role in the problem solving process. The most successful continuous improvement programs focus on the local issues and available resources in that specific environment (Kawakami & Kogi, 2001). Active involvement from employees utilizes the knowledge and ingenuity of employees and leads to a better workplace and products (Marras & Karwowski, 2006). Employee involvement helps to address basic factors in the problem, since the employee actually doing the job typically has invaluable insight toward possible improvements. By involving employees throughout the process the workers gain a sense of empowerment and ownership over the new changes (Marras & Karwowski, 2006). These involvement efforts make employees more aware of healthy and safe working environments and more involved in the improvement process. When employees are more involved there is an increase in moral and thus job satisfaction (Hackman & Oldham, 1980; Marras & Karwowski, 2006). The strongest companies often realize that the level of employees' job satisfaction correlates with their productivity and both should be monitored (Aveta, 2012). Companies should have strategies in place to ensure that employees are happy and want to be productive. This is because people need incentives in order to get jobs done quicker and better (Aveta,

2012). Many manufacturing jobs have numerous physical limitations and barriers that restrict productivity. When these issues are addressed and are reduced or eliminated there is improved productivity as well as employee morale and enthusiasm (Smith, 2002). There is growing evidence that lean facilities report higher worker satisfaction (Aveta, 2012).

Lean can help encourage companies and employees to take an active role in continuous improvements for their work area and tasks. Employees then become more aware of safe and healthy working environments and practices. An integrated approach with lean is a proactive way to have positive effects on productivity, ergonomics, and safety. This approach forces all stakeholders to become actively involved and responsible for improvements (Hafey, 2009). The research is controversial, however Lean appears to offer significant improvement opportunities for other initiatives and concerns such as employee satisfaction (Holden, 2011).

The literature provided information to support simultaneous benefits when using lean and ergonomics in environments like manufacturing that are more repetitive. From the literature, safety is impacted from ergonomic improvements however the benefits are mostly reactive. When using lean to address ergonomics and safety the literature supports the proactive ability to reduce and/or eliminate ergonomic and safety risks. The literature also supported overall increases to employee moral as a result of process frustrations being reduced and/or eliminated. However, the literature did not provide conclusive evidence for or against improving job satisfaction, some studies reported increases and others reported decreases employee satisfaction. In reviewing the literature there are remaining gaps. The main gap that remains in the literature is addressing the impact on all the factors rather than one or two factors at a time; lean, ergonomics, safety, and job satisfaction. The literature supports that companies have a need to be able to “do more with less.” An integrate approach that accelerates process improvements for different areas would provide companies a much needed tool. It is difficult to provide an integrated approach with a controversial and divided view of the relationship between lean, ergonomics, safety, and employee satisfaction. The controversy surrounding the relationship between different improvement initiatives creates the need for further study and evaluation. The current research seeks to better understand the impact on employee satisfaction from lean improvements implemented via a kaizen event (K2) or a kaizen event integrated with ergonomics and safety for a single process improvement framework (K1).

EVALUATING THE IMPACT OF LEAN

An investigation was performed on the production line of a tractor, including a feeding station where components are welded as a subassembly part for the final product. The tractor is used in the construction industry to make grading projects easier and to increase hauling capacity with maximum uptime. This piece of equipment has excellent productivity on the job site, because of the increased uptime and lower daily operating costs. Before the tractor can be delivered to the customer, there is an extensive process of materials traveling through the production line- from tooling centers, weld, paint, preassembly, and ultimately to the main assembly line. Quality standards are inspected throughout every step of the production process to ensure that the best product is delivered to the customer.

Setting

A growth opportunity exists to allow the manufacturing facility to move forward and maintain a competitive position in the industry by improving the efficiency for the production of the tractor; specifically, improving production by streamlining the manufacturing process for Main Station #1 and a welding feeder station. This facility manufactures many different pieces of equipment. The factory is unique in the aspect that the fabrication and primary manufacturing machines and equipment are not product exclusive and are shared between all product lines, work tickets, and service orders. The assembly process is dependent on everything arriving at the desired time for optimum just-in-time production. If there is an over-stock of inventory the profit margin is dramatically reduced because of the high overhead cost. If there is not enough of a needed stock item the production cost also increases due the assembly line stopping. Confusion often begins prior to assembly as a result of sharing machines and the complicated material flow process. Final assembly often experiences exponential delays at the end of the production process, if the first step in the manufacturing process starts behind schedule.

Objectives

The goal of this research was to explore the proposed relationship, seen in Figure 11, between employee satisfaction, ergonomics, and safety while implementing a Kaizen event. In order to address this goal, two Kaizen events were conducted (K1 and K2). Employee satisfaction levels were documented for K1 and K2 participants as well as for non-Kaizen (NK) employees. Safety and Ergonomics levels were documented on K1.

The objective of the first Kaizen event (K1) was to improve the efficiency of the task of torquing the rear axle bolts while integrating ergonomic and safety tools (e.g. JHA and REBA). The objective of the second Kaizen event (K2) was to improve the efficiency of the manufacturing process for a feeding station where components are weld as a subassembly part for the final product. Employees' satisfaction levels for K1 and K2 participants as well as employees that were not involved in any of the Kaizen events (NK) were documented using the Job Diagnostic Survey (JDS). The employees completed the survey before and after (e.g., 30 days after) the implementation of the improvements.

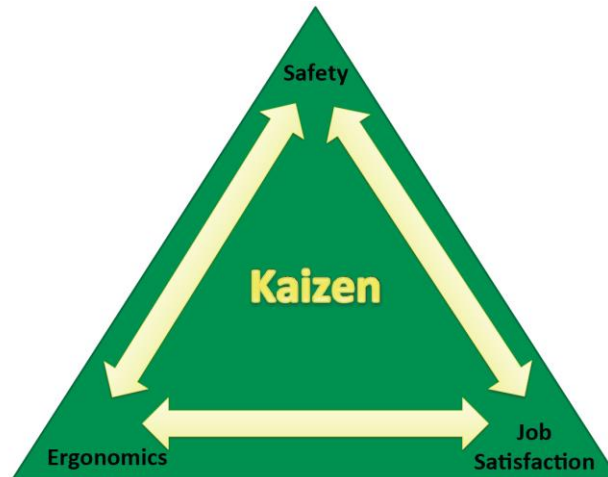


Figure 11: Proposed relationship between lean and employee satisfaction, ergonomics, and safety.

Methodology

After completing a high-level Value Stream Map for the tractor as a product line, seen in Figure 12, an action list for projects and process improvements was developed. One of the problems that became apparent was that the skid used on the main assembly line was constantly causing substantial problems for the employees to complete required tasks. After communications with the Continuous Improvement Department it was determined that the best way to tackle the skid problem was to conduct a Kaizen event (K1) to specifically evaluate the issues surrounding the skid and take quick corrective action. Since the problems that the employees were experiencing related to their ability to perform the task safely; an ergonomic and safety evaluation was also deemed as necessary. Another problem that became apparent surrounded one of the welded component's constant late arrival to the final assembly line. To determine the root cause of the component's consistent delays, a component-level Value Stream Map was conducted, seen in Figure 13, a list of action items for projects and process improvements was developed. The noted issues showed that pieces usually arrived late or in quantities not proper to weld the subassembly part. The higher-level problem that the component level VSM exposed was that there was a gap in the unification of required materials to the welding subassembly from joint operations that needed to take place simultaneously. The previous documentation also noted that the subassembly traveled a considerable distance back and forth between plants on a daily basis. After communications with the line supervisor, a Kaizen event (K2) was scheduled to specifically target the process for materials required to weld the subassembly and take quick corrective action. Since none of the noted experienced problems for the component related to safety or employee physical ability, ergonomic and safety evaluations were not deemed as necessary. By having three distinct groups, Non-Kaizen participants (NK), Kaizen participants (K2), and Kaizen with ergonomics and safety evaluation participants (K1), various aspects of employee satisfaction were evaluated across unique varying situations to better see patterns and correlations relating to the proposed relationship between lean and employee satisfaction, ergonomics, and safety.

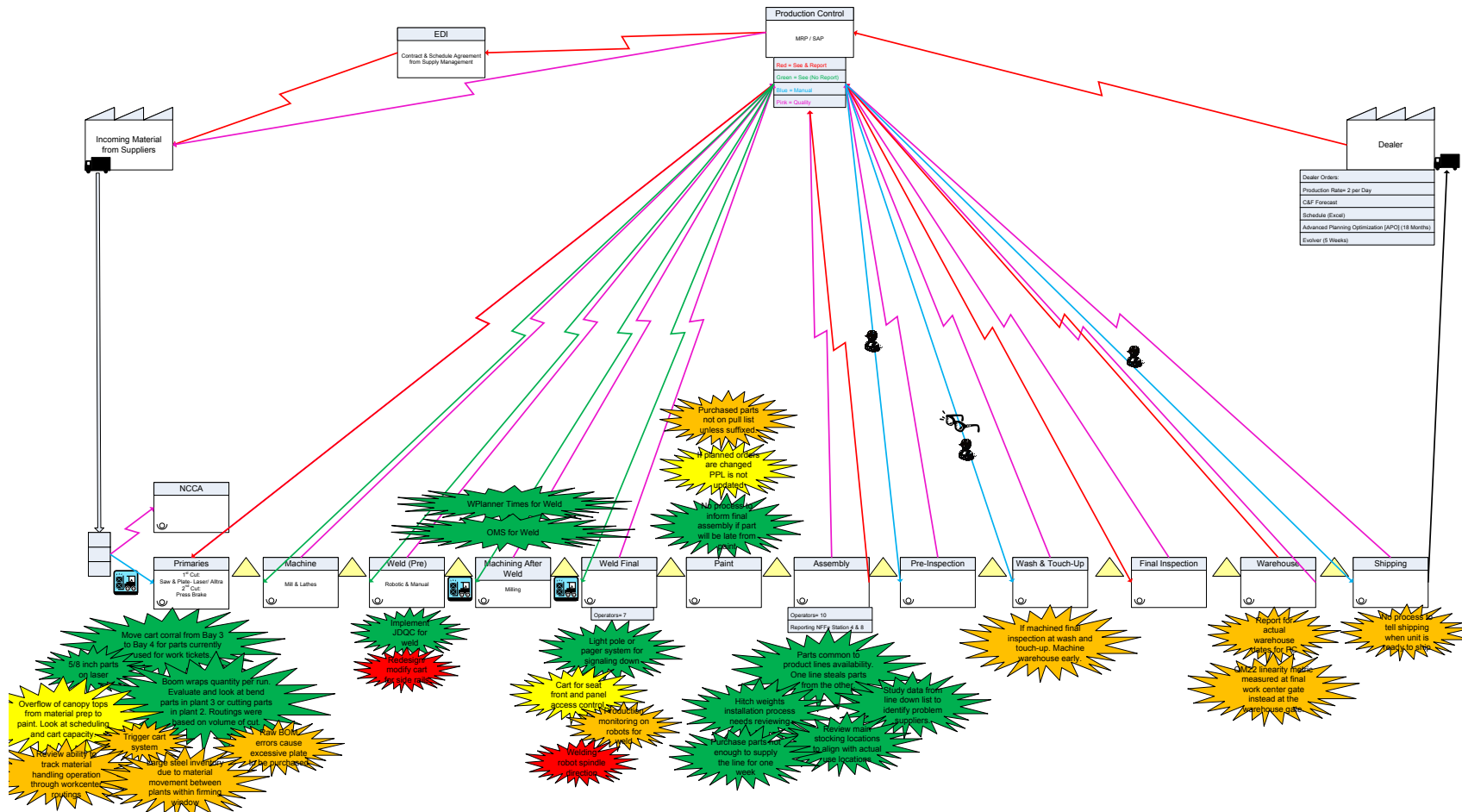


Figure 12: High level Value Stream Map for tractor product line.

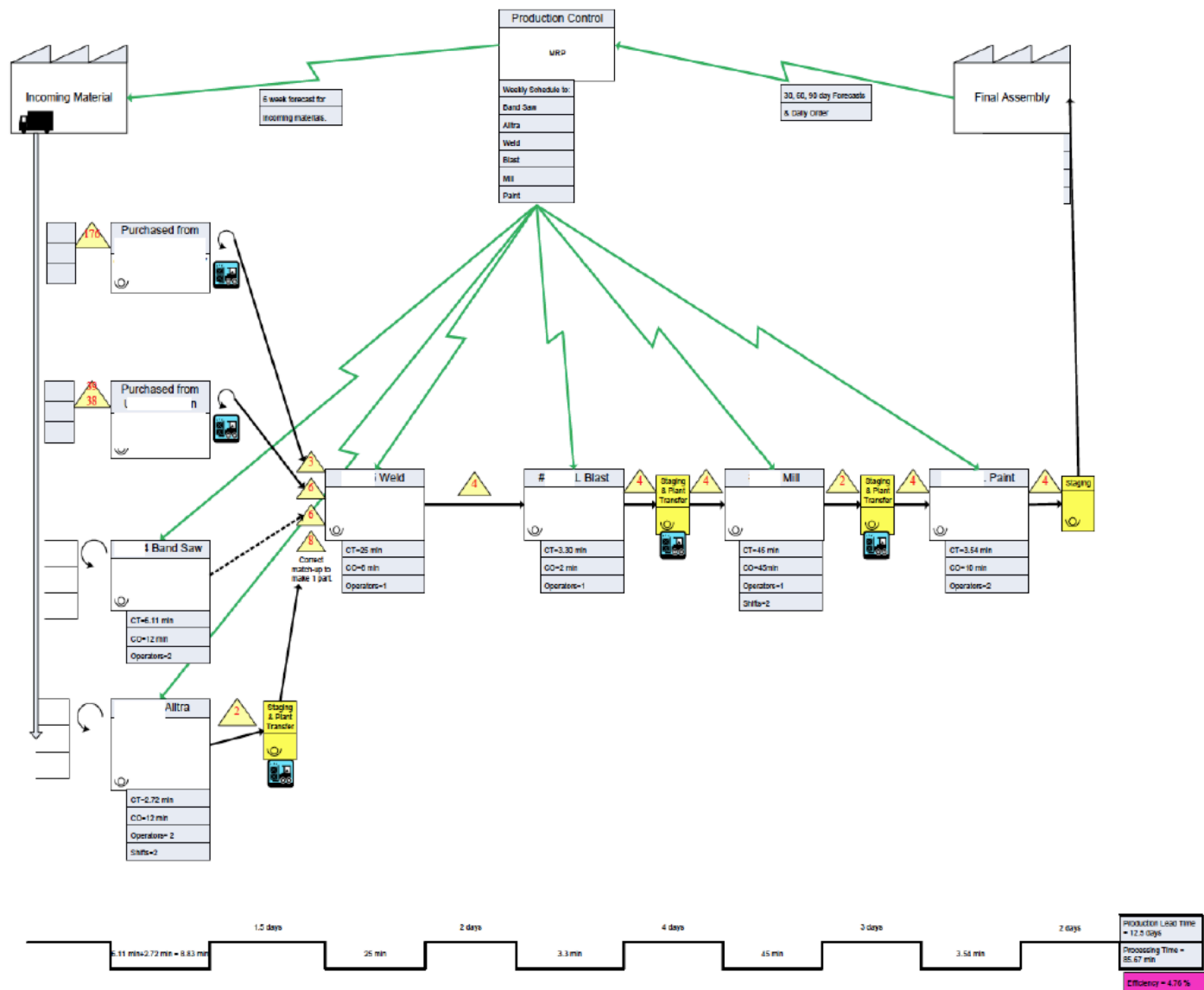


Figure 13: Component level Value Stream Map.

The key support team and those involved in the improvements was established for each Kaizen event. In an effort to provide insight from all angles many different departments were included; representatives from the departments of continuous improvement, manufacturing engineering, production support, and quality as well as production employees from material handling, paint, assembly, the crew chief, and supervisor were all involved. Responsibilities for specific team members were determined. The Manufacturing Engineering department served as the event sponsor and identified the preliminary objectives as well as the scope of the event. By establishing a team from various departments all stakeholders were represented and had a vested interest in improving the process.

Before any improvements were implemented, employee satisfaction levels for the 15 employees on the tractor line were documented using the JDS methodology. The 15 employees were made up of six K1 participants, five K2 participants, and four NK employees. The employees were selected based on their involvement in the Kaizen events. All 15 employees worked in some area of the same tractor manufacturing line under the same supervisor. All 15 employees shared a common goal of manufacturing the best tractor product. The K2 participants all worked in the welding subassembly area. The K1 participants all worked on the main assembly line in Main Station #1 where the task of torquing the rear axle bolts is completed. The NK employees all worked on the assembly line after Main Station #1. The NK employees add more parts as the machine moves down the assembly line and at the end of the assembly process complete final touch-up, roll-off, and warehouse of the finished tractor. Work flows from the K2 group, through paint, to the K1 group, and then to the NK group. The manufacturing workflow process can be seen in Figure 14.

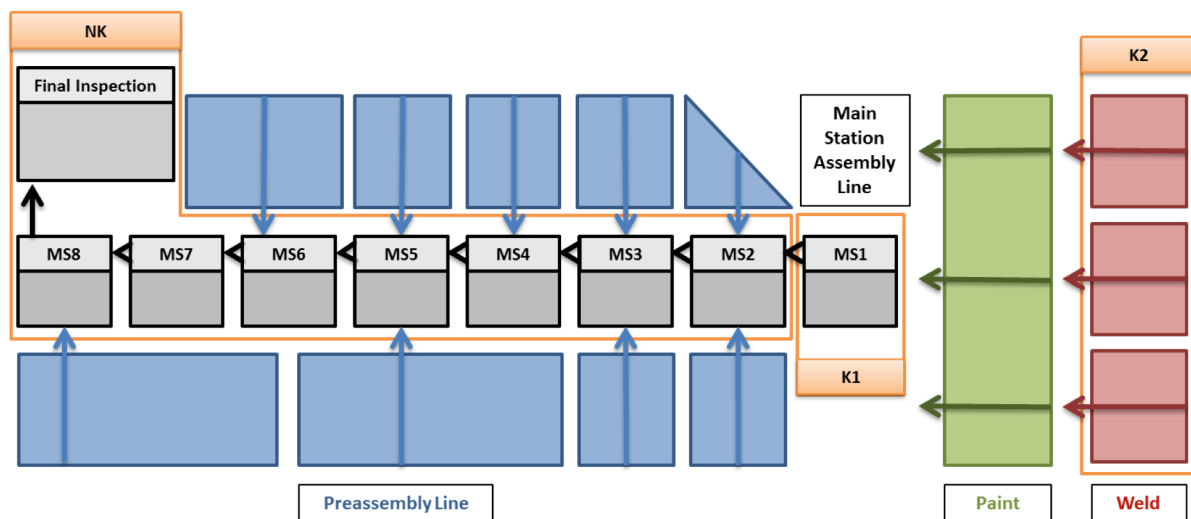


Figure 14: Manufacturing work flow process.

The objective of the K1 event was to improve the efficiency of the process of torquing the rear axle bolts in Main Station #1, while integrating ergonomic and safety tools. The methodology for the K1 event followed a traditional Kaizen event structure, enhanced with ergonomic and safety evaluation tools, seen in Figure 15. Prior to the Kaizen

event the factory Ergonomist and Safety professional used the REBA and JHA methodology respectively to independently evaluated employee ergonomics and safety. For the REBA evaluation, employees were interviewed to learn more about the job tasks and demands. The employees' movements and postures were observed over 10 cycles, where one cycle was represented by the series of activities completed to torque the rear axle bolts. The cycles were observed over a week period using random work sampling. The postures to be evaluated were selected by looking for the most difficult or extreme posture, the posture sustained for the longest period of time, and the posture with the highest force load. Two photographs of the employees' completing the task of torquing the rear axle bolt were selected for evaluation and scoring by the factory ergonomic professional.

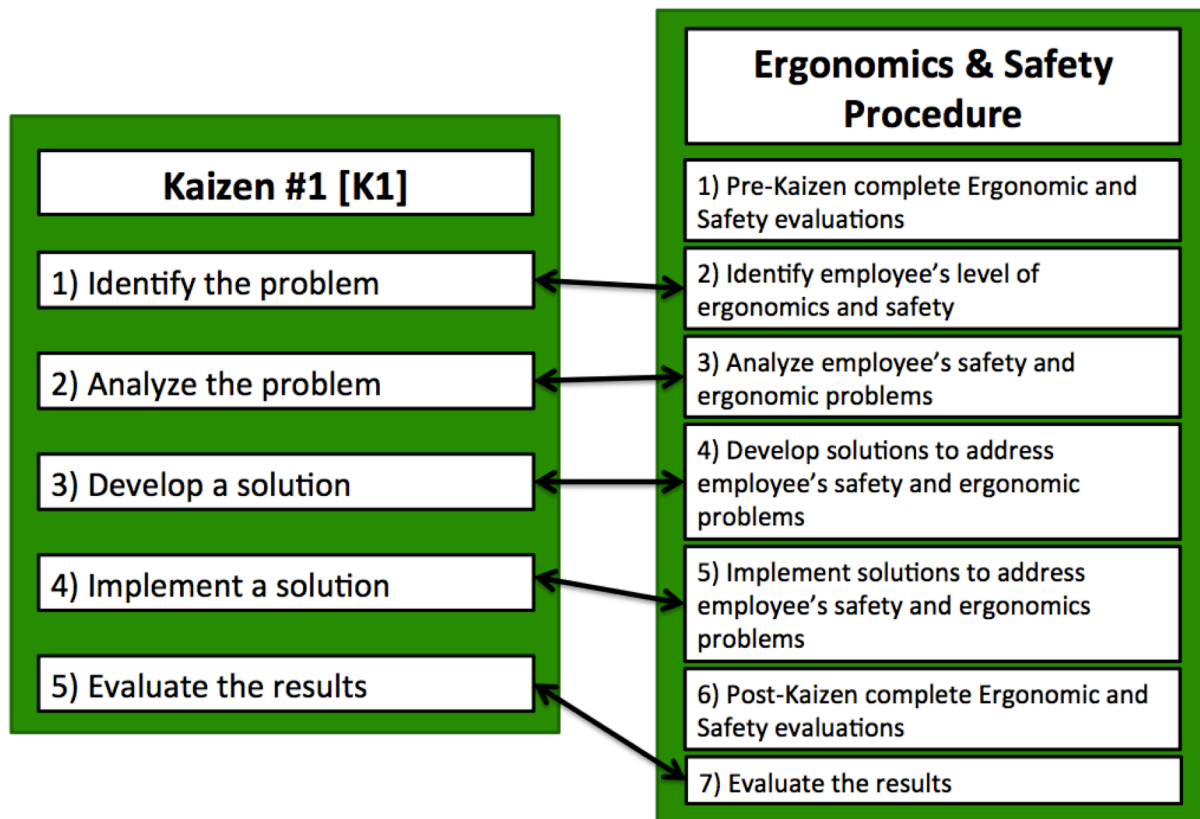


Figure 15: Methodology Kaizen event (K1) integrated with Ergonomic and Safety Tools.

For the JHA evaluation, historical records for the past 5 years were gathered and compared with current practices. Current practices were observed and documented by the safety professional during a one-day period. The review of historical incidents provided indicators of hazards that are still present. The Ergonomic and Safety professionals focused the historical review of the tractor assembly line on work illnesses or injuries that required treatment, any losses that required repairs or replacement, as well as any near-misses where there was the potential for incident or loss. Through the observation of current practices the following were identified and documented: all possible hazards, process steps, failure points in the process, possible consequences, any possible contributing

factors, and the likeliness for a hazard occurring. The safety professional then listed the noted hazards with unacceptable risks and enlisted the employees to determine the likeliness of hazards to occur and the most severe consequences. The employees brainstormed possible control measures to eliminate or reduce the identified hazards. The team first discussed the possibilities for engineering controls that physically change the machine or work environment to prevent the hazard since that would be the most effective. Then the team discussed any administrative controls that could change the process.

During the Kaizen event the team identified the root cause of the problem and analyzed the issues. The task cycle time was determined by observing the operation to document 10 cycle time samples, both before and after implementation. Then the cycle times were averaged to determine the average cycle time to torque the rear axle bolts per tractor. The team then developed and implemented improvements to the process. weeks after the solution was implemented, employee's ergonomics and safety assessment was again performed, following the same processes. The data for the ergonomic and safety evaluations were compared to determine a percentage change. The task cycle time was again documented. The data for the total man minutes for the task cycle time was compared to determine a percentage change. The team then evaluated all of the results. The success of the Kaizen event was determined from the task cycle time as well as the REBA and JHA scores.

The objective of the second Kaizen event (K2) was to improve the efficiency of the manufacturing process for a feeding station where components are weld as a subassembly part for the final product. The methodology for the K2 event followed a traditional Kaizen event structure, seen in Figure 16. During the Kaizen event the team identified the problems surrounding the component, analyzed the issues, developed a solution,

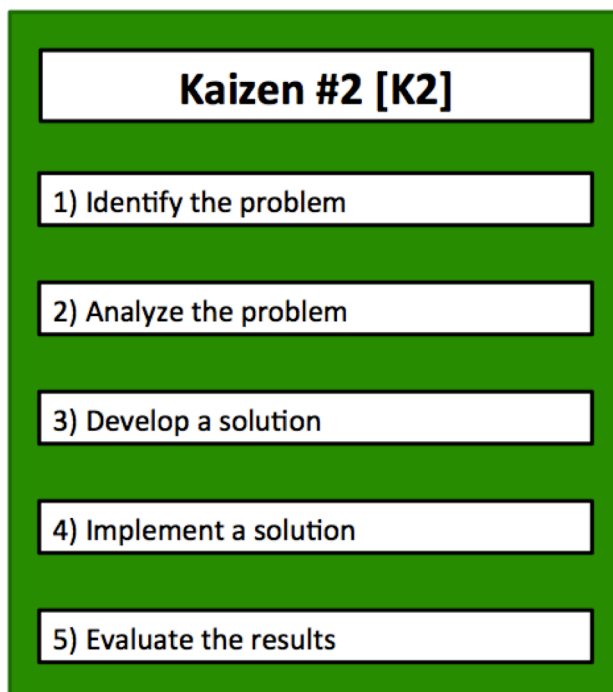


Figure 16: Methodology Kaizen event (K2).

implemented a solution, and evaluated the results of the changes. The success of the Kaizen event was determined with respect to the actual component, not materials; overall production process as it feeds to final assembly. The current manufacturing process for the component from raw materials to final assembly was observed. The inventory on hand was documented 10 random times over one week, to determine the production lead-time. The cycle time at each station was also documented for 10 samples, to determine the total processing time. The inventory production lead-time and total processing time was determined in this manner both before and after (e.g. 30 days after) implementation. The data was then averaged to determine the average efficiency for the component's manufacturing process. The data for the production lead-time, total processing time, and efficiency was compared to determine a percentage change.

The 15 employees on the tractor line, K1 and K2 participants as well as NK's participants were documented using the JDS methodology again 30 days after the completion of improvement implementations.

The delta value for each JDS category was calculated using the difference of the before and after value divided by the before value. Statistical analysis was then conducted with the delta value across the three participant groups (K1, K2, and NK) using the Shapiro-Wilk test because of the small sample size. If the normality test revealed that some of the datasets were normally distributed and some deviated from a normal distribution non-parametric analysis was required. Non-Parametric Kruskal-Wallis test was then conducted for each of the JDS categories in order to test the hypothesis; H_0 : there is no significant difference between the samples (K1, K2, and NK), H_a : there is a significant difference between the samples (K1, K2, and NK). The non-parametric statistical analysis for each category individually was calculated across K1, K2, and NK samples. In the event that the null hypothesis was rejected a multiple comparisons test was performed since the overall test showed significant differences across the samples.

Case Study

Pre-Kaizen (NK, K1 and K2) Events

Employees' satisfaction levels were documented for 15 employees, K1 and K2 participants as well as NK employees. The 15 employees included six K1 employees, five K2 employees, and four NK employees.

Kaizen Event (K1): Main Station #1

The focus of K1 was to improve the task of torqueing of the rear axle bolts in Main Station #1, while integrating ergonomic and safety tools. The major issue at this station was the material handling system, particularly the skid used to move the product down the assembly line. K1 included the line employees, the line crew chief, the line supervisor, and the mechanical/manufacturing engineer. The team was selected so that different aspects of the process could be represented.

Step #1: Identify the Problem

The scope of the K1 event was to evaluate the current skid used on the main assembly line. Previous documentation noted that the current process was not ideal and resulted in errors being made. These errors were causing many delays and incurred costs.

The first step for the K1 event was to identify the problem. The current state of the process was established after brainstorming about the problems associated to the skid in Station #1 with all stakeholders. The current assembly process for the tractor in Station #1 required an additional employee to complete the task of torqueing the rear axle bolts. The employees reported that they were unable to complete the required task independently because there is low accessibility for the employee. When a single employee attempts to torque the bolt alone the bolt head spins and thus is not torqued properly, which reduced the quality and reliability of the product delivered to customer. To compensate for the axle bolt spinning, Employee #2 would hold the bolt secure with a backup wrench while Employee #1 torqued it. As a result of pulling other workers to help complete the required task, there was an increase in man-hours and decreases for productivity as well as efficiency. This process involved both employees working in poor ergonomic positions because of the need for them to work in unusual and restricted postures. Safety records and employee communication also showed incidents of falls and strains during this task. Quality issues like scratches from the current skid were experienced at the end of the assembly line during roll-off.

Step #2: Analyze the Problem

The second step for the Kaizen event was to analyze the problem. The Kaizen team focused the improvements on Station #1 as a result of the discussion and previous documentation that noted the numerous problems. The ultimate reason to focus on assembly Station #1 was that the current assembly tasks required an additional employee to torque the rear axle bolts. During the focused K1 event for improving the skid used in final assembly employees were asked to analyze the current state of the process in order to identify the constraints and key problems. By using a “five whys” approach to get to the root of the problems numerous other constraints were noted. The key issues that were identified include: 1) additional workers required, 2) poor material handling equipment, 3) maintenance of the material handling equipment, and 4) compounding issues.

1) Additional workers required. The team reported that an additional employee is needed to complete the necessary task of torqueing the rear axle bolts, which increased man-hours and decreased productivity as well as efficiency. The employees noted that even with assistance the positioning needed to torque the rear axle bolts was awkward and straining. Additional help to torque the rear axle bolt is necessary because there is low accessibility and visibility for a single employee to complete the task. When a single employee attempts to torque the bolt, the bolt head would spin and could not be torqued properly, which reduced the quality and reliability of the product being delivered to the customer. Figure 17 shows the team of employees attempting to properly torque the rear axle bolts both in awkward and straining positions. By using participatory ergonomics it was possible to gather everyone’s personal needs. The team also pointed out that this was not the only station having difficulties as a result of the current skid. It was necessary for them to ask other employees for assistance at multiple points along the main assembly line. Later in the assembly process the front wheels are placed on prior to the rear wheels. In



Figure 17: Employee attempts to torque the rear axle bolts with assistance of an additional employee, both in awkward and straining positions.

order to safely lift the front end an additional employee was needed due to the weight of the machine.

2) Poor material handling equipment. The current skid design was causing issues. The plates for the rear frame on the skid were bending due to the weight of the tractor when the front end was lifted. These plates hold the bolts for the rear axle. Employees pointed out that over time the plates were being bent so much that it restricted their ability to torque the rear axle bolts even more. The employees assigned to Station #1 noted that when it was impossible to torque the rear axle bolts properly they would have to be called to finish properly torquing the bolts in the run-off station. Before K1, the washers would not stay in the desired location on top of the plate, preventing the bolt to pass through on the first time. The lack of visibility made it difficult for employees to hold the washers in place while inserting the bolts. Another issue noticed was that employees were often scratching the paint while attempting to get access to torquing the rear axle bolts. This resulted in spending extra time and resources to repair scratches, creating another waste that could be eliminated or reduced with a better skid design. The current skid with the plates bent can be seen in Figure 18.

3) Maintenance of the material handling equipment. Another problem for the employees was maintenance on the current skid. Employees often tried to fix the bent plates line side so that it would not have to be sent to a welding repair work center. While this did not actually fix the problem it sometimes made it better, but at a loss on assembly production man-hours. There was an exponential result of waste from the bent plates that was seen as production rates increased, reinforcing the project as a top priority.



Figure 18: Current cart with bent unreliable part for axle to rest on which needed increased maintenance.

4) Compounding issues. The employees also commented that as production rates increase, difficulty torquing the rear axle bolts became a more pronounced problem. Therefore, the supervisor and employees noted that fixing this before it became a large constraint again would be optimum.

Many possible alternatives for improvement were suggested. In order to fully evaluate and prioritize the alternatives, the current state was evaluated using lean, ergonomics, and safety principles. This was done so that the true needs could be quantified and addressed in a feasible alternative. The current state of the process was evaluated by documenting employee productivity level associated with the task of torquing the rear axle bolts.

The ergonomic and safety scores were independently evaluated. The Ergonomic professional selected two pictures of extreme ergonomic postures during the task to be scored for the REBA evaluation. The ergonomic score associated with the task of torquing the rear axle bolts, was determined using the REBA methodology after photographing the task over 10 cycles and resulted in a score of 13 for Employee #1, and a score of 13 for Employee #2. For the JHA evaluation, historical records were gathered and compared with current practices by an independent safety professional. The safety score (based on potential hazardous conditions), for Station #1 was determined using the JHA methodology and resulted in 5 potentially hazardous conditions; ergonomic strain, fall, mechanical failure, struck against, and visibility. Historical safety records showed that there were near-misses and recordable injuries for the torquing the bolts in Main Station #1. The historical records included incidents for falling, mechanical failure, and struck against.

The task was documented for the two employees needed to complete the task for 10 tractors. The 10 cycle times were documented and then averaged to determine the average cycle time to torque the rear axle bolts per tractor. The observations showed that the employees always worked together to torque the rear axle bolts in Main Station #1 with an

average cycle time of 15 minutes (± 1.49) per tractor. The cycle time ranged from 13 to 17 minutes. The higher cycle time resulted when the employees were unable to properly torque the rear axle bolts in Main Station #1. However, when their efforts were unsuccessful, on approximately 1 in every 4 tractors, because of the constraints placed on the bolts from the bent plates on the rear skid they would stop and complete this task during roll-off later in the assembly process. When there was a deviation from the standard production path and the rear axle bolts were torqued outside of Main Station #1, observations showed that there was often another 15 minutes spent by two employees to properly torque the rear axle bolts. As a result, the tractor availability for warehouse and scheduled for shipping was delayed. During observations, it was noted that as more tractors were produced the skids were used more frequently and therefore the top plates became more bent, increasing the number of tractors needing to be properly torqued in the roll-off station. On average it took approximately 30 man minutes (± 2.98) (e.g. man hours) to properly torque the rear axle bolt in Main Station #1. This calculation does not take into account the lost time and delays associated with employees being pulled from their assigned stations and tasks.

Step #3: Develop a Solution

The third step for the K1 event was to develop possible solutions to address key problems identified, which included: 1) additional workers required, 2) poor material handling equipment, 3) maintenance of the material handling equipment, and 4) compounding issues as well as employee safety and ergonomics. Improvements were determined based on the Kaizen participant's input and previously gathered data for employee's ergonomics and safety. To develop a feasible alternative for the skid that would reduce the number of required employees as well as reduce ergonomic issues a manufacturing engineer and design expert, Daniel Verret (Verret, 2012), was consulted. The key problems with the current skid and best possible alternatives were then evaluated.

The base plates first needed to be made out of stronger steel to increase the weight capacity. The stronger material would aid in solving the problems noted with poor material handling equipment as well as maintenance required. Two additional plates would be stacked on top of the base plate; one plate with hexagonal holes the same size as the bolt heads and the second plate with circular holes the same size as the washers. The plate with hexagonal holes would successfully back and secure the bolt heads, which eliminates the need for an additional person to secure the bolts with a backup wrench. The second plate with circular holes would keep the washers centered and in place while the bolt passed through, which eliminated the visibility issues. The plate to hold the washers eliminated unnecessary muda in time delays and aided in mistake proofing the process. A priority for the new axle stand was that it needed to be able to be repaired and maintained more easily. The new design took into account the base plate bending as well as the hexagonal holes becoming worn out and the bolt turning freely (Verret, 2012).

A pivot was added on the base plates for the rear frame skid to alleviate the bending issue experienced when the machine is tilted after the front wheels are installed. There were safety concerns that the pivot would be a problem. As a result it was designed so that the pivot only tilts backwards because only the front end of the machine needs to be elevated. Weights were added so that the pivot would always fall forward but it would remain level because of the additional height on the front of the shaft. The proposed alternative would allow the employees to remove the front axle skid while maintaining the

current stability they experience prior to tilting the machine to remove the front skid once the front wheels are added. After evaluation it was established that the pivot did not need to freely have the ability to move because of ergonomic and safety concerns. A locking pin was added so that the plate would remain secure and level when desired as well as have the ability to tilt when needed. The addition of a pivot with a safety lock pin, will dramatically increase the safety stability of the machine while tilted (Verret, 2012).

For easier maintenance, the plates would be bolted on top of the pivot instead of welded. Thus allowing the pieces to be repaired line side rather than transported to a welding repair center. All of the changes in the new design helped to encourage a continuous flow and allowed for a quick changeover in the event something breaks. A Pro-Engineer generated model of the proposed rear axle stand for the final assembly skid can be seen in Figure 19 (Verret, 2012).

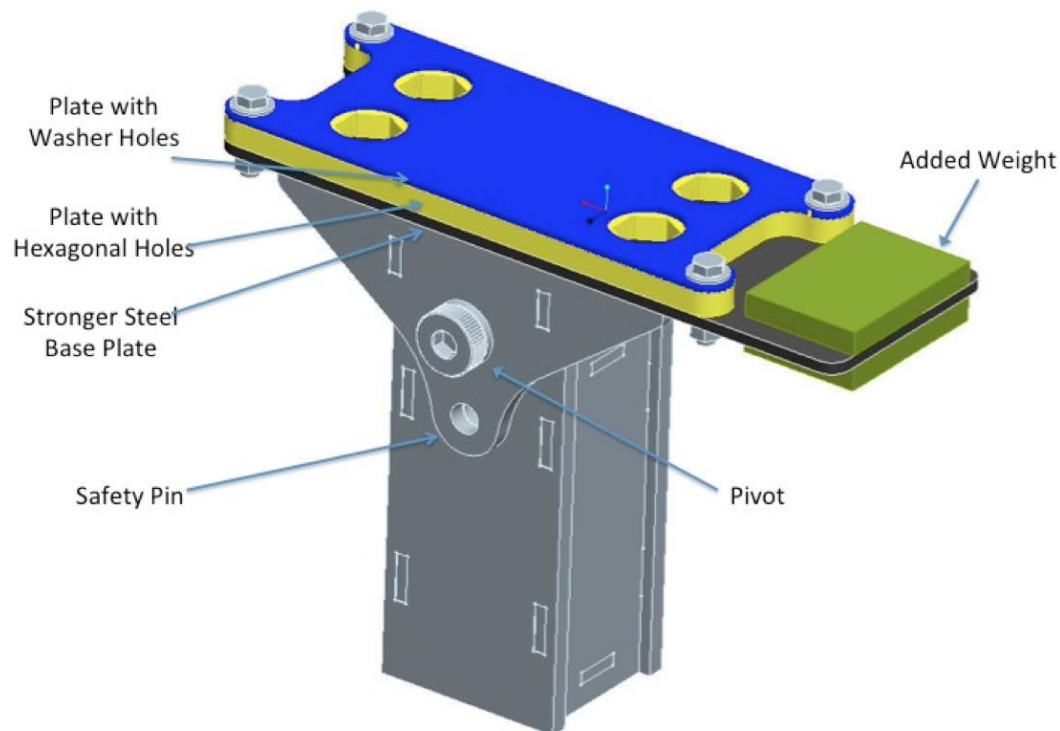


Figure 19: Model of the proposed rear axle stand for the final assembly skid (Verret, 2012).

The relationship between the proposed rear axle stand that will be mounted to a skid with the mainframe and axles can be seen in the Pro-Engineer generated model in Figure 20 (Verret, 2012). These models depict how the axle and mainframe for the tractor are attached.

The proposed design addressed the key problems that the team noted. The new skid for final assembly eliminated the need for additional workers to properly torque the rear axle bolts. The material handling equipment will be more reliable and no longer limit the assembly employees. With the proposed design there will be a reduction in the incurred costs and time associated with maintenance for the material handling equipment. The compounding issues that are seen when production demands increases are eliminated as a result of the proposed changes for the final assembly skid.

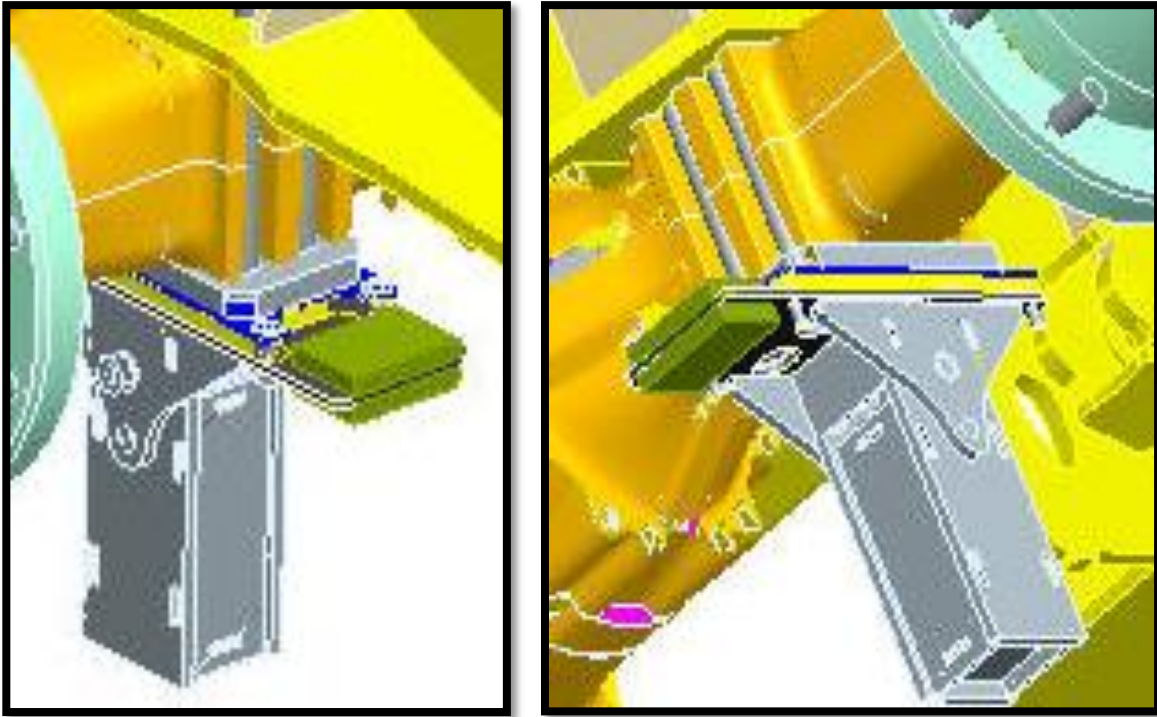


Figure 20: Proposed rear axle stands for final assembly skid (Verret, 2012).

Step #4: Implement a Solution

The developed design was proposed to factory safety and production representatives. After receiving approval from safety, the materials were gathered to build the new design. The new skid was then introduced to the team by the implementation via a prototype test of the proposed rear axle stands for the final assembly skid on one machine though the final assembly main stations. The team felt that the design exceeded their expectations. The design addressed issues that the employees had not expressed and alleviated the current process inefficiencies and ergonomic strains. The new skid design addressed the key problems that the team noted. The new skid for final assembly eliminated the need for additional workers to properly torque the rear axle bolts. The material handling equipment is now more reliable and no longer limits the assembly employees. Numerous employees reported that they could see how their ideas contributed and were expanded to form the new alternative. The new skid, seen in Figure 21, was then reproduced to replace all existing skids with the previous design.

Step #5: Evaluate the Results

The fifth step for the Kaizen event was to evaluate the results. The new state of the process was evaluated two weeks after implementation by again documenting the productivity, safety, and ergonomics levels. The post-Kaizen average cycle time associated with torquing the rear axle bolts was again evaluated over 10 cycles. The data was averaged and resulted in 5 minutes (± 0.50) with one employee per tractor. On average it now takes 5 man minutes (± 0.50) (e.g. man hours) to properly torque the rear axle bolts in assembly Main Station #1.



Figure 21: New final assembly skid.

After the new design was implemented, employee ergonomic and safety levels were again independently evaluated using the REBA and JHA methodology respectively. The ergonomic score resulted in 11 for Employee #1 and 0 for Employee #2 (only one employee is required to complete the torqueing task in the improved process). The REBA score went down for Employee #1 as a result of Employee #2 no longer near the equipment. Employee #1 now has the ability to move on both feet rather than having to shift his weight to one foot to avoid Employee #2. The extra space to work also meant that Employee #1 has an increased range of motion and does not have to raise his shoulders for additional movement on the torque tool. The before implementation REBA scoring for Employee #1 and Employee #2 can be seen in Figure 22 and the after implementation scoring can be seen in Figure 23. The safety score resulted in 1 hazardous condition (e.g. ergonomic strain). The JHA score went down as a result of the improved skid for final assembly, which eliminated mechanical failure and visibility issues when inserting the rear axle bolts, nuts, and washer. The JHA score also went down as a result of the increased range of motion Employee #2 gained with Employee #1 out of the way. The extra range of motion eliminated the possibility of falls and struck against for Employee #1. The before implementation JHA scoring can be seen in Figure 24 and the after implementation scoring can be seen in Figure 25.

REBA Employee Assessment Worksheet

Before!Employee' #1'
based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 2: Locate Trunk Position
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 2a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Step 3: Legs
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 3a: Adjust...
If legs are twisted: +1
If legs are side bending: +1

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, locate score in Table A

Step 5: Add Force/Load Score
If load < 11 lbs: +0
If load 11 to 22 lbs: +1
If load > 22 lbs: +2
Adjust: If shock or rapid build up of force: add +1

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A. Find Row in Table C.

Scoring:
1 = negligible risk
2 or 3 = low risk, change may be needed
4 to 7 = medium risk, further investigation, change soon
8 to 10 = high risk, investigate and implement change
11+ = very high risk, implement change

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 7a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Step 8: Locate Lower Arm Position:
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 8a: Adjust...
If wrist is bent from midline or twisted: Add +1

Step 9: Locate Wrist Position:
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 9a: Adjust...
If wrist is bent from midline or twisted: Add +1

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

Step 11: Add Coupling Score
Well fitting Handle and mid range power grip: good: +0
Acceptable but not ideal hand hold or coupling acceptable with another body part: fair: +1
Hand hold not acceptable but possible: poor: +2
No handles, awkward, unsafe with any body part: unacceptable: +3

Step 12: Score B, Find Column in Table C
Add values from steps 10 & 11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Final REBA Score
Table C Score + Activity Score = Final REBA Score

REBA Employee Assessment Worksheet

Before!Employee' #2'
based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 2: Locate Trunk Position
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 2a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Step 3: Legs
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 3a: Adjust...
If legs are twisted: +1
If legs are side bending: +1

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, locate score in Table A

Step 5: Add Force/Load Score
If load < 11 lbs: +0
If load 11 to 22 lbs: +1
If load > 22 lbs: +2
Adjust: If shock or rapid build up of force: add +1

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A. Find Row in Table C.

Scoring:
1 = negligible risk
2 or 3 = low risk, change may be needed
4 to 7 = medium risk, further investigation, change soon
8 to 10 = high risk, investigate and implement change
11+ = very high risk, implement change

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 7a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Step 8: Locate Lower Arm Position:
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 8a: Adjust...
If wrist is bent from midline or twisted: Add +1

Step 9: Locate Wrist Position:
+1 0-20° +2 20-30° +3 30-40° +4 40-50° +5 50-60° +6 60-70° +7 70-80° +8 80-90° +9 90-100° +10 100-110° +11 110-120° +12 120-130° +13 130-140° +14 140-150° +15 150-160° +16 160-170° +17 170-180° +18 180-190° +19 190-200° +20 200-210° +21 210-220° +22 220-230° +23 230-240° +24 240-250° +25 250-260° +26 260-270° +27 270-280° +28 280-290° +29 290-300° +30 300-310° +31 310-320° +32 320-330° +33 330-340° +34 340-350° +35 350-360°

Step 9a: Adjust...
If wrist is bent from midline or twisted: Add +1

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

Step 11: Add Coupling Score
Well fitting Handle and mid range power grip: good: +0
Acceptable but not ideal hand hold or coupling acceptable with another body part: fair: +1
Hand hold not acceptable but possible: poor: +2
No handles, awkward, unsafe with any body part: unacceptable: +3

Step 12: Score B, Find Column in Table C
Add values from steps 10 & 11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Final REBA Score
Table C Score + Activity Score = Final REBA Score

Figure 22: Before K1 Event task REBA score for Employee #1 and Employee #2.

REBA Employee Assessment Worksheet

based on Technical note: Rapid Entire Body Assessment (REBA), Hagberg, Mathiassen, Applied Ergonomics 31 (2000) 201-205

AKerl'Employee'#1'

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

 Step 1a: Adjust...
 If neck is twisted: -1
 If neck is side bending: +1
Neck Score: 2'

Step 2: Locate Trunk Position

 Step 2a: Adjust...
 If trunk is twisted: +1
 If trunk is side bending: +1
Trunk Score: 3'

Step 3: Legs

 Step 3a: Adjust...
 If load < 11 lbs: +0
 If load 11 to 22 lbs: +1
 If load > 22 lbs: +2
 Adjust: If shock or rapid build up of force: add +1
Leg Score: 2'

Step 4: Look-up Posture Score in Table A
 Using values from steps 1-3 above, locate score in Table A
Posture Score A: 5'

Step 5: Add Force/Load Score
 If load < 11 lbs: +0
 If load 11 to 22 lbs: +1
 If load > 22 lbs: +2
 Adjust: If shock or rapid build up of force: add +1
Force/Load Score: 3'

Step 6: Score A. Find Row in Table C
 Add values from steps 4 & 5 to obtain Score A. Find Row in Table C.
Score A: 8'

Scoring:
 1 = negligible risk
 2 or 3 = low risk, change may be needed
 4 to 7 = medium risk, further investigation, change soon
 8 to 10 = high risk, investigate and implement change
 11+ = very high risk, implement change

SCORES

Table A

	Neck		
	1	2	3
Legs	1 2 3 4	1 2 3 4	1 2 3 4
Trunk Posture Score	1 1 2 3 4	1 2 3 4	1 2 3 4
	2 2 3 4 5 6	3 4 5 6 7 8	4 5 6 7 8 9
	3 2 3 3 4 5	4 5 6 7 8 9	5 6 7 8 9 10
	4 3 4 4 5 6	5 6 7 8 9 10	6 7 8 9 10 11
	5 4 5 5 6 7	6 7 8 9 10 11	7 8 9 10 11 12

Table B

	Lower Arm		
	1	2	
Wrist	1 2 3 1 2 3	1 2 3	
Upper Arm Score	1 1 2 2 1 2 3	2 1 2 3 2 3 4	
	2 1 2 3 2 3 4	3 3 4 5 4 5 5	
	3 3 4 5 4 5 5	4 4 5 5 5 6 7	
	4 4 5 5 5 6 7	5 6 7 8 7 8 8	
	5 6 7 8 7 8 8	6 7 8 8 8 9 9	

Table C

Score A (score from table A + force/load score)	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	5	5	5	6	7	8	8	9	9	10	10	10
7	6	6	6	7	8	8	9	9	10	10	11	11
8	7	7	7	8	9	9	10	10	10	11	11	11
9	8	8	8	9	10	10	10	11	11	11	12	12
10	9	9	9	10	10	11	11	11	12	12	12	12
11	10	10	10	11	11	11	12	12	12	12	12	12
12	11	11	11	11	12	12	12	12	12	12	12	12

Step 7: Locate Upper Arm Position:

 Step 7a: Adjust...
 If shoulder is raised: +1
 If upper arm is abducted: +1
 If arm is supported or person is leaning: -1
Upper Arm Score: 2'

Step 8: Locate Lower Arm Position:

Lower Arm Score: 1'

Step 9: Locate Wrist Position:

 Step 9a: Adjust...
 If wrist is bent from midline or twisted: Add +1
Wrist Score: 2'

Step 10: Look-up Posture Score in Table B
 Using values from steps 7-9 above, locate score in Table B
Posture Score B: 2'

Step 11: Add Coupling Score
 Well fitting Handle and mid range power grip: good: +0
 Acceptable but not ideal hand hold or coupling acceptable with another body part: fair: +1
 Hand hold not acceptable but possible: poor: +2
 No handles, awkward, unsafe with any body part: unacceptable: +3
Coupling Score: 1'

Step 12: Score B. Find Column in Table C
 Add values from steps 10 & 11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.
Score B: 3'

Step 13: Activity Score
 +1 = or more body parts are held for longer than 1 minute (static)
 +1 Repeated small range actions (more than 4x per minute)
 +1 Action causes rapid large range changes in postures or unstable base
Activity Score: 3'

Final REBA Score: 11'

REBA Employee Assessment Worksheet

based on Technical note: Rapid Entire Body Assessment (REBA), Hagberg, Mathiassen, Applied Ergonomics 31 (2000) 201-205

AKerl'Employee'#2'

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

 Step 1a: Adjust...
 If neck is twisted: -1
 If neck is side bending: +1
Neck Score: 2'

Step 2: Locate Trunk Position

 Step 2a: Adjust...
 If trunk is twisted: +1
 If trunk is side bending: +1
Trunk Score: 3'

Step 3: Legs

 Step 3a: Adjust...
 If load < 11 lbs: +0
 If load 11 to 22 lbs: +1
 If load > 22 lbs: +2
 Adjust: If shock or rapid build up of force: add +1
Leg Score: 2'

Step 4: Look-up Posture Score in Table A
 Using values from steps 1-3 above, locate score in Table A
Posture Score A: 5'

Step 5: Add Force/Load Score
 If load < 11 lbs: +0
 If load 11 to 22 lbs: +1
 If load > 22 lbs: +2
 Adjust: If shock or rapid build up of force: add +1
Force/Load Score: 3'

Step 6: Score A. Find Row in Table C
 Add values from steps 4 & 5 to obtain Score A. Find Row in Table C.
Score A: 8'

Scoring:
 1 = negligible risk
 2 or 3 = low risk, change may be needed
 4 to 7 = medium risk, further investigation, change soon
 8 to 10 = high risk, investigate and implement change
 11+ = very high risk, implement change

SCORES

Table A

	Neck		
	1	2	3
Legs	1 2 3 4	1 2 3 4	1 2 3 4
Trunk Posture Score	1 1 2 3 4	1 2 3 4	1 2 3 4
	2 2 3 4 5 6	3 4 5 6 7 8	4 5 6 7 8 9
	3 2 3 3 4 5	4 5 6 7 8 9	5 6 7 8 9 10
	4 3 4 4 5 6	5 6 7 8 9 10	6 7 8 9 10 11
	5 4 5 5 6 7	6 7 8 9 10 11	7 8 9 10 11 12

Table B

	Lower Arm		
	1	2	
Wrist	1 2 3 1 2 3	1 2 3	
Upper Arm Score	1 1 2 2 1 2 3	2 1 2 3 2 3 4	
	2 1 2 3 2 3 4	3 3 4 5 4 5 5	
	3 3 4 5 4 5 5	4 4 5 5 5 6 7	
	4 4 5 5 5 6 7	5 6 7 8 7 8 8	
	5 6 7 8 7 8 8	6 7 8 8 8 9 9	

Table C

Score A (score from table A + force/load score)	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	5	5	5	6	7	8	8	9	9	10	10	10
7	6	6	6	7	8	8	9	9	10	10	11	11
8	7	7	7	8	9	9	10	10	10	11	11	11
9	8	8	8	9	10	10	10	11	11	11	12	12
10	9	9	9	10	10	11	11	11	12	12	12	12
11	10	10	10	11	11	11	12	12	12	12	12	12
12	11	11	11	11	12	12	12	12	12	12	12	12

Step 7: Locate Upper Arm Position:

 Step 7a: Adjust...
 If shoulder is raised: +1
 If upper arm is abducted: +1
 If arm is supported or person is leaning: -1
Upper Arm Score: 2'

Step 8: Locate Lower Arm Position:

Lower Arm Score: 1'

Step 9: Locate Wrist Position:

 Step 9a: Adjust...
 If wrist is bent from midline or twisted: Add +1
Wrist Score: 2'

Step 10: Look-up Posture Score in Table B
 Using values from steps 7-9 above, locate score in Table B
Posture Score B: 2'

Step 11: Add Coupling Score
 Well fitting Handle and mid range power grip: good: +0
 Acceptable but not ideal hand hold or coupling acceptable with another body part: fair: +1
 Hand hold not acceptable but possible: poor: +2
 No handles, awkward, unsafe with any body part: unacceptable: +3
Coupling Score: 1'

Step 12: Score B. Find Column in Table C
 Add values from steps 10 & 11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.
Score B: 3'

Step 13: Activity Score
 +1 = or more body parts are held for longer than 1 minute (static)
 +1 Repeated small range actions (more than 4x per minute)
 +1 Action causes rapid large range changes in postures or unstable base
Activity Score: 0'

Final REBA Score: 0'

Figure 23: After K1 Event task REBA score for Employee #1 and Employee #2.

Job Title: MS1-Rear Axle	Job Location: Main Station #1	Analyst EH&S	Date Before
Task # Main Station #1- Rear Axle	Task Description: Torqueing rear axle bolts		
Hazard Type: Ergonomic Strain. Fall. Mechanical Failure. Struck Against. Visibility.	Hazard Description: Ergonomic Strain- damage of tissue from overexertion (sprains/ sprains) & repetitive motion. Fall- conditions resulting in an impact (slip/trip). Mechanical Failure- occurring when devices exceed design capacity or inadequately maintained. Struck Against- injury to body after coming into contact with surface. Visibility- obstructed vision resulting in error or other hazard.		
Consequence: Near-misses. Recordable injuries. Lost-Time injuries.	Hazard Controls: Reduce strains by decreasing exertion needed and repetitive motions. Eliminate possible falls by removing obstacle of employee #2. Current tooling exceeds design capacity and difficult to maintain. Remove obstacle of employee #2 so that employee #1 has an increased range of motion. New tooling to gain visibility when inserting rear axle bolts, nuts, and washers.		
Rational or Comment: Employee #2 is currently necessary but increases risks for Employee #1; ergonomic strain, falling, and struck against. Inadequate tooling for the final assembly skid increases risks for both employees; mechanical failure and visibility.			

Figure 24: Before K1 Event task JHA.

Job Title: MS1-Rear Axle	Job Location: Main Station #1	Analyst EH&S	Date A^er
Task # Main Station #1- Rear Axle	Task Description: Torqueing rear axle bolts		
Hazard Type: Ergonomic strain.	Hazard Description: Ergonomic strain- damage of tissue from overexertion (sprains/sprains) & repetitive motion.		
Consequence: Near-misses. Recordable injuries. Lost-Time injuries.	Hazard Controls: Reduce strains by decreasing exertion needed and repetitive motions. Purchase an air powered torque gun to be used.		
Rational or Comment: The risk of ergonomic strain is still present for Employee #1. The purchase of an air powered torque gun should be made.			

Figure 25: After K1 Event task JHA.

The success of the Kaizen event was determined from the percentage change for the task cycle time as well as the change in REBA and JHA scores. Safety was reduced from 5 hazards to 1 hazard after the K1 event. The ergonomic score was reduced; there was not a substantial improvement. The REBA score for Employee #1 was slightly reduced (REBA score from 13 to 11), the score indicated that it was still in the high-risk zone and further improvements were required. To address the remaining ergonomic and safety concerns the team determined that the next step would be to purchase an air powered torque gun for Employee #1 to use for this task. The team decided to request for the purchase of new air powered torque tooling as a reinvestment of funds that would be saved from the productivity improvements over the coming months as a result of the K1 event. Once the new powered torque gun is implemented the REBA and JHA scores could be reevaluated and should show further improvements. The severity of consequences and probability of exposure could also be included for further research in the future.

The data gathered for productivity before and after the implementation was compared to determine the improvement percentage after the Kaizen event. The task cycle time determined before and after the K1 event, in Figure 26, showed that the project had improved the task cycle time by 83%.

Task Cycle Time			
	BEFORE AVERAGE (STDEV)	AFTER AVERAGE (STDEV)	PERCENT IMPROVEMENT
Number of Employees	2	1	83%
Number of Minutes	15 (1.49)	5 (0.50)	
	TOTAL MAN MINUTES	TOTAL MAN MINUTES	
	30 (2.98)	5 (0.50)	

Figure 26: Before and After K1 Event task cycle time comparison.

After the new skid was implemented the employees were then able to complete the required task independently, seen in Figure 27. Additional workers were no longer needed to successfully torque the rear axle bolts. The employees noted that even without assistance from another employee the positioning needed to torque the rear axle bolts was less awkward and straining. The new skid design addressed the key problems that the team noted and eliminated the need for additional workers to properly torque the rear axle bolts in assembly Main Station #1 or during roll-off. The material handling equipment is now more reliable and no longer limits the assembly employees. It is believed that long-term verification will show that with the new skid there is a reduction in the incurred costs and time associated with maintenance for the material handling equipment. As production demands increases in the future, verification should show that the compounding issues are eliminated as a result of the changes for the final assembly skid.



Figure 27: A single employee can now torque the rear axle bolts in less awkward and straining positions, making the task more efficient, ergonomic, and safer.

Kaizen Event (K2): Feeder Station- Welding Subassembly

The focus of the second Kaizen event (K2) was on improving the efficiency of the manufacturing process for a feeding station where components are weld as a subassembly part for the final product. The methodology for the K2 event followed a traditional Kaizen event structure. The Kaizen event included the line employees, the line crew chief, the line supervisor, and the mechanical/manufacturing engineer as well as production employees from material handling, paint, assembly line, laser, band saw, machining, weld. The team was selected so that different aspects of the process could be represented.

Step #1: Identify the Problem

The scope of this Kaizen event was to evaluate the current problems with material availability for welding the subassembly. Previous documentation noted that the current process used was not ideal and resulted in delays. This evaluation focused on improving the unification of required materials to the welding subassembly from joint operations, materials, which needed to take place simultaneously. The effects were evaluated with respect to the actual component, not at a piece by piece level, overall production process efficiency as it feeds to final assembly.

The first step for the Kaizen event was to identify the problem. The waste and inefficiencies seen as a result of the manufacturing process used for the component was identified as a large opportunity for improvement. The current state of the process was established after discussing with all stakeholders the problems that were experienced

surrounding the welding subassembly and materials. The current manufacturing process for the subassembly is consistently delayed when arriving at the final assembly line. The subassembly also travels a substantial distance during the manufacturing process. The employees noted that with the high travel distances the material handling issues were more apparent. Previous documentation showed that there was poor coordination and delivery of the parts required for the welding subassembly. These parts required for the welding subassembly typically arrived late or inadequate quantities to allow the completion of an assembly. The higher-level that the previous documentation exposed was that there was a gap in coordination for materials from operations that needed to take place simultaneously. The team decided to target changes on the parts required for the welding subassembly. The Kaizen event was focused on the welding work center because it was the common point to experience those problems and had a direct impact on the main assembly line as well.

The non-value added activities have many limiting effects on the manufacturing process and the productivity of the employees. Resources are limited as a result of constant reactive resolution of issues rather than a more proactive approach. The waste in the process also causes unnecessary confusion with the computer tracking, ordering systems, and material flow process. The manufacturing process for the component needs to be properly evaluated to see where improvements can be made in order to better balance non-value and value added tasks. Better material flow is needed to help the manufacturing facility optimize and balance just-in-time production by having a leaner environment. As a result of just-in-time production and lean manufacturing there could be a reduction in cycle time and fewer throughput problems. Addressing the MRP scheduling issues could also reduce throughput problems and delays.

Step #2: Analyze the Problem

The second step for the Kaizen event was to analyze the problem. The Kaizen team determined to focus on the current problems with material availability for welding the subassembly. Previous documentation noted that the current process used was not ideal and resulted in delays. The Kaizen team focused on improving the coordination for the required material to the welding subassembly. The current manufacturing process was analyzed to address the complaints and problems that were reported surrounding the materials arriving at the welding work center. During the Kaizen event employees were first asked to establish the current state of the process in order to see where the constraints and key problems were. By using a “five whys” approach to get to the root of the problem, numerous other constraints were noted. As a means to define the subassembly’s materials that share common process, component design drawings and the manufacturing production process from order entry to shipment as well as optional processes used for work tickets or service were all made available to the team.

Many possible alternatives for improvement were suggested during the Kaizen event. In order to fully evaluate and prioritize the alternatives, the current state was evaluated using lean principles. This was done so that the true needs could be quantified and addressed in a feasible alternative. The current manufacturing process for the subassembly from raw materials to final assembly was documented for the inventory on hand to determine the production lead-time and the cycle time at each station to determine the total processing time. The production lead-time and processing time associated with the manufacturing process for the component from materials to final assembly were

determined by observing the operation for 10 samples. The 10 production lead-time and processing samples were documented and then averaged to determine the average efficiency for the component's manufacturing process. Observations resulted in a production lead-time of 12.5 days (± 1.08) and a processing time of 85.67 minutes (± 1.68) per assembly. By looking at the value creating time versus the production lead-time the average efficiency of this process then was determined to be 4.76% (± 0.40).

Step #3: Develop a Solution

To develop the changes that needed to occur the team reported issues were addressed with production scheduling. The team reported that the small materials and already purchased parts were traveling an unnecessary distance for just-in-time production. The material cart, seen in Figure 28, where materials are loaded and then brought to weld holds significantly more than is currently being loaded on it. The team suggested batching the materials on the band saw for a week or two weeks. The team noted that the materials often arrived late or inadequate quantities that limited actually welding the subassembly. Band saw pieces prior to the Kaizen event implementation on the cart can be seen in Figure 29. The employees addressed that the materials cut on the Alltra laser needed to be batched not only for the welder but to optimize the machine capability. The Alltra laser has two torches that can cut the same piece simultaneously. This meant that when production demands were at an odd number per day the laser was cutting one piece at the same rate the equipment could have cut two. The Alltra employees also reported that the parts needed to be nested together on the same sheet in the software program to ensure that they were cut on the same day and thus arrived at the welding work center simultaneously. Alltra parts prior to the Kaizen event implementation on the cart at weld, seen in Figure 30, demonstrate the uneven set. Material handling and welders noted that a supermarket/kanban system for the purchased parts, band saw parts, and Alltra parts would be beneficial. The kanban system would add more of a notification system to tell material handling when purchased parts needed to be brought from the storage location for refilling as well as begin to better organize the material flow and reduce transportation throughout the facility.



Figure 28: Before- Material cart at weld.



Figure 29: Before- Band saw material on cart at weld.



Figure 30: Before- Alltra material on cart at weld.

Step #4: Implement a Solution

The fourth step for the Kaizen event was to implement a solution. The changes that were needed were then simultaneously implemented for the component manufacturing process. The MRP work queue was reorganized to provide better scheduling and a more efficient work center for both the band saw and Alltra. The parts cut on the Alltra laser were batched to an even quantity to supply the material cart at weld. The quantity was determined to be an even value because the team had previously established the importance of optimizing the productivity and efficiency of the Alltra laser by using both available torches. The parts cut on the band saw were batched to the same even quantity as the Alltra parts to supply the material cart at weld. While the band saw parts did not need the parts to be issued in even quantities the team felt that by making that change it would provide an even set of all the parts required to the welding subassembly. These changes would increase productivity of the work centers by reducing material movement. A supermarket/kanban system was implemented to refill the material cart at weld for the purchased parts, band saw parts, and Alltra laser parts so that the available material is more consistent and in quantities for a complete component. The kanban system provided a notification system to tell material handling when purchased parts needed to move from the storage location for refilling as well as begin to better organize the material flow and reduce transportation throughout the facility. These changes helped to reduce excess idle

waiting time at weld for parts to arrive and increased the capacity of the welding work center and Alltra laser work center.

Step #5: Evaluate the Results

The fifth step for the Kaizen event was to evaluate the results. The new state of the process was evaluated 30 days after implementation by again evaluating the production lead time, processing time, and efficiency. The post Kaizen observations resulted on a production lead time of 9.60 days (± 2.07) and a processing time of 85.68 minutes (± 1.76) per subassembly. The average efficiency of this process then was determined to be 6.51% (± 1.68).

The success of the Kaizen event was determined from the percentage change for the process efficiency. The before and after efficiency was compared, seen in Figure 31, to determine that the project improved the efficiency by 36%.

Efficiency			
	BEFORE AVERAGE (STDEV)	AFTER AVERAGE (STDEV)	PERCENT IMPROVEMENT
Production Lead Time (days)	12.50 (1.08)	9.6 (2.07)	36%
Processing Time (minutes)	85.67 (1.68)	85.67 (1.76)	
	Efficiency (%)	Efficiency (%)	
	4.79% (0.40)	6.51% (1.68)	

Figure 31: Before and After event Efficiency comparison.

The changes for the material cart at weld addressed numerous key issues that the team noted for the manufacturing process from raw materials to final assembly for the component. The material cart has more inventory on hand at the weld work center but reduced the overall production lead-time for the larger manufacturing process. The welding work center is no longer starting the manufacturing process behind scheduled since parts are now available. As production demands increase, verification should show that the compounding problems are eliminated as a result of the changes for the parts arriving at weld. The material cart at weld, seen in Figure 32, now holds more material but allows the component to travel quicker from the welding work center to the next station (machining) and reduces the overall production lead time associated with the component. The material cart now holds the required parts from all feeder operations in consistent quantities. Alltra materials after the implementation event on the cart at weld, seen in Figure 33, are now in an even quantity for the set. The band saw material after the implementation event on the cart at weld, seen in Figure 34, are now available in a supply quantity consistent with the set provided from the Alltra laser. These changes reduce change over time and increase productivity of the work centers by reducing the material change over movement. The new supermarket/kanban system to refill the material cart at weld for the purchased parts, band saw parts, and Alltra laser parts helps provide more consistency and sets for the quantities needed to complete the component. The kanban system provides a notification system to tell material handlers when purchased parts need to be moved from the storage location for refilling as well as begin to better organize the material flow and reduce transportation throughout the facility. The changes also optimized the productivity and efficiency of the people and machines used throughout the

manufacturing process for the component. Rather than simply addressing the components direct needs the team looked at the larger process and the effects from the changes as a whole. Therefore, it was possible to decrease experienced problems throughout the manufacturing process at a higher level. It is believed that long-term verification will show that the benefits from the changes are substantial even for the assembly portion since there are exponential delays experienced at the end of the production process if the first step in the process starts behind schedule.



Figure 32: After- Material cart at weld.



Figure 33: After- Alltra material cart at weld.



Figure 34: After- Band saw material on cart at weld.

Post-Kaizen (K1 and K2) Events

Employee satisfaction for 15 employees (six K1 participants and five K2 participants as well as four employees that were not involved in the Kaizen events (NK)) was evaluated 30 days after the implementation of all improvement changes using the JDS methodology.

Results

Employee satisfaction scores for the 15 employees were determined using the scoring key for the JDS provided by Hackman and Oldham (1980), where each category is determined from the average of the given score or reverse score for specific questions in the survey. The score was then compared to the job family norms provided by Hackman and Oldham (1980), which can be seen in Appendix C.

The total group average Pre-Kaizen event JDS scores for Job Characteristics (Skill Variety=4.16, Task Identity=4.71, Task Significance=5.62, Autonomy=4.78, Feedback from the Job Itself=4.93, Feedback from Agents=4.33, Dealing with Others=4.89), Affective Outcomes (General Satisfaction=4.22, Internal Work Motivation=4.79, Growth Satisfaction=4.68), Context Satisfaction (Satisfaction with Job Security=5.10, Satisfaction with Compensation=4.43, Satisfaction with Co-Workers=5.36, Satisfaction with Supervision=4.89), Individual Growth Need Strength("Would Like" Format=5.01, "Job Choice" Format=3.62, Combined Growth Need Strength Score=4.31), and Motivating Potential Score (MPS=109.97), were all determined to be within expected ranges by comparing with the norms for the job family provided by Hackman and Oldham (Hackman & Oldham, 1980). The total group average JDS scores for Experienced Psychological States varied. The total group average score for Experienced Meaningfulness of the work (4.87) and Knowledge of Results (4.22) were both within the expected range for the job family norms. However, the average score for Experienced Responsibility for the Work (5.31) was higher than the expected range for the job family norms. Different from the total group average the K1 group average was higher than the expected range for the job family norms for Feedback from Agents (5.06) and lower than the expected range for Knowledge of Results (3.79). Also deviating from the total group average the NK group was below the expected norms for Internal Work Motivation (4.33). The average Pre-Kaizen scores for each group can be seen in Figure 34, (individual scores, seen in Appendix D) and have been compared to the norms for the job family provided by Hackman and Oldham (Hackman & Oldham, 1980), where the red values indicate that the score was outside of the norms.

The total group average Post-Kaizen event JDS scores for Job Characteristics (Skill Variety=4.00, Task Identity=4.38, Task Significance=5.44, Autonomy=4.82, Feedback from the Job Itself=4.33, Feedback from Agents=4.11, Dealing with Others=4.31), Affective Outcomes (General Satisfaction=5.01, Internal Work Motivation=4.46, Growth Satisfaction=4.73), Context Satisfaction (Satisfaction with Job Security=5.50, Satisfaction with Compensation=4.53, Satisfaction with Co-Workers=5.22, Satisfaction with Supervision=4.80), Individual Growth Need Strength("Would Like" Format=5.47, "Job Choice" Format=3.37, Combined Growth Need Strength Score=4.42), and Motivating Potential Score (MPS=90.73) were all determined to be within expected ranges by comparing with the norms for the job family provided by Hackman and Oldham (Hackman & Oldham, 1980). The total group average JDS scores for Experienced Psychological States

varied. The total average score for Experienced Meaningfulness of the work (4.65) and Knowledge of Results (4.07) were both within the expected range for the job family norms. However, the average score for Experienced Responsibility for the Work (5.20) was higher than the expected range for the job family norms. Different from the total group average the K1 group average was below the expected range for the job family norms for Dealing with Others (3.89). Also deviating from the total group average the K2 group was higher than the expected norms for Feedback from Agents (5.33) and Satisfaction with Job Security (6.20), but below the expected range for "Job Choice" Format (3.18). Another difference from the total group average, the NK group average was lower than the expected range for Knowledge of Results (3.88) and Internal Work Motivation (3.88). The average Post-Kaizen scores for each group can be seen in Figure 35, (individual scores, seen in Appendix E) and have been compared to the norms for the job family provided by Hackman and Oldham (Hackman & Oldham, 1980), where the red values indicate that the score was outside of the norms.

JDS Averages								
JDS Category	Before				After			
	K1	K2	NK	TOTAL	K1	K2	NK	TOTAL
I. Job Characteristics								
A. Skill Variety	3.89	4.47	4.17	4.16	3.83	3.87	4.42	4.00
B. Task Identity	4.89	5.13	3.92	4.71	4.39	4.40	4.33	4.38
C. Task Significance	5.89	5.40	5.50	5.62	5.06	5.53	5.92	5.44
D. Autonomy	5.22	4.20	4.83	4.78	4.39	5.27	4.92	4.82
E. Feedback from the Job Itself	5.39	5.07	4.08	4.93	4.39	4.40	4.17	4.33
F. Feedback from Agents	5.06	4.27	3.33	4.33	3.94	5.33	2.83	4.11
G. Dealing with Others	5.17	4.60	4.83	4.89	3.89	4.20	5.08	4.31
II. Experienced Psychological States								
A. Experienced Meaningfulness of the Work	5.21	4.80	4.44	4.87	4.13	5.35	4.56	4.65
B. Experienced Responsibility for the Work	5.20	5.60	5.10	5.31	4.87	5.76	5.00	5.20
C. Knowledge of Results	3.79	4.25	4.81	4.22	4.25	4.00	3.88	4.07
III. Affective Outcomes								
A. General Satisfaction	5.10	3.60	4.35	4.40	4.90	5.20	4.95	5.01
B. Internal Work Motivation	4.81	5.13	4.33	4.79	4.58	4.77	3.88	4.46
C. Growth Satisfaction	5.46	3.80	4.63	4.68	4.88	5.20	3.94	4.73
IV. Context Satisfaction								
A. Satisfaction with Job Security	5.58	4.70	4.88	5.10	5.42	6.20	4.75	5.50
B. Satisfaction with Compensation (Pay)	5.08	3.60	4.50	4.43	4.92	4.60	3.88	4.53
C. Satisfaction with Co-Workers	5.39	5.73	4.83	5.36	5.17	5.40	5.08	5.22
D. Satisfaction with Supervision	5.06	4.80	4.75	4.89	4.72	5.73	3.75	4.80
V. Individual Growth Need Strength								
A. "Would Like" Format	5.36	4.93	4.58	5.01	5.97	5.43	4.75	5.47
B. "Job Choice" Format	3.85	3.48	3.44	3.62	3.56	3.18	3.31	3.37
C. Combined Growth Need Strength Score	4.61	4.20	4.01	4.31	4.77	4.30	4.03	4.42
VI. Motivating Potential Score								
MPS	139.70	106.69	69.48	109.97	76.03	131.07	62.35	90.73

Figure 35: Job Diagnostic Survey Before and After Averages.

The delta value for each JDS category was calculated using the difference of the before and after value divided by the before value. Given that happier employees typically have a higher JDS score, a negative delta value, indicates an improvement since the score increased after the Kaizen events. The average employee satisfaction levels for each JDS category was determined using the average scores for the K1 participants, K2 participants, Non-Kaizen participants (NK), and total of all 15 employees. As a whole improvements

were seen after the Kaizen events for Autonomy ($\Delta = -0.01$), General Satisfaction ($\Delta = -0.14$), Growth Satisfaction ($\Delta = -0.01$), Satisfaction with Job Security ($\Delta = -0.08$), Satisfaction with Compensation ($\Delta = -0.02$), “Would Like” Format ($\Delta = -0.09$), and the Combined Growth Need Strength Score ($\Delta = -0.02$).

When looking at the categories broken down between the participant groups some areas improved while other areas did not. The findings also show that a positive or negative impact of the Kaizen events on job satisfaction varies for the categories and participant groups (K1, K2, and NK). For Knowledge of Results ($\Delta = -0.12$) the score for the K1 group improved but did not for the K2 or NK groups. For some of the JDS categories the score for the K2 participants improved but the K1 and NK participants did not; Feedback from Agents ($\Delta = -0.25$), Experienced Responsibility for the Work ($\Delta = -0.03$), Growth Satisfaction ($\Delta = -0.37$), Satisfaction with Job Security ($\Delta = -0.32$), Satisfaction with Compensation ($\Delta = -0.28$), Satisfaction with Supervision ($\Delta = -0.19$), and Motivating Potential Score ($\Delta = -0.23$). For some of the JDS categories the score only improved for the NK participants; Skill Variety ($\Delta = -0.06$), Task Identity ($\Delta = -0.11$), Feedback from the Job Itself ($\Delta = -0.02$), Dealing with Others ($\Delta = -0.05$), and Satisfaction with Co-Workers ($\Delta = -0.05$). Task Significance, Autonomy, Experienced Meaningfulness of the Work, and General Satisfaction showed improvements for both the K2 and NK groups but not for the K1 group.

Across all of the groups (K1, K2, and NK) there was a decrease for Internal Work Motivation and “Job Choice” Format after the Kaizen events. The average delta values for each JDS category and participant group can be seen in Figure 36, where the green values indicate the areas that improved after the Kaizen events.

The delta values were then statistically evaluated for normality across the three participant groups (K1, K2, and NK) using the Shapiro-Wilk test. For the K1 (Test Statistic=0.981; $p=0.002$) and K2 (Test Statistic=0.802; $p=0.000$) participant groups the dataset significantly deviated from normal distribution while the NK participant dataset had a normal distribution.

Since the normality test revealed that some of the datasets were not normal, non-parametric analysis was used. The delta values and associated group (K1, K2, and NK) was then statistically evaluated for each of the JDS categories using Kruskal-Wallis non-parametric test. The hypothesis tested was:

Ho: there is no significant difference between the samples (K1, K2, and NK)

Ha: there is a significant difference between the samples (K1, K2, and NK).

In the event that the null hypothesis was rejected a multiple comparisons test was performed since the overall test showed significant differences across the samples. The statistical analysis for each category individually was calculated across K1, K2, and NK samples. For some of the categories the analysis showed that there was no statistical difference across the K1, K2, and NK samples. Thus the null hypothesis was retained for Skill Variety, Task Identity, Task Significance, Autonomy, Feedback from the Job Itself, Dealing with Others, Experienced Responsibility for the Work, Knowledge of the Results, General Satisfaction, Internal Work Motivation, Satisfaction with Job Security, Satisfaction with Co-Workers, Satisfaction with Supervision, “Would Like” Format, “Job Choice” Format, and Combined Growth Need Strength Score. For other categories there was a statistical difference across the K1, K2, and NK samples, seen in Figure 37. Thus the null hypothesis

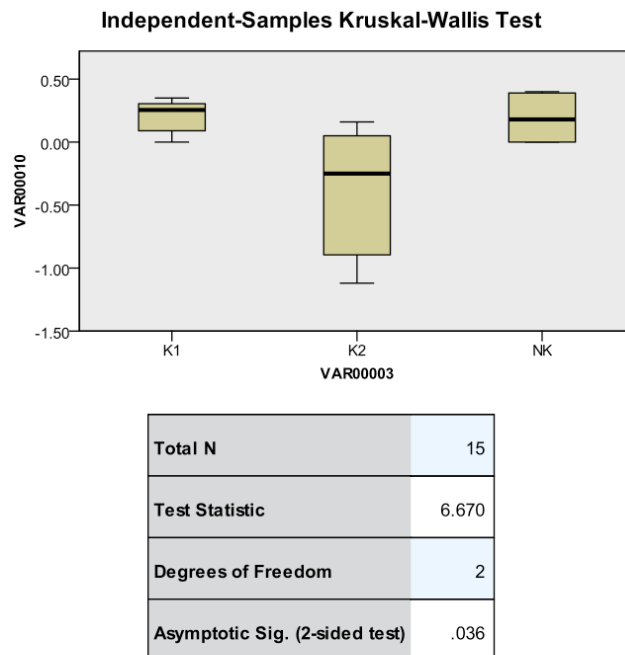
was rejected for the Feedback from Agents (Test Statistic=6.670; p=0.036) (Figure 38), Experienced Meaningfulness of the Work (Test Statistic=6.628; p=0.036) (Figure 39), Growth Satisfaction (Test Statistic=7.195; p=0.027) (Figure 40), Satisfaction with Compensation (Test Statistic=6.737; p=0.034) (Figure 41), and Motivating Potential Score (Test Statistic=7.361; p=0.025) (Figure 42). All five JDS categories that had a significant difference across the samples showed that K2 sample improved more than the K1 and NK samples. A full summary and graphs of the statistical analysis and results can be seen in Appendix F.

JDS Deltas					
JDS Category		DELTA			
		K1	K2	NK	TOTAL
I. Job Characteristics					
	A. Skill Variety	0.01	0.13	-0.06	0.04
	B. Task Identity	0.10	0.14	-0.11	0.07
	C. Task Significance	0.14	-0.02	-0.08	0.03
	D. Autonomy	0.16	-0.25	-0.02	-0.01
	E. Feedback from the Job Itself	0.19	0.13	-0.02	0.12
	F. Feedback from Agents	0.22	-0.25	0.15	0.05
	G. Dealing with Others	0.25	0.09	-0.05	0.12
II. Experienced Psychological States					
	A. Experienced Meaningfulness of the Work	0.21	-0.11	-0.03	0.04
	B. Experienced Responsibility for the Work	0.06	-0.03	0.02	0.02
	C. Knowledge of Results	-0.12	0.06	0.19	0.04
III. Affective Outcomes					
	A. General Satisfaction	0.04	-0.44	-0.14	-0.14
	B. Internal Work Motivation	0.05	0.07	0.11	0.07
	C. Growth Satisfaction	0.11	-0.37	0.15	-0.01
IV. Context Satisfactions					
	A. Satisfaction with Job Security	0.03	-0.32	0.03	-0.08
	B. Satisfaction with Compensation (Pay)	0.03	-0.28	0.14	-0.02
	C. Satisfaction with Co-Workers	0.04	0.06	-0.05	0.02
	D. Satisfaction with Supervision	0.07	-0.19	0.21	0.02
V. Individual Growth Need Strength					
	A. "Would Like" Format	-0.11	-0.10	-0.04	-0.09
	B. "Job Choice" Format	0.08	0.09	0.04	0.07
	C. Combined Growth Need Strength Score	-0.03	-0.02	-0.01	-0.02
VI. Motivating Potential Score					
	MPS	0.46	-0.23	0.10	0.17

Figure 36: JDS delta for group averages before versus after.

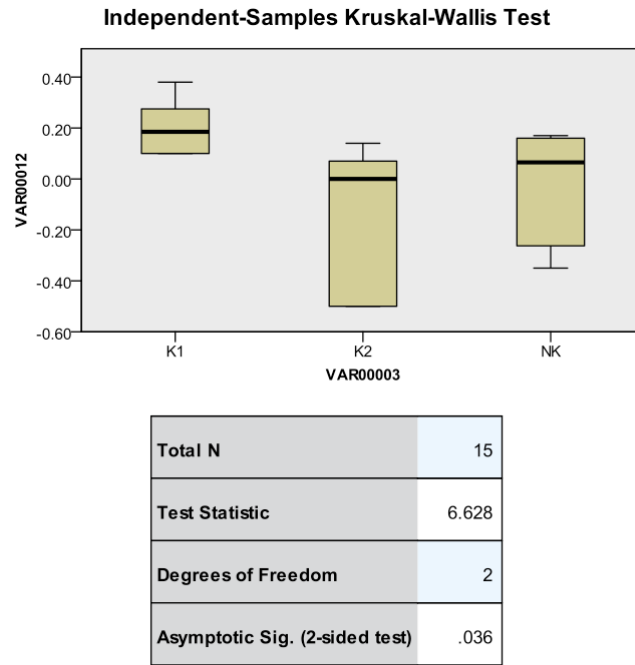
Kruskal-Wallis Test Summary			
Null Hypothesis	Stat.	Sig.	Decision
The distribution of Feedback from Agents is the same across categories of K1, K2, and NK.	6.670	0.036	Reject the null hypothesis.
The distribution of Experienced Meaningfulness of the Work is the same across categories of K1, K2, and NK.	6.628	0.036	Reject the null hypothesis.
The distribution of Growth Satisfaction is the same across categories of K1, K2, and NK.	7.195	0.027	Reject the null hypothesis.
The distribution of Satisfaction with Compensation is the same across categories of K1, K2, and NK.	6.737	0.034	Reject the null hypothesis.
The distribution of Motivating Potential Score (MPS) is the same across categories of K1, K2, and NK.	7.361	0.025	Reject the null hypothesis.
* Asymptotic Significances are displayed. The significance level is 0.05.			

Figure 37: Significant elements from non-parametric Kriskal-Wallis Hypothesis Testing.



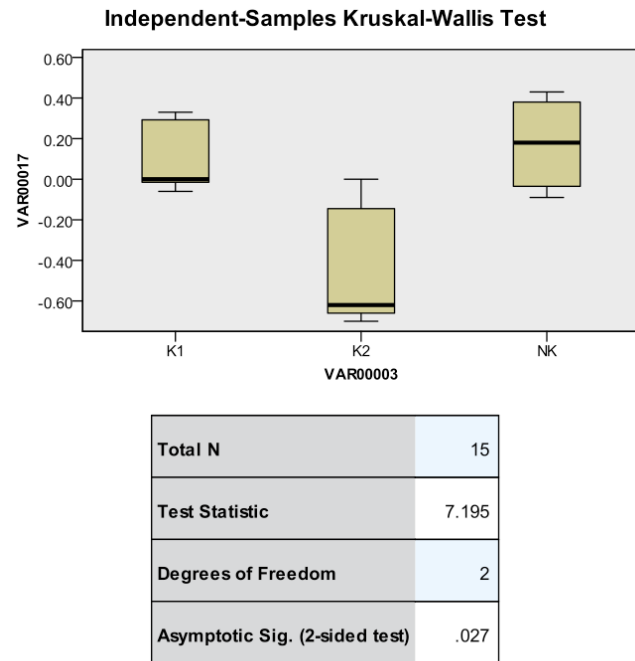
1. The test statistic is adjusted for ties.

Figure 38: Box plot for Feedback from Agents a significant category from JDS Hypothesis Testing.



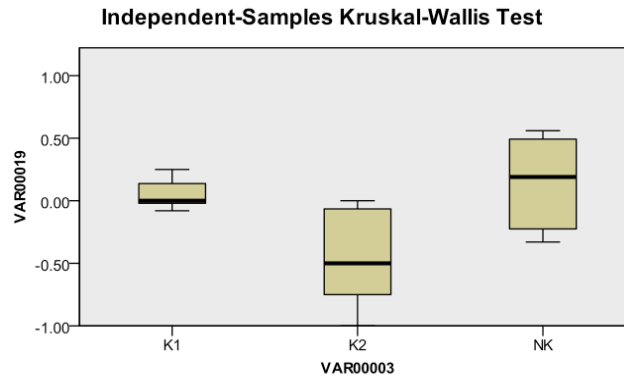
1. The test statistic is adjusted for ties.

Figure 39: Box plot for Experienced Meaningfulness of the Work a significant category from JDS Hypothesis Testing.



1. The test statistic is adjusted for ties.

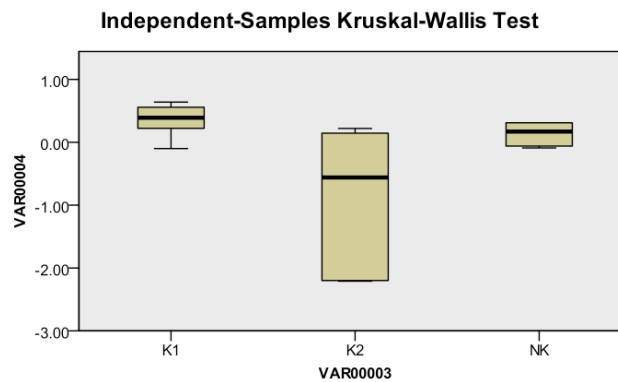
Figure 40: Box plot for Growth Satisfaction a significant category from JDS Hypothesis Testing.



Total N	15
Test Statistic	6.737
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.034

1. The test statistic is adjusted for ties.

Figure 41: Box plot for Satisfaction with Compensation a significant category from JDS Hypothesis Testing.



Total N	15
Test Statistic	7.361
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.025

1. The test statistic is adjusted for ties.

Figure 42: Box plot for Motivating Potential Score (MPS) a significant category from JDS Hypothesis Testing.

CONCLUSION AND DISCUSSION

This case study demonstrates the impact of lean on employees' ergonomics, safety, and job satisfaction. The results support the proposed relationship, seen in Figure 11, between employee satisfaction, ergonomics, and safety while implementing a high quality Kaizen event. Like Kelby (2012) suggested, the integrated approach did allow for the wastes in human performance to be measured and accounted for, with benefits seen for production, quality, and safety. The K1 event showed that lean principles could be used for simultaneous benefits for employee ergonomics and safety but did not yield significant differences. By using Kaizen in conjunction with safety and ergonomic evaluation tools to redesign the process, it was possible to improve productivity (83%) as well as reduce employee safety (from 5 hazards to 1 hazard) and ergonomics (REBA score from 13 to 11) for the K1 event. While improvements were made for employee ergonomics, the REBA score for Employee #1 (e.g. REBA score of 11) is still in the critical range. This indicates that more improvements are needed in order to see a significant improvement to employee ergonomics.

The REBA ergonomic score was reduced for Employee #1 since both feet can now be planted rather than shifting weight to avoid Employee #2. With both feet planted there was no longer a risk of falling and thus reduced the JHA score. Another factor contributing to the reduced REBA score was the increased range of motion for Employee #1 since it is no longer necessary to elevate the shoulder to avoid hitting the machine while torqueing the bolts. The increase range of motion meant that the JHA score was also reduced since there was no longer a risk of being struck against the machine. The JHA safety score reduction can also be attributed to the new skid's increased visibility and the removal of possible mechanical failure. Even though there were benefits to ergonomics and safety there is still more improvements that could be done. The REBA score for Employee #1 shows that it remains as a high-risk activity and requires immediate action. The team has investigated the possibility of an air powered torque gun to use for the task of torqueing the rear axle bolts to further reduce the ergonomic strains. The proposed torque gun will also serve as a backup for other torque gun tasks at the end of the line. Once the team is able to reinvest the savings from the K1 event to purchase an air powered torque gun the safety and ergonomic concerns for Employee #1 should be reduced even more. During the K1 event ergonomics proved to be an essential part of better design as well as a method for preventing health and safety issues similar to the results Fadier and De la Garza (2006) noted. The effects were also seen in increased reliability and decreased maintenance for the material handling tools. Prior to the K1 event there were historical safety records for near-misses and recordable injuries as a result of the documented hazards; falling, struck against, and mechanical failure. In the year and a half since the K1 event, there have been zero safety incidents. The K2 event showed that by using Kaizen as a tool to enhance the process, it was possible to improve manufacturing process efficiency (36%).

The delta value findings from this study show that a positive or negative impact of the Kaizen events on job satisfaction varies for the JDS categories and participant groups (K1, K2, and NK). Some areas improved while others did not after the Kaizen events. Likewise, some areas showed that there were different levels of impact depending if the employees were involved or not involved in the Kaizen event. As a whole improvements

were seen after the Kaizen events for Autonomy, General Satisfaction, Growth Satisfaction, Satisfaction with Job Security, Satisfaction with Compensation, “Would Like” Format, and the Combined Growth Need Strength Score.

When looking at the delta value for each category broken down between the participant groups some areas improved while other areas did not. For Knowledge of Results the score for the K1 group improved but did not for the K2 or NK groups. One possible explanation for this is that the K1 group could see tangible changes after the event but the K2 group could not physically see their changes since adjustments were mostly made in the MRP scheduling system. The adjustments made to the MRP scheduling did give employees more control over the process. The physical changes like Kanban bins, removal of excess parts, and better storage utilization of carts, that were seen by the K2 group did help to better organize the materials needed but did not address the root cause of the problem. For some of the JDS categories the score for the K2 participants improved but the K1 and NK participants did not; Feedback from Agents, Experienced Responsibility for the Work, Growth Satisfaction, Satisfaction with Job Security, Satisfaction with Compensation, Satisfaction with Supervision, and Motivating Potential Score. The significant improvement impact seen to the score for Feedback from Agents, Experienced Responsibility for the Work, and the Motivating Potential Score for the K2 group after the Kaizen event but not for the K1 and NK groups suggests that the unique characteristics of the second Kaizen event contributed to the success that was seen. The first Kaizen event had been scheduled for over 200 days after an earlier Product Line Value Stream Map. When the Product Line was revisited for a new Value Stream Map the employees again noted the need for an improvement to the skid used in assembly Main Station #1. The company had not actively pursued the employee recognized improvement initiatives. On the other hand the K2 event was more actively pursued; within 3 months the K2 employees contributed to the Product Line VSM, a Component Level VSM that was conducted to address one of the noted action items, and a Kaizen event (K2) to address the new noted action items. Unlike the K1 employees, the K2 employees saw leadership taking immediate action to address their improvement initiatives. Thus the K2 JDS evaluation improvements could stem from management’s commitment and the perceptions of the K2 employees. For some of the JDS categories the score only improved for the NK participants; Skill Variety, Task Identity, Feedback from the Job Itself, Dealing with Others, and Satisfaction with Co-Workers. One possible explanation for this is that the NK group was no longer busy doing rework and was able to engage with other co-workers while completing new tasks, thus increasing the NK groups score for those JDS categories. Task Significance, Autonomy, Experienced Meaningfulness of the Work, and General Satisfaction showed improvements for both the K2 and NK groups but not for the K1 group. Across all of the groups (K1, K2, and NK) there was a decrease for Internal Work Motivation and “Job Choice” Format after the Kaizen events. The data shows that the K2 and NK groups both saw improvements for Autonomy and that K2 showed improvements for Satisfaction with Job Security after the Kaizen events which is the opposite of the findings by Parker (2003). One possible reason for the differences is the high quality of the K2 event. Consistent with the findings of Vidal (2007), the K1 data shows that an increase in employee involvement is not always related to an increase in satisfaction.

The K1 event reduced the ergonomic and safety concerns employees had shared but did not eliminate the issues. If the company had immediately made funds available to

purchase a new air powered torque gun for the task, the employees may have felt that their problems and solutions were being more adequately addressed. Rather than focusing on what remained that employees could not fix, more success may have been seen for K1 if there had been a greater focus placed on the local issues and available resources in that specific environment as Kawakami and Kogi (2001) noted.

The data from the Kruskal-Wallis test shows that the impact of a Kaizen event on job satisfaction had significant differences across the K1, K2, and NK samples for some categories (Feedback from Agents, Experienced Meaningfulness of the Work, Growth Satisfaction, Satisfaction with Compensation, and Motivating Potential Score) but did not yield a significant difference in other categories. Thus overall findings, determined from the Motivating Potential Score, showed that there was a significant difference across the K1, K2, and NK samples for job satisfaction after a Kaizen event.

Despite the small sample size on this study, if done correctly Kaizen events appear to offer many significant improvement opportunities not only to productivity but also to employee's ergonomics, safety and satisfaction levels. However, many questions still remain about lean's effects on employees and how lean can best be integrated with other initiatives. The results on employee satisfaction, like the results seen in the examination by Anderson-Connolly and Associates (2002), show conflicts. The results are limited and cannot be generalized to the whole manufacturing industry. The results may differ for manufacturing operations that are not highly repetitious or activities that are in other areas like material flow, machining, paint, etc.

The data for the delta values show that of the three groups (K1, K2, and NK) K2 had the largest positive impact on employee job satisfaction, 13 of the 21 JDS categories. The data and knowledge of the unique characteristic surrounding each Kaizen event suggests that employees are more satisfied when they are more actively involved and when leaders quickly address noted problems. Therefore, companies should strive to improve the quality of the Continuous Improvement programs as well as Kaizen improvement events since it appears to have a direct correlation with employee satisfaction. Similar to Holden (2011), this study supports an integrated approach even with the controversy since lean does appear to offer improvements for other initiatives like employee satisfaction. The data shows that the NK group also had a large positive impact on employee job satisfaction, 11 of the 21 JDS categories. This suggests that the company culture impacted the views and satisfaction of the employees not involved in the Kaizen events. The NK group saw their team's problems being actively addressed by their leaders and peers thus experiencing the benefits without any additional activities or variations from their normal workday. The NK group also experienced positive side effects of the K1 and K2 changes since those employees work further downstream.

This study also supports the theory that simultaneously implementing multiple improvement tools through an integrated approach could result in an increased benefit for the company since steps and documentation are not duplicated and the project area receives support from many angles. An integrated approach, as demonstrated in Figure 11, allows improvements to be implemented that will positively impact multiple areas (Lean, employee satisfaction, ergonomics, and safety) and reduces the chance of an improvement in one area coming at the detriment of another area. By having an integrated approach benefits from productivity can later be reinvested for ergonomic and safety improvements or vice versa. The impact that a quality Kaizen event can provide to employee satisfaction

appears to be yet another reason for companies to pursue a Lean environment. The results seen in this research could be duplicated for other product lines and processes to improve process efficiency and serves as a benchmark that the company can use toward other processes. The observed improvements can be applied to many other processes within the company by following the steps that were taken to identify the root cause of problems and optimize processes.

The improvements seen for the NK group supported larger benefits in the company culture becoming more prone and open to continuous improvements. The employees are more active when looking for ways to revive their work environment. The team has requested that the high-level Value Stream Map be conducted semi-annually so that they can better address isolated issues that arise from the low or high production rate cycles. The team has also noted that a focused Value Stream Map should also be conducted when new products are deployed so that any concerns and problems can be addressed quickly in a formal Kaizen setting. Unlike Glendon (2008) suggested, the company safety culture also improved with many employees now identifying other safety and even ergonomic issues. This study could be enhanced in the future by repeating the JHA, REBA, and JDS evaluations so that the long term effects and stability of the changes could be quantitatively accessed. A longitudinal study would help better understand the short and long term changes on employee satisfaction, ergonomics, and safety after a Kaizen event.

In conclusion, this study supports the theory that companies could experience increases in productivity as well as benefits in employee ergonomics, safety, and job satisfaction when Lean strategies are implemented through an integrated approach. The integrated approach for a Kaizen event supports the proposed relationship between employee satisfaction, ergonomics, and safety. Maximum benefits can be seen in all of the areas if leadership acts quickly and properly involves employees. Overall, the Kaizen events helped to encourage communication and employee involvement. As a result, the new processes are both more efficient and less frustrating for employees.

REFERENCES

- Abegglen, J. C., & Stalk, G. J. (1985). *Kaisha, the Japanese Corporation*. New York: Basic Books.
- Anderson-Connolly, R., Grunberg, L., Greenberg, E. S., & Moore, S. (2002). Is lean mean? Workplace transformation and employee well-being. *Work, Employment and Society*, 16(3), 389-413. doi: 10.1177/095001702762217407.
- Appicharla, S. K. (2006). *System for Investigation of Railway Interfaces*. Paper presented at the The 1st Institution of Engineering and Technology International Conference on System Safety, Savoy Palace, London, UK.
- Askin, R. G., & Goldberg, J. B. (2002). *Design and Analysis of Lean Production Systems*: John Wiley & Sons, Inc.
- Aveta. (2012). The Relationship between Employee Job Satisfaction and Business Productivity. *Six Sigma Online Training* Retrieved April 30, 2012, from <http://www.sixsigmaonline.org/six-sigma-training-certification-information/the-relationship-between-employee-job-satisfaction-and-business-productivity.html>.
- Bentley, T., & Tappin, D. (2010). Incorporating organisational safety culture within ergonomics practice. *Ergonomics*, 53(10), 1167-1174.
- Bernard, T. E. (2007). Analysis Tools for Ergonomists, from <http://personal.health.usf.edu/tbernard/ergotools/index.html>.
- Bernstein, R. (2009). Lean and Ergonomics: A Good Match. *Lean Insider* Retrieved April 30, 2012, from <http://leaninsider.productivitypress.com/2009/11/lean-and-ergonomics-good-match.html>.
- Boswell, W. R., Boudreau, J. W., & Tichy, J. (2005). The relationship between employee job change and job satisfaction: the honeymoon-hangover effect. *The Journal of applied psychology*, 90(5), 882-892. doi: 10.1037/0021-9010.90.5.882.
- Brief, A. P., & Roberson, L. (1989). Job Attitude Organization: An Exploratory Study. *Journal of Applied Social Psychology*, 19(9), 717-727. doi: 10.1111/j.1559-1816.1989.tb01254.x.
- Brief, A. P., & Weiss, H. M. (2002). Organizational behavior: affect in the workplace. *Annual review of psychology*, 53, 279-307.
- Burgoon, J. K., Buller, D. B., & Woodall, W. G. (1996). *Nonverbal communication: The unspoken dialogue* (2nd ed.). New York: McGraw-Hill.

- Caseley, P. R., Guerra, S., & Froome, P. (2006). *Measuring Hazard Identification*. Paper presented at the The 1st Institution of Engineering and Technology International Conference on System Safety, Savoy Palace, London, UK.
- Côté, S., & Morgan, L. M. (2002). A longitudinal analysis of the association between emotion regulation, job satisfaction, and intentions to quit. *Journal of Organizational Behavior*, 23(8), 947-962. doi: 10.1002/job.174.
- Cotton, J. L. (1993). *Employee Involvement: Methods for Improving Performance and Work Attitudes*: Sage Publication, Inc.
- Coyle, A. (2005). Comparison of the Rapid Entire Body Assessment and the New Zealand Manual Handling 'Hazard Control Record', for assessment of manual handling hazards in the supermarket industry. *Work: A Journal of Prevention, Assessment and Rehabilitation*, 24(2), 111-116.
- Deming, W. E. (1982). *Out of the Crisis*: Massachusetts Institute of Technology.
- Dempsey, P. G., McGorry, R. W., & Maynard, W. S. (2005). A survey of tools and methods used by certified professional ergonomists. *Applied Ergonomics*, 36(4), 489-503. doi: 10.1016/j.apergo.2005.01.007.
- Evans, J. R., & Lindsay, W. M. (2008). *Managing for Quality and Performance Excellence* (Seventh Edition ed.): Thomson South-Western.
- Fadier, E., & De la Garza, C. (2006). Safety design: Towards a new philosophy. *Safety Science*, 44(1), 55-73. doi: 10.1016/j.ssci.2005.09.008.
- Farace, R. V., Monge, P. R., & Russell, H. M. (1977). *Communicating and Organizing*: Addison-Wesley Pub. Co.
- Feld, W. M. (2001). *Lean Manufacturing : Tools, Techniques, and How to Use Them*. Boca Raton, Florida: St. Lucie Press / APICS Series on Resource Management.
- Fisher, C. D. (2000). Mood and emotions while working: Missing pieces of job satisfaction? *Journal of Organizational Behavior*, 21(Spec Issue), 185-202. doi: 10.1002/(sici)1099-1379(200003)21:2<185::aid-job34>3.0.co;2-m.
- Gagnon, M. A., & Michael, J. H. (2003). Employee strategic alignment at a wood manufacturer: An exploratory analysis using lean manufacturing. *Forest products journal*, 53(10), 24-29.
- Glendon, I. (2008). Safety culture and safety climate: How far have we come and where could we be heading? *Journal of Occupational Health and Safety - Australia and New Zealand*, 24(3).
- Glenn, D. D. (2011). Job Safety Analysis; Its Role Today. *Professional Safety*(March), 10.

- Hackman, J. R., & Oldham, G. R. (1980). *Work Redesign*: Addison-Wesley Publishing Company, Inc.
- Hafey, R. B. (2009). *Lean Safety: Transforming Your Safety Culture with Lean Management*: Productivity Press.
- Hignett, S., & McAtamney, L. (2000). Rapid Entire Body Assessment [REBA] Employee Worksheet 205. 32.
- Holden, R. J. (2011). Lean Thinking in Emergency Departments: A Critical Review. *Annals of emergency medicine*, 57(3), 265-278.
- Humantech. (2003). *Applied Industrial Ergonomics*: Humantech Inc.
- Humantech. (2011). Clients and Ergonomics Success Stories Retrieved April 30, 2012, from <http://www.humantech.com/about/clients>.
- Ikuma, L. H., Nahmens, I., & James, J. (2011). Use of Safety and Lean Integrated Kaizen to Improve Performance in Modular Homebuilding. *Journal of Construction Engineering and Management*, 137(7), 551-560.
- Jones, D. T., & Womack, J. P. (2002). *Seeing the Whole: Mapping the Extended Value Stream*: Lean Enterprise Institute.
- Kawakami, T., & Kogi, K. (2001). Action-Oriented Support for Occupational Safety and Health Programs in Some Developing Countries in Asia. *International Journal of Occupational Safety and Ergonomics*, 7(4), 421-434.
- Kawakami, T., & Kogi, K. (2005). Ergonomics support for local initiative in improving safety and health at work: International Labour Organization experiences in industrially developing countries. *Ergonomics*, 48(5), 581-590.
- Kelby, J. (2012). How Much Waste are you Still Missing by Doing Lean Without Ergonomics? Retrieved April 30, 2012, from <http://www.kelbyergodesign.com>.
- Kelleher, B. (2010). The Link Between High Performance and Employee Engagement *Louder Than Words: The Practical Employee Engagement Steps That Drive Results*. Portland, Oregon: BLKB Publishing.
- Kluck, B. (2003). Value Stream Mapping. In I. NW Lean (Ed.).
- Krafcik, J. F. (1988). Triumph of the lean production system. *Sloan Management Review*(Fall), 41-52.
- Lee, K. S. (2005). Ergonomics in total quality management: How can we sell ergonomics to management? *Ergonomics*, 48(5), 547-558.
- Leff, D. (2011). Lean-- Not Just a Manufacturing Concept. *Iron & Steel Technology*, 2.

- Li, G., & Buckle, P. (1999). Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods. [Review]. *Ergonomics*, 42(5), 674-695. doi: 10.1080/001401399185388.
- Lindberg, P., Voss, C., & Blackmon, K. L. (Eds.). (1998). *International Manufacturing Strategies; Context, Content and Change*: Kluwer Academic Publishers.
- Loch, C. H., Heyden, L. V. D., Wassenhove, L. N. V., Huchzermeier, A., & Escalle, C. (2003). *Industrial Excellence: Management Quality in Manufacturing*: Springer.
- Louis, R. S. (1997). Integrating Kanban with MRPII: Automating a Pull System for Enhanced JIT Inventory Management. New York, NY: Productivity Press.
- Marras, W. S., & Karwowski, W. (Eds.). (2006). The Occupational Ergonomics Handbook: Interventions, Controls, and Applications in Occupational Ergonomics. (Second Edition ed.). Boca Raton, FL: Taylor & Francis.
- McAtamney, L., & Nigel Corlett, E. (1993). RULA: a survey method for the investigation of work-related upper limb disorders. *Applied Ergonomics*, 24(2), 91-99. doi: 10.1016/0003-6870(93)90080-s.
- Meister, D. (1999). *The History of Human Factors and Ergonomics*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Montgomery, D. C. (2009). *Introduction to Statistical Quality Control* (6th ed.): Wiley.
- National Safety Council. (1964). *Accident prevention manual for industrial operations* (5th ed.). Chicago.
- National Safety Council. (2009). Accident prevention manual for business and industry; Administration and programs. Chicago. (Reprinted from: 13).
- Nicholson, A. S., & Ridd, J. E. (Eds.). (1988). *Health, Safety, and Ergonomics*: Butterworth & Co.
- Occupational Safety and Health Administration. (2002). Job Hazard Analysis (Vol. 3071, pp. 51): United States Department of Labor.
- Occupational Safety and Health Administration. (2012). Safety and Health Programs, Program Implementation.
- Parker, S. K. (2003). Longitudinal effects of lean production on employee outcomes and the mediating role of work characteristics. *The Journal of applied psychology*, 88(4), 620-634.
- Pillastrini, P., Mugnai, R., Farneti, C., Bertozzi, L., Bonfiglioli, R., Curti, S., . . . Violante, F. S. (2007). Evaluation of two preventive interventions for reducing musculoskeletal

- complaints in operators of video display terminals. [Randomized Controlled Trial]. *Physical therapy*, 87(5), 536-544. doi: 10.2522/ptj.20060092.
- Ramsay, J., Denny, F., Szirotnyak, K., Thomas, J., Corneliuson, E., & Paxton, K. L. (2006). Identifying nursing hazards in the emergency department: a new approach to nursing job hazard analysis. *Journal of Safety Research*, 37(1), 63-74. doi: 10.1016/j.jsr.2005.10.018.
- Rother, M., & Shook, J. (2003). Learning to See: Value Stream Mapping to Add Value and Eliminate Muda: Lean Enterprise Institute.
- Rowe, D. C. (1987). Resolving the person-situation debate: Invitation to an interdisciplinary dialogue. *American Psychologist*, 42(3), 218-227. doi: 10.1037/0003-066x.42.3.218.
- Rozenfeld, O., Sacks, R., Rosenfeld, Y., & Baum, H. (2010). Construction Job Safety Analysis. *Safety Science*, 48(4), 491-498. doi: 10.1016/j.ssci.2009.12.017.
- Schniederjans, M. J. (1993). *Topics in Just-in-Time Management*. Needham Heights, Massachusetts: Allyn & Bacon.
- Shadur, M. A., Rodwell, J. J., Simmons, D. E., & Bamber, G. J. (1994). International best practice, quality management and high performance: inferences from the Australian automotive sector. *The International Journal of Human Resource Management*, 5(3), 609-632. doi: 10.1080/09585199400000050.
- Smith, S. (2002, September 11, 2002). A systematic, data-driven approach to ergonomics can help you benefit from the drive for manufacturing excellence. *Ergonomics and Manufacturing Excellence* Retrieved April 30, 2012, from https://ehstoday.com/health/ergonomics/ehs_imp_35819.
- Stahl, M. J. (2004). *Encyclopedia of Health Care Management*: Sage Publications, Inc.
- Stanton, N., Hedge, A., Brookhuis, K., Salas, E., & Hendrick, H. (2004). Handbook of human factors and ergonomics methods: Chemical Rubber Company Press.
- Swartz, G. (2001). *Job hazard analysis*. Rockville, MD: Government Institute.
- Tapping, D. (2007). The Lean Pocket Handbook For Kaizen Events. Any Industry- Any Time. Your Team and Individual Improvement Plan.: MCS Media.
- United States General Accounting Office. (1997). Worker Protection: Private Sector Ergonomics Programs Yield Positive Results. Washington, D.C.: Health, Education, and Human Services Division.
- Verret, D. (2012). Fixture- Axle Cart Rear. In M. Engineer (Ed.), *Pro-Engineer* (pp. Fixture-Axle Cart Rear). United States.

- Vidal, M. (2007). Lean Production, Worker Empowerment, and Job Satisfaction: A Qualitative Analysis and Critique. *Critical Sociology*, 33(1-2), 247-278. doi: 10.1163/156916307x168656.
- Vieira, E., & Kumar, S. (2004). Working Postures: A Literature Review. *Journal of Occupational Rehabilitation*, 14(2), 143-159. doi: 10.1023/b:joor.0000018330.46029.05.
- Walder, J., Karlin, J., & Kerk, C. (2007). Integrated Lean Thinking and Ergonomics: Utilizing Material Handling Assist Device Solutions for a Productive Workplace. *Material Handling Industry of America*.
- Walker, W. F. (1966). *Engineering Productivity* (Vol. Volume II: New Manufacturing Processes). New York, NY: Chemical Publishing Co., Inc.
- Weiss, H. M. (2002). Deconstructing job satisfaction: Separating evaluations, beliefs and affective experiences. *Human Resource Management Review*, 12(2), 173-194. doi: 10.1016/s1053-4822(02)00045-1.
- Weiss, H. M., Nicholas, J. P., & Daus, C. S. (1999). An Examination of the Joint Effects of Affective Experiences and Job Beliefs on Job Satisfaction and Variations in Affective Experiences over Time. *Organizational Behavior and Human Decision Processes*, 78(1), 1-24. doi: 10.1006/obhd.1999.2824.
- Womack, J. P., & Jones, D. T. (2003). *Lean Thinking; Banish Waste and Create Wealth in Your Corporation*. New York, NY: Free Press. A Division of Simon & Schuster, Inc.
- Zeng, S. X., Shi, J. J., & Lou, G. X. (2007). A synergetic model for implementing an integrated management system: an emperical study in China. *Journal of Cleaner Production*, 15, 1760-1767.

APPENDIX A: INSTITUTIONAL REVIEW BOARD

An approval procedure for this research project was completed with the Louisiana State University Institutional Review Board (IRB). The purpose of the IRB is to facilitate research, protect research participants, and comply with all research regulations. An Application for Exemption was completed and submitted to the Louisiana State University IRB Office since the current research qualified for exemption. A Security of Data Agreement was also completed with the Louisiana State University IRB Office. All participants voluntarily agreed to participate in this research and signed a written consent.

Application for Exemption from Institutional Oversight

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/ projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.



Institutional Review Board
Dr. Robert Mathews, Chair
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— Applicant, Please fill out the application in its entirety and include the completed application as well as parts A-F, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at <http://research.lsu.edu/CompliancePoliciesProcedures/InstitutionalReviewBoard%28IRB%29/item24737.html>

A Complete Application Includes All of the Following:

- (A) Two copies of this completed form and two copies of parts B thru F.
- (B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
- (C) Copies of all instruments to be used.
*If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
- (D) The consent form that you will use in the study (see part 3 for more information.)
- (E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (<http://php.nihtraining.com/users/login.php>)
- (F) IRB Security of Data Agreement: (<http://research.lsu.edu/files/item26774.pdf>)

1) Principal Investigator: Amanda Morse

Rank: Graduate Student

Dept: Industrial Engineering

Ph: 985-507-5907

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2) Co Investigator(s): please include department, rank, phone and e-mail for each
*If student, please identify and name supervising professor in this space

Isabelina Nahmens, Ph.D.
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Telephone: (225) 578-0943 Email: nahmens@lsu.edu

IRB# E7055 LSU Proposal #

- ☒ Complete Application
- ☒ Human Subjects Training

3) Project Title:

Evaluating the Impact
of Lean on
Employee Ergonomics, Safety,
and Job Satisfaction
in Manufacturing

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 10/17/2015

4) Proposal? (yes or no)

no

If Yes, LSU Proposal Number

Also, if YES, either

☐ This application completely matches the scope of work in the grant

OR

☐ More IRB Applications will be filed later

5) Subject pool (e.g. Psychology students)

Employees at John Deere Thibodaux Facility

*Circle any "vulnerable populations" to be used: (children <18; the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature

Amanda Morse

Date 10-11-12

(no per signatures)

** I certify my responses are accurate and complete. If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted ☒ Not Exempted ☐ Category/Paragraph 2

Signed Consent Waived?: Yes / No

Reviewer Mathews

Signature Robert Mathews

Date 10/18/12

Consent Form

Dear Participant:

This survey is designed to evaluate current levels of productivity, ergonomics, and employee satisfaction before and after a Kaizen event. Pictures will be taken throughout the process; however faces will be blurred out to protect your identity. The purpose of this project is to analyze the value added and non value added activities during the process and to explore the shortcoming of the process for the necessary improvements. This study has been approved by the Institutional Review Board (IRB), and the contact information can be found in the next page which has to be noted down upon signing this form.

Your answers for the questionnaire and original photographs will be kept completely confidential and your identity will be protected. Participation and Non-Participation is completely your decision and will not affect your current employment status. If the questions of questionnaire are not comfortable for you to answer feel free to skip it or stop filling it further. Please state if you are not comfortable being photographed. Your participation is on voluntary basis and will be highly appreciated. By participating you will greatly contribute in our process for finding the problem areas and suggesting the feasible solution to the problem.

By signing this consent form, it is believed that you have read and understood the idea and purpose of this survey and you give your consent to participate in it. As well as agree to be photographed while working. This sheet with your signature will be detached from the actual survey to protect your identity. The next page contains contact information of Principal Investigator's and IRB for your reference which is to be separated by you after completing the survey.

Name: _____

Signature: _____

Date: _____

Thank you for participation!

Study Exempted By:
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Exemption Expires: 10/17/2015

APPENDIX B: JOB DIAGNOSTIC SURVEY

1

Job Diagnostic Survey

This questionnaire was developed as part of a Yale University study of jobs and how people react to them. The questionnaire helps to determine how jobs can be better designed, by obtain

On the following pages you will find several different kinds of questions about your job. Specific instructions are given at the start of each section. Please read them carefully. It should take no more than 25 minutes to complete the entire questionnaire. Please move through it quickly.

The questions are designed to obtain *your* perceptions of your job and *your* reactions to it.

There are no trick questions. Your individual answers will be kept completely confidential. Please answer each item as honestly and frankly as possible.

Thank you for your cooperation.

Section One

This part of the questionnaire asks you to describe your job, as *objectively* as you can.

Please do *not* use this part of the questionnaire to show how much you like or dislike your job. Questions about that will come later. Instead, try to make your descriptions as accurate and as objective as you possibly can.

A sample question is given below.

To what extent does your job require you to work with mechanical equipment?

1	2	3	4	5	6	7
Very little;			Moderately.			Very much;
The job requires almost						The job requires almost
no contact with						constant work with
mechanical equipment of						mechanical equipment.
any kind.						

You are to *circle* the number which is the most accurate description of your job.

If you do not understand these instructions, please ask for assistance.

If you do understand these instructions, please begin.

1. To what extent does your job require you to *work closely with other people* (either "clients," or people in related jobs in your own organization)?

1	2	3	4	5	6	7
Very little; Dealing with other people is not at all necessary in doing the job.		Moderately; Dealing with others is necessary.			Very much; Dealing with other people is an absolutely essential and crucial part of doing the job.	

2. How much *autonomy* is there in your job? That is, to what extent does your job permit you to decide *on your own* how to go about doing the work?

1	2	3	4	5	6	7
Very little; The job gives me almost no personal "say" about how and when the work is done.		Moderate autonomy; Many things are standardized and not under my control, but I can make some decisions about the work.			Very much; The job gives me almost complete responsibility for deciding how and when the work is done.	

3. To what extent does your job involve doing a "*whole*" and *identifiable piece of work*? That is, is the job a complete piece of work that has an obvious beginning and end? Or is it only a small *part* of the overall piece of work, which is finished by other people or by automatic machines?

1	2	3	4	5	6	7
My job is only a tiny part of the overall piece of work; the results of my activities cannot be seen in the final product or service.		My job is a moderate-sized "chunk" of the overall piece of work; my own contribution can be seen in the final outcome.			My job involves doing the whole piece of work, from start to finish; the results of my activities are easily seen in the final product or service.	

4. How much *variety* is there in your job? That is, to what extent does the job require you to do many different things at work, using a variety of your skills and talents?

1	2	3	4	5	6	7
Very little; The job requires me to do the same routine things over and over again.		Moderate variety.			Very much; The job requires me to do many different things, using a number of different skills and talents.	

5. In general, how *significant or important* is your job? That is, are the results of your work likely to significantly affect the lives or well-being of other people?

1	2	3	4	5	6	7
Not very significant; The outcomes of my work are <i>not</i> likely to have important effects on other people			Moderately significant.			Highly significant; The outcomes of my work can affect other people in very important ways.

6. To what extent do *managers or co-workers* let you know how well you are doing on your job?

1	2	3	4	5	6	7
Very little; People almost never let me know how well I am doing.		Moderately; Sometimes people may give me "feedback;" other times they may not.			Very much; Managers or co-workers provide me with almost constant "feedback" about how well I am doing.	

7. To what extent does *doing the job itself* provide you with information about your work performance? That is, does the actual *work itself* provide clues about how well you are doing—aside from any "feedback" co-workers or supervisors may provide?

1	2	3	4	5	6	7
Very little; The job itself is set up so I could work forever without finding out how well I am doing.		Moderately; Sometimes doing the job provides "feedback" to me; sometimes it does not.			Very much; The job is set up so that I get almost constant "feedback" as I work about how well I am doing.	

Section Two

Listed below are a number of statements which could be used to describe a job.

You are to indicate whether each statement is an *accurate* or an *inaccurate* description of *your* job.

Once again, please try to be as objective as you can in deciding how accurately each statement describes your job—regardless of whether you like or dislike your job.

Write a number in the blank beside each statement, based on the following scale:

<i>How accurate is the statement in describing your job?</i>						
1	2	3	4	5	6	7
Very Inaccurate	Mostly Inaccurate	Slightly Inaccurate	Uncertain	Slightly Accurate	Mostly Accurate	Very Accurate

1. The job requires me to use a number of complex or high-level skills.

2. The job requires a lot of cooperative work with other people.

3. The job is arranged so that I do *not* have the chance to do an entire piece of work from beginning to end.

4. Just doing the work required by the job provides many chances for me to figure out how well I am doing.

5. The job is quite simple and repetitive.

6. The job can be done adequately by a person working alone—without talking or checking with other people.

7. The supervisors and co-workers on this job almost *never* give me any “feedback” about how well I am doing in my work.

8. This job is one where a lot of people can be affected by how well the work gets done.

9. The job denies me any chance to use my personal initiative or judgment in carrying out the work.

10. Supervisors often let me know how well they think I am performing the job.

11. The job itself provides very few clues about whether or not I am performing well.

12. The job gives me considerable opportunity for independence and freedom in how I do the work.

13. The job gives me considerable opportunity for independence and freedom in how I do the work.

14. The job itself is *not* very significant or important in the broader scheme of things.

Section Three

Now please indicate how you *personally feel about your job*.

Each of the statements below is something that a person might say about his or her job. You are to indicate your own personal *feelings* about your job by marking how much you agree with each of the statements.

Write a number in the blank beside each statement, based on the following scale.

How much do you agree with the statement?

1	2	3	4	5	6	7
Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly

- _____ 1. It's hard, on this job, for me to care very much about whether or not the work gets done right.
- _____ 2. My opinion of myself goes up when I do this job well.
- _____ 3. Generally speaking I am very satisfied with this job.
- _____ 4. Most of the things I have to do on this job seem useless or trivial.
- _____ 5. I usually know whether or not my work is satisfactory on this job.
- _____ 6. I feel a great sense of personal satisfaction when I do this job well.
- _____ 7. The work I do on this job is very meaningful to me.
- _____ 8. I feel a very high degree of *personal* responsibility for the work I do on this job.
- _____ 9. I frequently think of quitting this job.
- _____ 10. I feel bad and unhappy when I discover that I have performed poorly on this job.
- _____ 11. I often have trouble figuring out whether I'm doing well or poorly on this job.
- _____ 12. I feel I should personally take the credit or blame for the results of my work on this job.
- _____ 13. I am generally satisfied with the kind of work I do in this job.
- _____ 14. My own feelings generally are *not* affected much one way or the other by how well I do on this job.

Section Four

Now please indicate how *satisfied* you are with each aspect of your job listed below. Once again, write the appropriate number in the blank beside each statement.

<i>How satisfied are you with this aspect of your job?</i>						
1	2	3	4	5	6	7
Extremely Dissatisfied	Dissatisfied	Slightly Dissatisfied	Neutral	Slightly Satisfied	Satisfied	Extremely Satisfied

- _____ 1. The amount of job security I have.
- _____ 2. The amount of pay and fringe benefits I receive.
- _____ 3. The amount of personal growth and development I get in doing my job.
- _____ 4. The people I talk and work with on my job.
- _____ 5. The degree of respect and fair treatment I receive from my boss.
- _____ 6. The feelings of worthwhile accomplishment I get from doing my job.
- _____ 7. The chance to get to know other people while on the job.
- _____ 8. The amount of support and guidance I receive from my supervisor.
- _____ 9. The degree to which I am fairly paid for what I contribute to this organization.
- _____ 10. The amount of independent thought and action I can exercise in my job.
- _____ 11. How secure things look for me in the future in this organization.
- _____ 12. The chance to help other people while at work.
- _____ 13. The amount of challenge in my job.
- _____ 14. The overall quality of the supervision I receive in my work.

Section Five

Now please think of the *other people* in your organization who hold the same job you do. If no one has exactly the same job as you, think of the job which is most similar to yours.

Please think about how accurate each of the statements describes the feelings of those people about the job.

It is quite all right if your answers here are different from when you described your *own* reactions to the job. Often different people feel quite differently about the same job.

Once again, write a number in the blank beside each statement, based on this scale.

How much do you agree with the statement?

1	2	3	4	5	6	7
Disagree Strongly	Disagree	Disagree Slightly	Neutral	Agree Slightly	Agree	Agree Strongly

- _____ 1. Most people on this job feel a great sense of personal satisfaction when they do the job well.
- _____ 2. Most people on this job are very satisfied with the job.
- _____ 3. Most people on this job feel that the work is useless or trivial.
- _____ 4. Most people on this job feel a great deal of personal responsibility for the work they do.
- _____ 5. Most people on this job have a pretty good idea of how well they are performing their work.
- _____ 6. Most people on this job find the work very meaningful.
- _____ 7. Most people on this job feel that whether or not the job gets done right is clearly their own responsibility.
- _____ 8. People on this job often think of quitting.
- _____ 9. Most people on this job feel bad or unhappy when they find that they have performed the work poorly.
- _____ 10. Most people on this job have trouble figuring out whether they are doing a good or a bad job.

Section Six

Listed below are a number of characteristics which could be present on any job. People differ about how much they would like to have each one present in their own jobs. We are interested in learning *how much you personally would like to have each one present in your job.*

Using the scale below, please indicate the *degree* to which you *would like to have each characteristic present in your job.*

NOTE: The numbers on this scale are different from those used in previous scales.

4	5	6	7	8	9	10
Would like having this only a moderate amount (or less).		Would like having this very much.			Would like having this <i>extremely</i> much.	

- _____ 1. High respect and fair treatment from my supervisor.
- _____ 2. Stimulating and challenging work.
- _____ 3. Changes to exercise independent thought and action in my job.
- _____ 4. Great job security.
- _____ 5. Very friendly co-workers.
- _____ 6. Opportunities to learn new things from my work.
- _____ 7. High pay and good fringe benefits.
- _____ 8. Opportunities to learn new things from my work.
- _____ 9. Quick promotions.
- _____ 10. Opportunities for personal growth and development in my job.
- _____ 11. A sense of worthwhile accomplishment in my work.

Section Seven

People differ in kinds of jobs they would most like to hold. The questions in this section give you a chance to say just what it is about a job that is most important to *you*.

For each question, two different kinds of jobs are briefly described. You are to indicate which of the jobs you personally would prefer—if you had to make a choice between them.

In answering each question, assume that everything else about the jobs is the same. Pay attention only to the characteristics actually listed.

Two examples are given below.

Job A			Job B	
A job requiring work with mechanical equipment most of the day.			A job requiring work with other people most of the day.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

If you like working with people and working with equipment equally well, you would circle the number 3, as has been done in the example.

Job A			Job B	
A job requiring you to expose yourself to considerable physical danger.			A job located 200 miles from your home and family.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

If you would slightly prefer risking physical danger to working far from your home, you would circle number 2.

Please ask for assistance if you do not understand exactly how to do these questions.

1.

Job A			Job B	
A job where the pay is very good.			A job where there is considerable opportunity to be creative and innovative.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

2.

Job A			Job B	
A job where you are often required to make important decisions.			A job with many pleasant people to work with.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

3.

Job A			Job B	
A job in which greater responsibility is given to those who do the best work.			A job in which greater responsibility is given to loyal employees who have the most seniority.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

4.

Job A			Job B	
A job in an organization which is in financial trouble—and might have to close down within the year.			A job in which you are not allowed to have any say whatever in how your work is scheduled, or in the procedures to be used in carrying it out.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

5.

Job A			Job B	
A very routine job.			A job where you co-workers are not very friendly.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

6.

Job A			Job B	
A job with a supervisor who is often very critical of you and your work in front of other people.			A job which prevents you from using a number of skills that you worked hard to develop.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

7.

Job A			Job B	
A job with a supervisor who respects you and treats you fairly.			A job which provides constant opportunities for you to learn new and interesting things.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

8.

Job A			Job B	
A job where there is a real chance you could be laid off.			A job with very little chance to do challenging work.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

9.

Job A			Job B	
A job in which there is a real chance for you to develop new skills and advance in the organization.			A job which provides lots of vacation time and an excellent fringe benefit package.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

10.

Job A			Job B	
A job with little freedom and independence to do your work in the way you think best.			A job where the working conditions are poor.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

11.

Job A			Job B	
A job with very satisfying teamwork.			A job which allows you to use your skills and abilities to the fullest extent.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

12.

Job A			Job B	
A job which offers little or no challenge.			A job which requires you to be completely isolated from co-workers.	
1	2	3	4	5
Strongly Prefer A	Slightly Prefer A	Neutral	Slightly Prefer B	Strongly Prefer B

Section Eight

Biographical Data

1. Sex:
☐ Male
☐ Female
2. Age (check one):
☐ Under 20
☐ 20-29
☐ 30-39
☐ 40-49
☐ 50-59
☐ 60 or over
3. Education (check one):
☐ Grade School
☐ Some High School
☐ High School Degree
☐ Some Business College or Technical School Experience
☐ Some College Experience (other than business or technical school)
☐ Business College or Technical School Degree
☐ College Degree
☐ Master's or Higher Degree
4. What is your brief job title? _____

APPENDIX C: JDS FAMILY NORMS

JDS Family Norms		
	Average	Standard Deviation
I. Job Characteristics		
A. Skill Variety	4.2	1.2
B. Task Identity	4.3	1.3
C. Task Significance	5.3	1.2
D. Autonomy	4.5	1.3
E. Feedback from the Job Itself	4.7	1.2
F. Feedback from Agents	3.6	1.4
G. Dealing with Others	5.3	1.2
II. Experienced Psychological States		
A. Experienced Meaningfulness of the Work	5	1
B. Experienced Responsibility for the Work	2.5	0.92
C. Knowledge of Results	5.1	1.2
III. Affective Outcomes		
A. General Satisfaction	4.6	1.2
B. Internal Work Motivation	5.3	0.89
C. Growth Satisfaction	4.7	1.2
IV. Context Satisfaction		
A. Satisfaction with Job Security	4.6	1.3
B. Satisfaction with Compensation (Pay)	4.5	1.4
C. Satisfaction with Co-Workers	5.3	0.95
D. Satisfaction with Supervision	4.6	1.4
V. Individual Growth Need Strength		
A. "Would Like" Format	5.3	1.2
B. "Job Choice" Format	3.9	0.71
C. Combined Growth Need Strength Score	4.6	0.79
VI. Motivating Potential Score		
MPS	105	57

APPENDIX D: PRE-KAIZEN JOB DIAGNOSTIC SURVEY RESULTS

Sample	BeforeNK	BeforeNK	BeforeK1	BeforeK1	BeforeK1	BeforeNK	BeforeNK	BeforeK1	BeforeK1	BeforeK2	BeforeK2	BeforeK2	BeforeK2	BeforeK2	BeforeK1	Average	STDV	
I. A. Skill Variety	5	4	4.666667	4.666667	4.666667	5	2.666667	3.333333	3.666667	4.333333	5.333333	3.333333	4.666667	4.666667	2.333333	4.16	0.90	
I. B. Task Identity	3	3.333333	4.666667	4.333333	4.333333	3.333333	6	5.333333	5	6.333333	4.666667	3.333333	4.333333	4.333333	7	5.666667	4.71	1.19
I. C. Task Significance	5	5	4.666667	6.666667	6.333333	6.666667	5.333333	6.333333	6.666667	6	6.666667	3.333333	4.333333	6.666667	4.666667	5.62	1.08	
I. D. Autonomy	4.666667	4	4.666667	6	6	6	4.666667	6	5.333333	4	5.666667	2.333333	3	6	3.333333	4.78	1.23	
I. E. Feedback from the Job Itself	5.666667	4	4.666667	6.666667	6.333333	4.333333	2.333333	6.333333	4	6	3.666667	4.666667	4.666667	6.333333	4.333333	4.93	1.24	
I. F. Feedback from Agents	6	3.666667	4	6.333333	6.666667	2	1.666667	5.666667	5.333333	3	5.333333	4	2.666667	6.333333	2.333333	4.33	1.73	
I. G. Dealing with Others	5	3.666667	4.666667	6.666667	6.666667	6.333333	4.333333	4.666667	4.333333	5.666667	6.333333	3	3	5	4	4.89	1.23	
II. A. Experienced Meaningfulness of the Work	5	5.75	5	5.25	6.5	4	3	5	5	5.25	6	3.5	3.5	5.75	4.5	4.87	1.00	
II. B. Experienced Responsibility for the Work	5.2	4.8	5.4	4.8	4.6	5.6	4.8	5	6	4.8	6.4	5.8	5.8	5.2	5.4	5.31	0.53	
II. C. Knowledge of Results	5.75	4.5	4	3.25	3.25	4.75	4.25	4	3.75	5.5	4.5	3.25	3.25	4.75	4.5	4.22	0.80	
III. A. General Satisfaction	5.2	5	5	5.6	5.8	4.6	2.6	5.4	5.4	2	4	3.6	3.6	4.8	3.4	4.40	1.15	
III. B. Internal Work Motivation	5	4.333333	5.166667	5.166667	4.666667	4.333333	3.666667	4.666667	5.333333	5.166667	5.5	4.666667	4.666667	5.666667	3.833333	4.79	0.58	
III. C. Growth Satisfaction	5.5	4	6	6	6.25	5.5	3.5	4.25	6.25	2.5	4.25	3.25	3.25	5.75	4	4.68	1.27	
IV. A. Satisfaction with Job Security	3.5	4	6	6	7	6	6	6	5	4	4.5	4.5	4.5	6	3.5	5.10	1.11	
IV. B. Satisfaction with Compensation (Pay)	4.5	4.5	5	6	6	5.5	3.5	4	5.5	1.5	4	3	3	6.5	4	4.43	1.36	
IV. C. Satisfaction with Co-Workers	4	4.666667	6	6	6.666667	5.333333	5.333333	5.333333	5	5.666667	6	5.333333	5.333333	6.333333	3.333333	5.36	0.87	
IV. D. Satisfaction with Supervision	6	4.333333	4.666667	6	6	6	2.666667	4.666667	6	2	6	4.666667	4.666667	6.666667	3	4.89	1.41	
V. A. "Would Like" Format	3.833333	4	4.833333	4	6.166667	4.5	6	5.166667	5	6	6.333333	4.166667	4.166667	4	7	5.01	1.04	
V. B. "Job Choice" Format	3.75	4	3.5	3.875	4.125	3.25	2.75	3.625	3.75	4	3	3.875	3.875	2.625	4.25	3.62	0.50	
V. C. Combined Growth Need Strength Score	3.791667	4	4.166667	3.9375	5.145833	3.875	4.375	4.395833	4.375	5	4.666667	4.020833	4.020833	3.3125	5.625	4.31	0.59	
VI. Motivating Potential Score	121.33333	60.296296	87.111111	198.44444	204.44444	60	36.296296	170	145.38272	66.66667	167.90123	31.111111	35.55556	232.22222	32.839506	109.97	70.98	

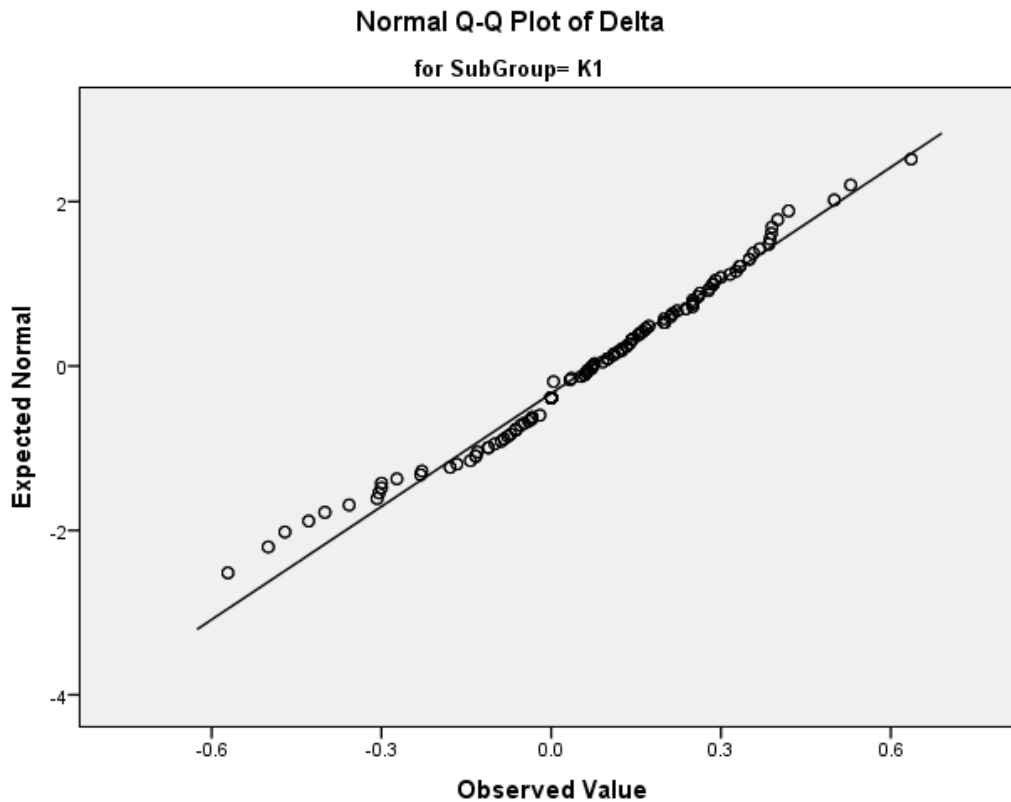
APPENDIX E: POST-KAIZEN JOB DIAGNOSTIC SURVEY RESULTS

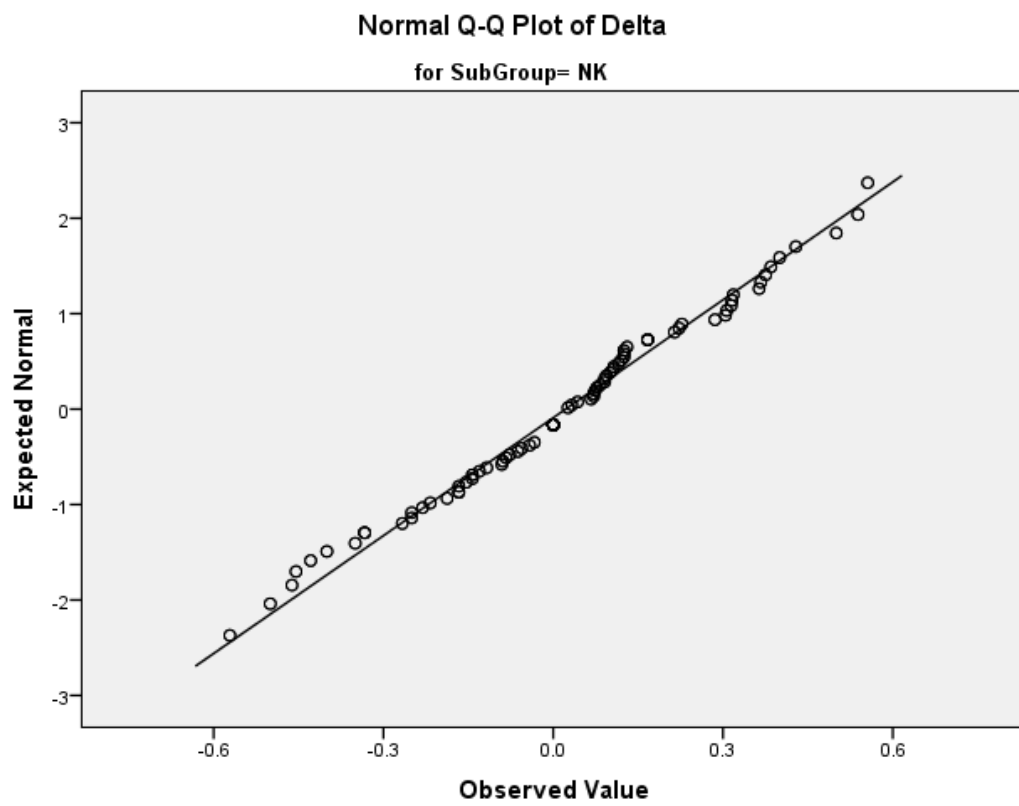
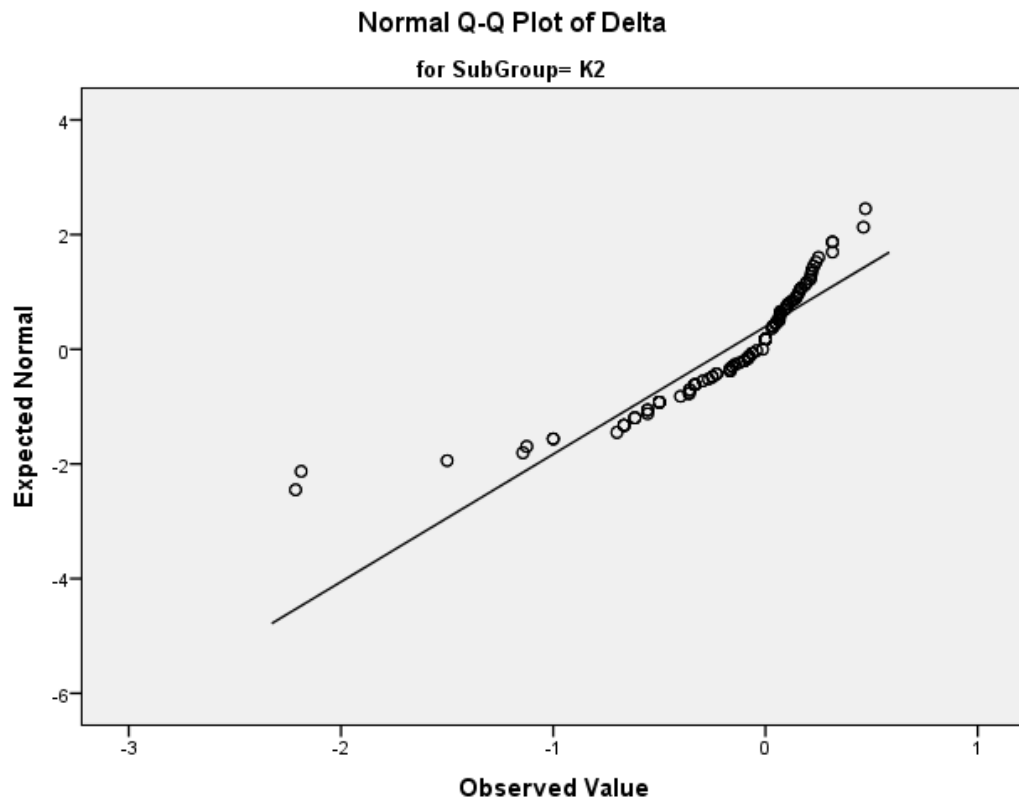
Sample	AfterNK	AfterNK	AfterK1	AfterK1	AfterK1	AfterNK	AfterNK	AfterK1	AfterK1	AfterK2	AfterK2	AfterK2	AfterK2	AfterK2	AfterK1	Average	STDV
I. A. Skill Variety	5	4.6666667	4	4	4.6666667	4.6666667	3.3333333	2.3333333	4.6666667	2.3333333	4.3333333	3.6666667	3.6666667	5.3333333	3.3333333	4.00	0.90
I. B. Task Identity	4	5	3.3333333	3.6666667	4.6666667	3.3333333	5	5	4.3333333	5	4.3333333	3.6666667	3.6666667	5.3333333	5.3333333	4.38	0.72
I. C. Task Significance	7	5	3.6666667	5	4	6	5.6666667	6	5.3333333	6	6	4.6666667	4.6666667	6.3333333	6.3333333	5.44	0.93
I. D. Autonomy	3.6666667	3.6666667	4	3.6666667	5	7	5.3333333	4.6666667	4.6666667	4.6666667	5.6666667	5	5	6	4.3333333	4.82	0.93
I. E. Feedback from the Job Itself	5.6666667	4.6666667	3.6666667	4.3333333	4.3333333	2.6666667	3.6666667	5	4.6666667	5	3.3333333	4.6666667	4.6666667	4.3333333	4.3333333	4.33	0.75
I. F. Feedback from Agents	6	2.3333333	4	4.6666667	4.3333333	2	1	5	4	5	5.6666667	5	5.6666667	5.3333333	1.6666667	4.11	1.60
I. G. Dealing with Others	6.3333333	3.3333333	5	3.3333333	4	5.6666667	5	3	4	3	4.3333333	4	5	4.6666667	4	4.31	0.97
II. A. Experienced Meaningfulness of the Work	6.75	5	4	4	4	2.5	4.5	4.5	4.5	4.5	6	5.25	5.25	5.75	3.75	4.65	1.05
II. B. Experienced Responsibility for the Work	5.6	5.2	4	4.2	5.2	5	4.2	5.2	5.8	5.2	6.2	5.4	5.4	6.6	4.8	5.20	0.72
II. C. Knowledge of Results	4	3.5	4.25	4	4.25	3.25	4.75	4.25	4.25	4.25	4.5	4	4	3.25	4.5	4.07	0.44
III. A. General Satisfaction	6.4	4.4	4	6.4	5	5.2	3.8	5	4	5	5	5.6	5.6	4.8	5	5.01	0.78
III. B. Internal Work Motivation	5.1666667	3.8333333	4.3333333	3.6666667	5.5	4	2.5	4.5	4.5	4.5	5.5	4.5	4.5	4.8333333	5	4.46	0.76
III. C. Growth Satisfaction	6	3.5	4	6	6.25	4.25	2	4.25	4.5	4.25	5.5	5.25	5.25	5.75	4.25	4.73	1.14
IV. A. Satisfaction with Job Security	5	2	4.5	6	6.5	6	6	6	4	6	6	6	6	7	5.5	5.50	1.22
IV. B. Satisfaction with Compensation (Pay)	6	2	4.5	6	6.5	5	2.5	3	5.5	3	4.5	4.5	4.5	6.5	4	4.53	1.43
IV. C. Satisfaction with Co-Workers	5	4.3333333	4.3333333	6	6.6666667	4.6666667	6.3333333	5	4.3333333	5	5	5.6666667	5.6666667	5.6666667	4.6666667	5.22	0.74
IV. D. Satisfaction with Supervision	6.3333333	2	4.3333333	6	6.6666667	5	1.6666667	4	4	4	6	6.3333333	6.3333333	6	3.3333333	4.80	1.62
V. A. "Would Like" Format	4.6666667	4.1666667	5	6	6.5	4.1666667	6	4.8333333	6.5	4.8333333	6.3333333	5.6666667	5.6666667	4.6666667	7	5.47	0.91
V. B. "Job Choice" Format	2.375	3.625	3.5	2.25	3.75	3.25	4	3	4.25	3	3.125	3.625	3.625	2.5	4.625	3.37	0.68
V. C. Combined Growth Need Strength Score	3.5208333	3.8958333	4.25	4.125	5.125	3.7083333	5	3.9166667	5.375	3.9166667	4.7291667	4.6458333	4.6458333	3.5833333	5.8125	4.42	0.70
VI. Motivating Potential Score	117.33333	41.82716	58.666667	72.246914	96.296296	65.333333	24.888889	103.7037	89.185185	103.7037	156.98765	100	113.33333	181.33333	36.111111	90.73	43.09

APPENDIX F: STATISTICAL ANALYSIS

Shapiro-Wilk Normality Test Summary

Shapiro-Wilk Test of Normality					
JDS	Group	Statistic	df	Sig.	Distribution
All Categories	K1	0.981	252	0.002	Non-Normal
	K2	0.802	210	0.000	Non-Normal
	NK	0.985	168	0.061	Normal





Kruskal-Wallis Hypothesis Test Summary

Hypothesis Test Summary

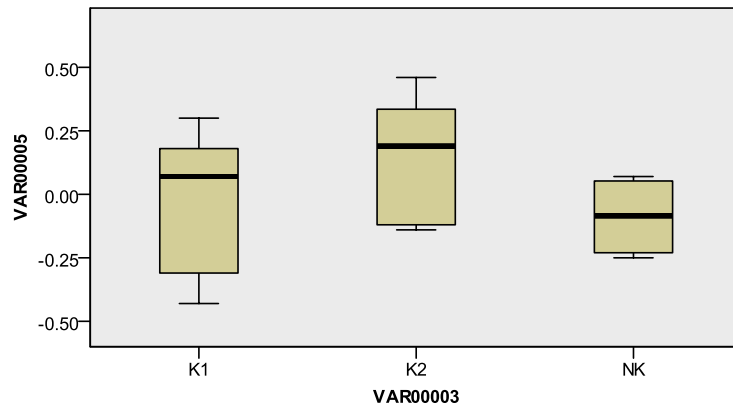
	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Skill Variety is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.337	Retain the null hypothesis.
2	The distribution of Task Identity is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.268	Retain the null hypothesis.
3	The distribution of Task Significance is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.117	Retain the null hypothesis.
4	The distribution of Autonomy is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.064	Retain the null hypothesis.
5	The distribution of Feedback from the Job Itself is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.522	Retain the null hypothesis.
6	The distribution of Feedback from Agents is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.036	Reject the null hypothesis.
7	The distribution of Dealing with Others is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.426	Retain the null hypothesis.
8	The distribution of Experienced Meaningfulness of the Work is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.036	Reject the null hypothesis.
9	The distribution of Experienced Responsibility for the Work is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.543	Retain the null hypothesis.
10	The distribution of Knowledge of Results is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.150	Retain the null hypothesis.
11	The distribution of General Satisfaction is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.059	Retain the null hypothesis.
12	The distribution of Internal Work Motivation is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.903	Retain the null hypothesis.
13	The distribution of Growth Satisfaction is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.027	Reject the null hypothesis.
14	The distribution of Satisfaction with Job Security is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.137	Retain the null hypothesis.
15	The distribution of Satisfaction with Compensation is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.034	Reject the null hypothesis.
16	The distribution of Satisfaction with Co-Workers is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.681	Retain the null hypothesis.
17	The distribution of Satisfaction with Supervision is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.061	Retain the null hypothesis.
18	The distribution of "Would Like" Format is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.733	Retain the null hypothesis.
19	The distribution of "Job Choice" Format is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.989	Retain the null hypothesis.
20	The distribution of Combined Growth Need Strength Score is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.550	Retain the null hypothesis.
21	The distribution of Motivating Potential Score (MPS) is the same across categories of K1, K2, and NK.	Independent- Samples Kruskal-Wallis Test	0.025	Reject the null hypothesis.
* Asymptotic Significances are displayed. The significance level is 0.05.				

I. A. Skill Variety

I. A. Skill Variety

	Before	After	Delta
K1	4.67	4.00	0.14
K1	4.67	4.00	0.14
K1	4.67	4.67	0.00
K1	3.33	2.33	0.30
K1	3.67	4.67	-0.27
K1	2.33	3.33	-0.43
K2	4.33	2.33	0.46
K2	5.33	4.33	0.19
K2	3.33	3.67	-0.10
K2	4.67	3.67	0.21
K2	4.67	5.33	-0.14
NK	5.00	5.00	0.00
NK	4.00	4.67	-0.17
NK	5.00	4.67	0.07
NK	2.67	3.33	-0.25

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	2.173
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.337

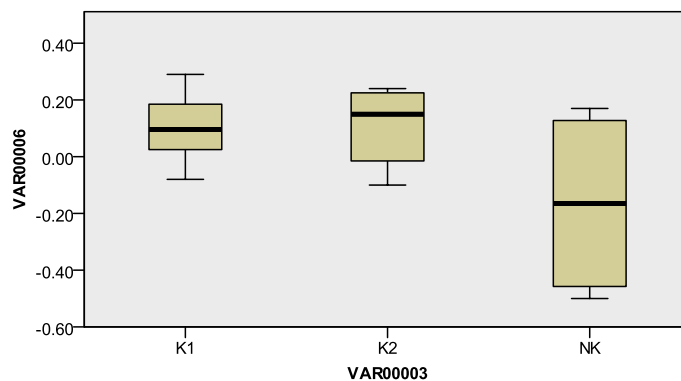
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

I. B. Task Identity

I. B. Task Identity

	Before	After	Delta
K1	4.67	3.33	0.29
K1	4.33	3.67	0.15
K1	4.33	4.67	-0.08
K1	5.33	5.00	0.06
K1	5.00	4.33	0.13
K1	5.67	5.33	0.06
K2	6.33	5.00	0.21
K2	4.67	4.33	0.07
K2	3.33	3.67	-0.10
K2	4.33	3.67	0.15
K2	7.00	5.33	0.24
NK	3.00	4.00	-0.33
NK	3.33	5.00	-0.50
NK	3.33	3.33	0.00
NK	6.00	5.00	0.17

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	2.634
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.268

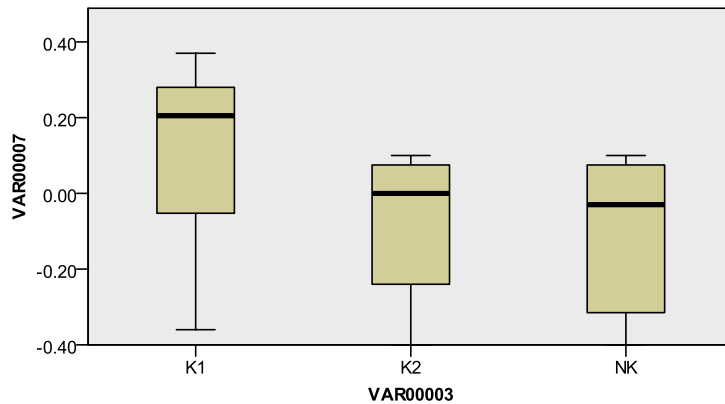
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

I. C. Task Significance

I. C. Task Significance

	Before	After	Delta
K1	4.67	3.67	0.21
K1	6.67	5.00	0.25
K1	6.33	4.00	0.37
K1	6.33	6.00	0.05
K1	6.67	5.33	0.20
K1	4.67	6.33	-0.36
K2	6.00	6.00	0.00
K2	6.67	6.00	0.10
K2	3.33	4.67	-0.40
K2	4.33	4.67	-0.08
K2	6.67	6.33	0.05
NK	5.00	7.00	-0.40
NK	5.00	5.00	0.00
NK	6.67	6.00	0.10
NK	5.33	5.67	-0.06

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	4.296
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.117

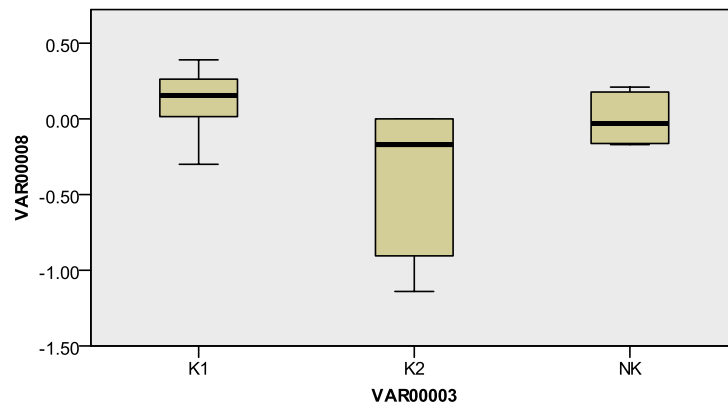
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

I. D. Autonomy

I. D. Autonomy

	Before	After	Delta
K1	4.67	4.00	0.14
K1	6.00	3.67	0.39
K1	6.00	5.00	0.17
K1	6.00	4.67	0.22
K1	5.33	4.67	0.12
K1	3.33	4.33	-0.30
K2	4.00	4.67	-0.17
K2	5.67	5.67	0.00
K2	2.33	5.00	-1.14
K2	3.00	5.00	-0.67
K2	6.00	6.00	0.00
NK	4.67	3.67	0.21
NK	4.00	3.67	0.08
NK	6.00	7.00	-0.17
NK	4.67	5.33	-0.14

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	5.494
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.064

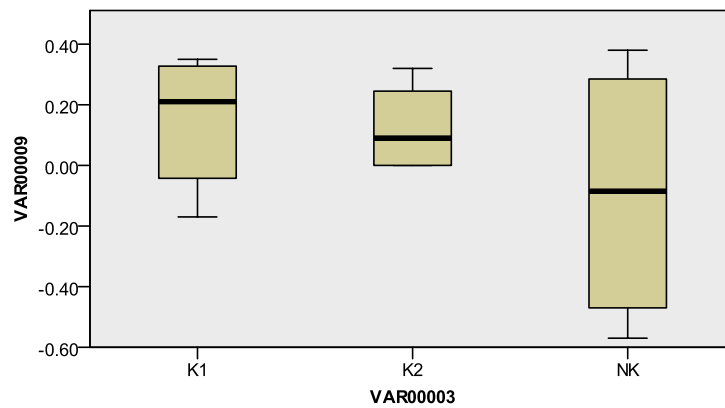
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

I. E. Feedback from the Job Itself

I. E. Feedback from the Job Itself

	Before	After	Delta
K1	4.67	3.67	0.21
K1	6.67	4.33	0.35
K1	6.33	4.33	0.32
K1	6.33	5.00	0.21
K1	4.00	4.67	-0.17
K1	4.33	4.33	0.00
K2	6.00	5.00	0.17
K2	3.67	3.33	0.09
K2	4.67	4.67	0.00
K2	4.67	4.67	0.00
K2	6.33	4.33	0.32
NK	5.67	5.67	0.00
NK	4.00	4.67	-0.17
NK	4.33	2.67	0.38
NK	2.33	3.67	-0.57

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	1.301
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.522

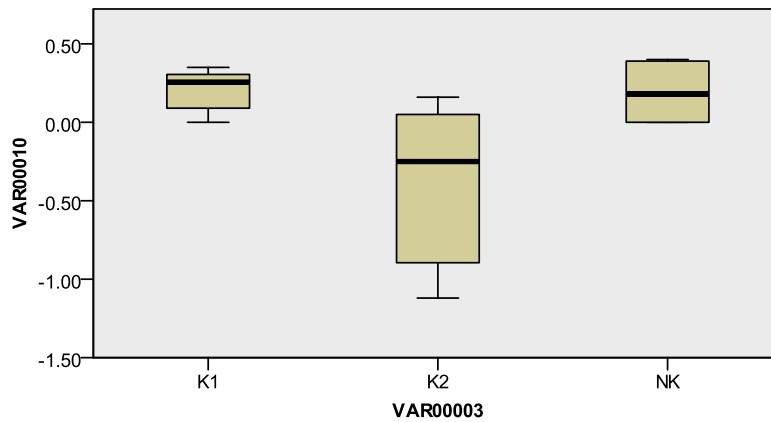
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

I. F. Feedback from Agents

I. F. Feedback from Agents

	Before	After	Delta
K1	4	4	0
K1	6.33	4.67	0.26
K1	6.67	4.33	0.35
K1	5.67	5.00	0.12
K1	5.33	4.00	0.25
K1	2.33	1.67	0.29
K2	3.00	5.00	-0.67
K2	5.33	5.67	-0.06
K2	4.00	5.00	-0.25
K2	2.67	5.67	-1.12
K2	6.33	5.33	0.16
NK	6.00	6.00	0.00
NK	3.67	2.33	0.36
NK	2.00	2.00	0.00
NK	1.67	1.00	0.40

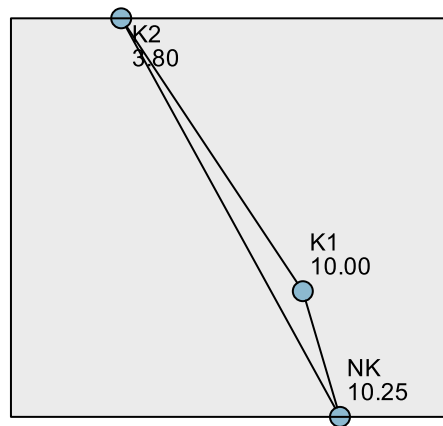
Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	6.670
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.036

1. The test statistic is adjusted for ties.

Pairwise Comparisons of VAR00003



Each node shows the sample average rank of VAR00003.

Sample 1-Sam...	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
1-0	6.200	2.698	2.298	.022	.065
1-2	-6.450	2.989	-2.158	.031	.093
0-2	-.250	2.876	-.087	.931	1.000

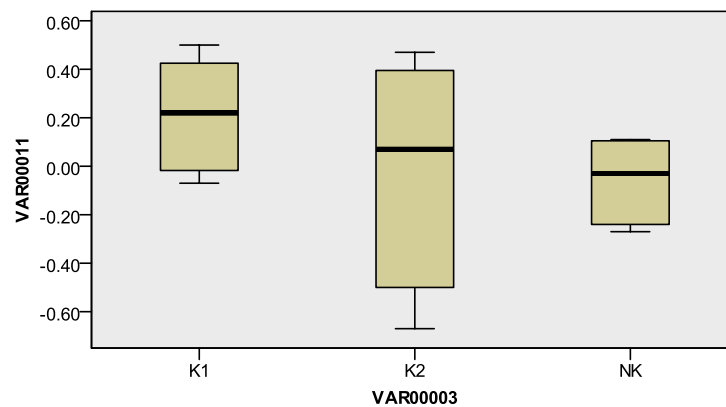
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

I. G. Dealing with Others

I. G. Dealing with Others

	Before	After	Delta
K1	4.67	5.00	-0.07
K1	6.67	3.33	0.50
K1	6.67	4.00	0.40
K1	4.67	3.00	0.36
K1	4.33	4.00	0.08
K1	4.00	4.00	0.00
K2	5.67	3.00	0.47
K2	6.33	4.33	0.32
K2	3.00	4.00	-0.33
K2	3.00	5.00	-0.67
K2	5.00	4.67	0.07
NK	5.00	6.33	-0.27
NK	3.67	3.33	0.09
NK	6.33	5.67	0.11
NK	4.33	5.00	-0.15

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	1.708
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.426

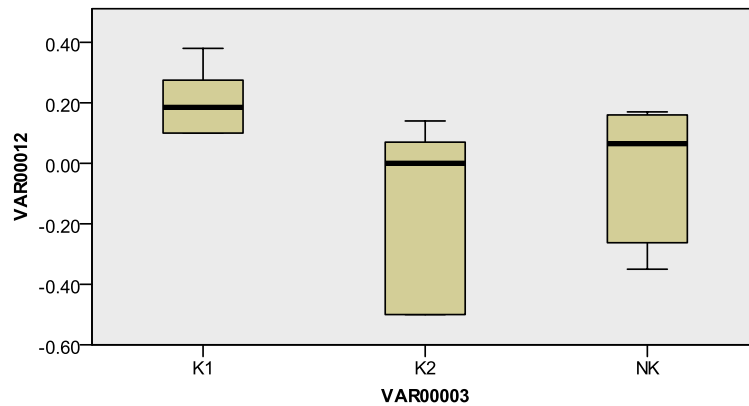
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

II. A. Experienced Meaningfulness of the Work

II. A. Experienced
Meaningfulness of the
Work

	Before	After	Delta
K1	5.00	4.00	0.20
K1	5.25	4.00	0.24
K1	6.50	4.00	0.38
K1	5.00	4.50	0.10
K1	5.00	4.50	0.10
K1	4.50	3.75	0.17
K2	5.25	4.50	0.14
K2	6.00	6.00	0.00
K2	3.50	5.25	-0.50
K2	3.50	5.25	-0.50
K2	5.75	5.75	0.00
NK	5.00	6.75	-0.35
NK	5.75	5.00	0.13
NK	4.00	4.00	0.00
NK	3.00	2.50	0.17

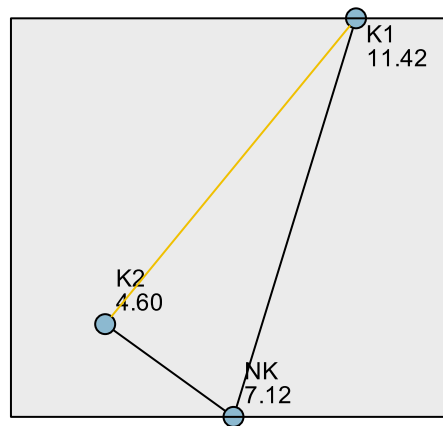
Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	6.628
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.036

1. The test statistic is adjusted for ties.

Pairwise Comparisons of VAR00003



Each node shows the sample average rank of VAR00003.

Sample 1-Sam...	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
1-2	-2.525	2.981	-.847	.397	1.000
1-0	6.817	2.691	2.533	.011	.034
2-0	4.292	2.869	1.496	.135	.404

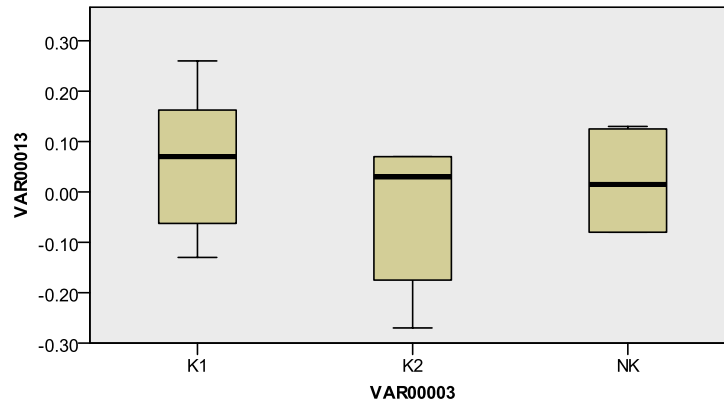
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

II. B. Experienced Responsibility for the Work

II. B. Experienced Responsibility for the Work

	Before	After	Delta
K1	5.40	4.00	0.26
K1	4.80	4.20	0.13
K1	4.60	5.20	-0.13
K1	5.00	5.20	-0.04
K1	6.00	5.80	0.03
K1	5.40	4.80	0.11
K2	4.80	5.20	-0.08
K2	6.40	6.20	0.03
K2	5.80	5.40	0.07
K2	5.80	5.40	0.07
K2	5.20	6.60	-0.27
NK	5.20	5.60	-0.08
NK	4.80	5.20	-0.08
NK	5.60	5.00	0.11
NK	4.80	4.20	0.13

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	1.221
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.543

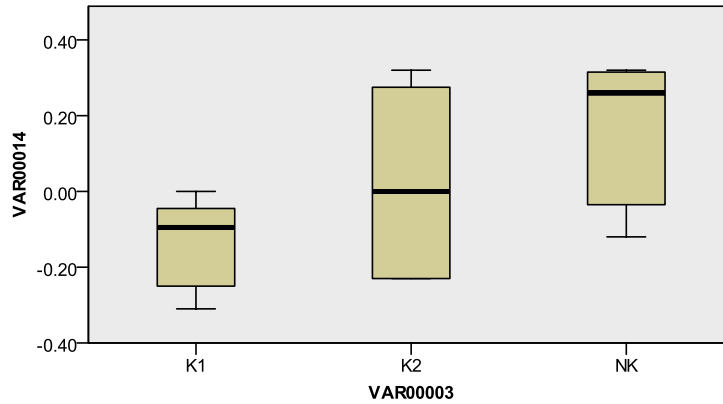
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

II. C. Knowledge of Results

II. C. Knowledge of Results

	Before	After	Delta
K1	4.00	4.25	-0.06
K1	3.25	4.00	-0.23
K1	3.25	4.25	-0.31
K1	4.00	4.25	-0.06
K1	3.75	4.25	-0.13
K1	4.50	4.50	0.00
K2	5.50	4.25	0.23
K2	4.50	4.50	0.00
K2	3.25	4.00	-0.23
K2	3.25	4.00	-0.23
K2	4.75	3.25	0.32
NK	5.75	4.00	0.30
NK	4.50	3.50	0.22
NK	4.75	3.25	0.32
NK	4.25	4.75	-0.12

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	3.793
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.150

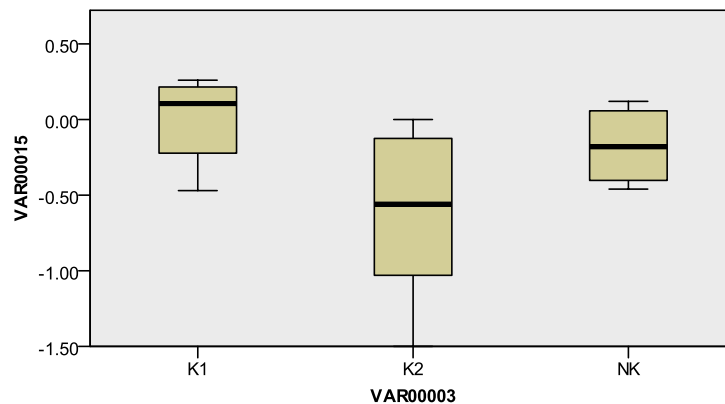
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

III. A. General Satisfaction

III. A. General Satisfaction

	Before	After	Delta
K1	5.00	4.00	0.20
K1	5.60	6.40	-0.14
K1	5.80	5.00	0.14
K1	5.40	5.00	0.07
K1	5.40	4.00	0.26
K1	3.40	5.00	-0.47
K2	2.00	5.00	-1.50
K2	4.00	5.00	-0.25
K2	3.60	5.60	-0.56
K2	3.60	5.60	-0.56
K2	4.80	4.80	0.00
NK	5.20	6.40	-0.23
NK	5.00	4.40	0.12
NK	4.60	5.20	-0.13
NK	2.60	3.80	-0.46

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	5.671
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.059

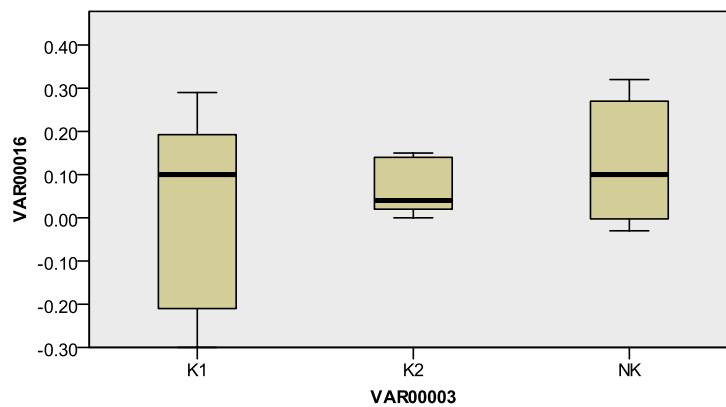
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

III. B. Internal Work Motivation

III. B. Internal Work Motivation

	Before	After	Delta
K1	5.17	4.33	0.16
K1	5.17	3.67	0.29
K1	4.67	5.50	-0.18
K1	4.67	4.50	0.04
K1	5.33	4.50	0.16
K1	3.83	5.00	-0.30
K2	5.17	4.50	0.13
K2	5.50	5.50	0.00
K2	4.67	4.50	0.04
K2	4.67	4.50	0.04
K2	5.67	4.83	0.15
NK	5.00	5.17	-0.03
NK	4.33	3.83	0.12
NK	4.33	4.00	0.08
NK	3.67	2.50	0.32

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	.204
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.903

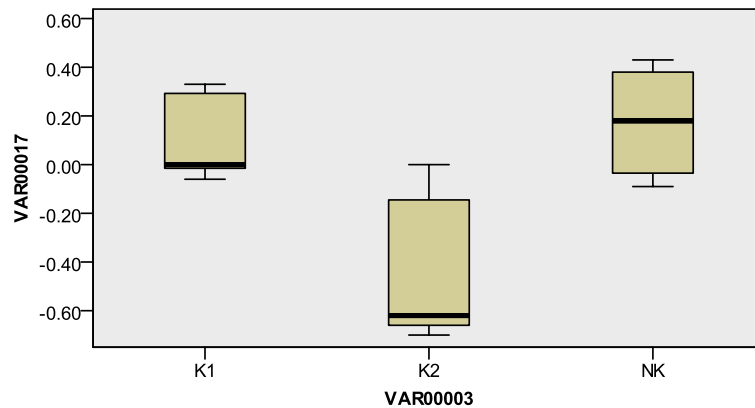
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

III. C. Growth Satisfaction

III. C. Growth Satisfaction

	Before	After	Delta
K1	6.00	4.00	0.33
K1	6.00	6.00	0.00
K1	6.25	6.25	0.00
K1	4.25	4.25	0.00
K1	6.25	4.50	0.28
K1	4.00	4.25	-0.06
K2	2.50	4.25	-0.70
K2	4.25	5.50	-0.29
K2	3.25	5.25	-0.62
K2	3.25	5.25	-0.62
K2	5.75	5.75	0.00
NK	5.50	6.00	-0.09
NK	4.00	3.50	0.13
NK	5.50	4.25	0.23
NK	3.50	2.00	0.43

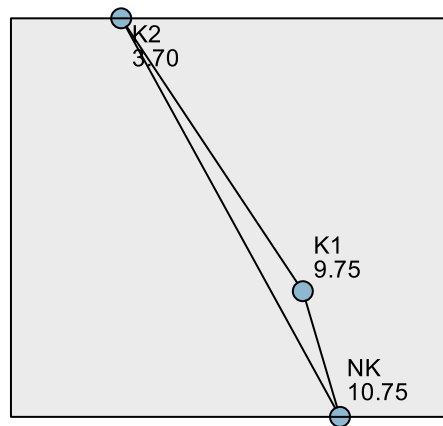
Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	7.195
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.027

1. The test statistic is adjusted for ties.

Pairwise Comparisons of VAR00003



Each node shows the sample average rank of VAR00003.

Sample 1-Sam...	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
1-0	6.050	2.681	2.256	.024	.072
1-2	-7.050	2.970	-2.373	.018	.053
0-2	-1.000	2.858	-.350	.726	1.000

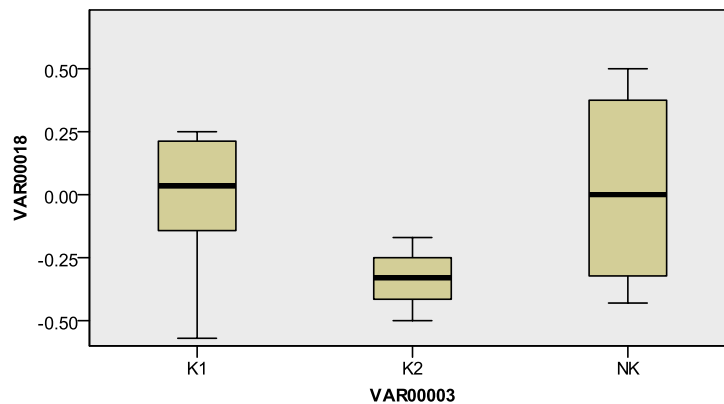
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

IV. A. Satisfaction with Job Security

IV. A. Satisfaction with Job Security

	Before	After	Delta
K1	6.00	4.50	0.25
K1	6.00	6.00	0.00
K1	7.00	6.50	0.07
K1	6.00	6.00	0.00
K1	5.00	4.00	0.20
K1	3.50	5.50	-0.57
K2	4.00	6.00	-0.50
K2	4.50	6.00	-0.33
K2	4.50	6.00	-0.33
K2	4.50	6.00	-0.33
K2	6.00	7.00	-0.17
NK	3.50	5.00	-0.43
NK	4.00	2.00	0.50
NK	6.00	6.00	0.00
NK	6.00	6.00	0.00

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	3.980
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.137

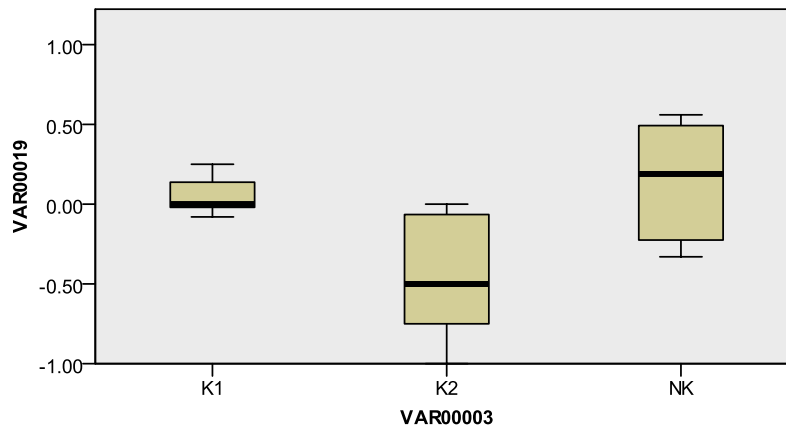
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

IV. B. Satisfaction with Compensation (Pay)

IV. B. Satisfaction with Compensation (Pay)

	Before	After	Delta
K1	5.00	4.50	0.10
K1	6.00	6.00	0.00
K1	6.00	6.50	-0.08
K1	4.00	3.00	0.25
K1	5.50	5.50	0.00
K1	4.00	4.00	0.00
K2	1.50	3.00	-1.00
K2	4.00	4.50	-0.13
K2	3.00	4.50	-0.50
K2	3.00	4.50	-0.50
K2	6.50	6.50	0.00
NK	4.50	6.00	-0.33
NK	4.50	2.00	0.56
NK	5.50	5.00	0.09
NK	3.50	2.50	0.29

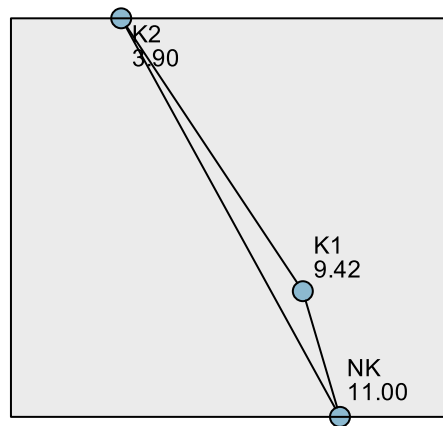
Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	6.737
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.034

1. The test statistic is adjusted for ties.

Pairwise Comparisons of VAR00003



Each node shows the sample average rank of VAR00003.

Sample 1-Sam...	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
1-0	5.517	2.681	2.057	.040	.119
1-2	-7.100	2.970	-2.390	.017	.051
0-2	-1.583	2.858	-.554	.580	1.000

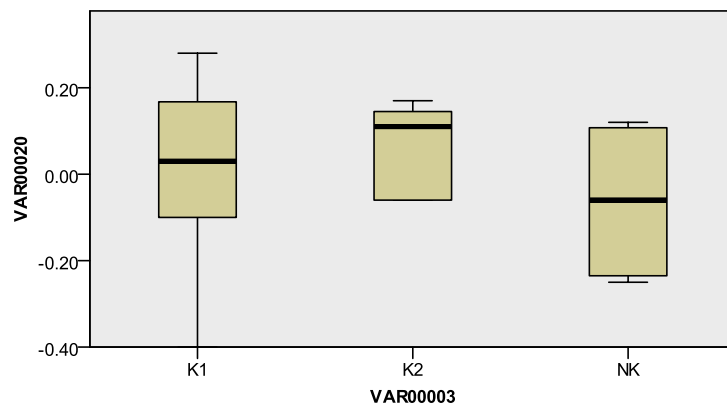
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

IV. C. Satisfaction with Co-Workers

IV. C. Satisfaction with Co-Workers

	Before	After	Delta
K1	6.00	4.33	0.28
K1	6.00	6.00	0.00
K1	6.67	6.67	0.00
K1	5.33	5.00	0.06
K1	5.00	4.33	0.13
K1	3.33	4.67	-0.40
K2	5.67	5.00	0.12
K2	6.00	5.00	0.17
K2	5.33	5.67	-0.06
K2	5.33	5.67	-0.06
K2	6.33	5.67	0.11
NK	4.00	5.00	-0.25
NK	4.67	4.33	0.07
NK	5.33	4.67	0.12
NK	5.33	6.33	-0.19

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	.768
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.681

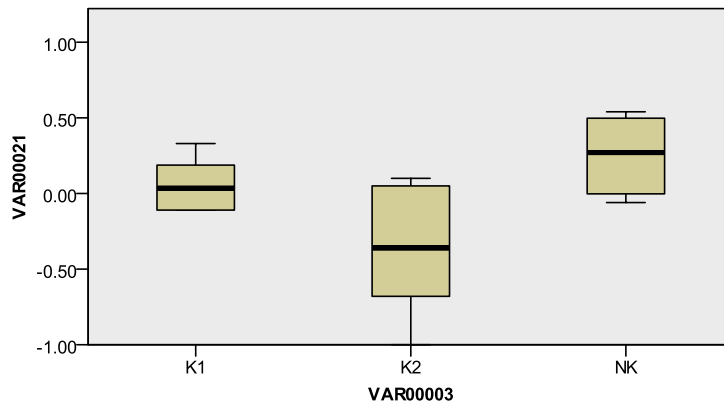
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

IV. D. Satisfaction with Supervision

IV. D. Satisfaction with Supervision

	Before	After	Delta
K1	4.67	4.33	0.07
K1	6.00	6.00	0.00
K1	6.00	6.67	-0.11
K1	4.67	4.00	0.14
K1	6.00	4.00	0.33
K1	3.00	3.33	-0.11
K2	2.00	4.00	-1.00
K2	6.00	6.00	0.00
K2	4.67	6.33	-0.36
K2	4.67	6.33	-0.36
K2	6.67	6.00	0.10
NK	6.00	6.33	-0.06
NK	4.33	2.00	0.54
NK	6.00	5.00	0.17
NK	2.67	1.67	0.37

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	5.584
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.061

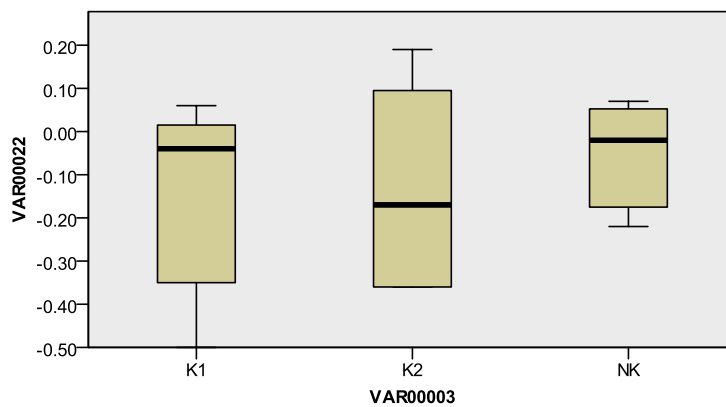
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

V. A. "Would Like" Format

V. A. "Would Like" Format

	Before	After	Delta
K1	4.83	5.00	-0.03
K1	4.00	6.00	-0.50
K1	6.17	6.50	-0.05
K1	5.17	4.83	0.06
K1	5.00	6.50	-0.30
K1	7.00	7.00	0.00
K2	6.00	4.83	0.19
K2	6.33	6.33	0.00
K2	4.17	5.67	-0.36
K2	4.17	5.67	-0.36
K2	4.00	4.67	-0.17
NK	3.83	4.67	-0.22
NK	4.00	4.17	-0.04
NK	4.50	4.17	0.07
NK	6.00	6.00	0.00

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	.621
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.733

1. The test statistic is adjusted for ties.

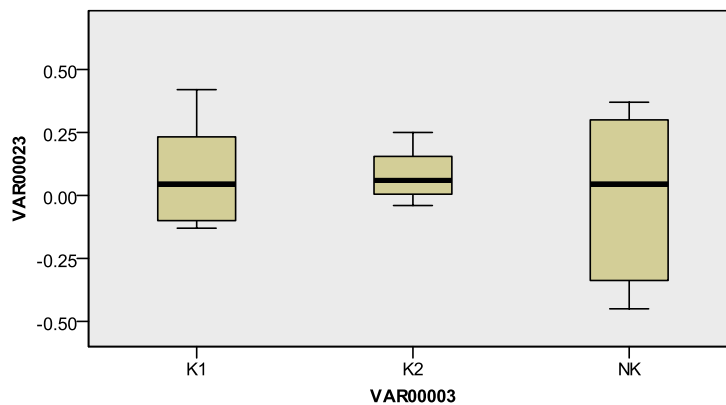
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

V. B. "Job Choice" Format

V. B. "Job Choice" Format

	Before	After	Delta
K1	3.50	3.50	0.00
K1	3.88	2.25	0.42
K1	4.13	3.75	0.09
K1	3.63	3.00	0.17
K1	3.75	4.25	-0.13
K1	4.25	4.63	-0.09
K2	4.00	3.00	0.25
K2	3.00	3.13	-0.04
K2	3.88	3.63	0.06
K2	3.88	3.63	0.06
K2	2.63	2.50	0.05
NK	3.75	2.38	0.37
NK	4.00	3.63	0.09
NK	3.25	3.25	0.00
NK	2.75	4.00	-0.45

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	.023
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.989

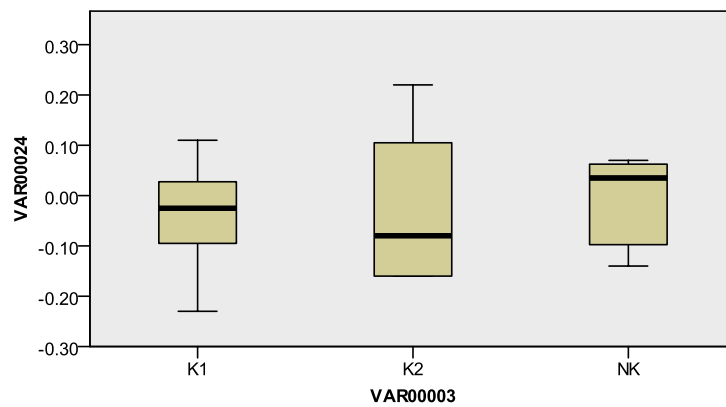
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

V. C. Combined Growth Need Strength Score

V. C. Combined Growth
Need Strength Score

	Before	After	Delta
K1	4.17	4.25	-0.02
K1	3.94	4.13	-0.05
K1	5.15	5.13	0.00
K1	4.40	3.92	0.11
K1	4.38	5.38	-0.23
K1	5.63	5.81	-0.03
K2	5.00	3.92	0.22
K2	4.67	4.73	-0.01
K2	4.02	4.65	-0.16
K2	4.02	4.65	-0.16
K2	3.31	3.58	-0.08
NK	3.79	3.52	0.07
NK	4.00	3.90	0.03
NK	3.88	3.71	0.04
NK	4.38	5.00	-0.14

Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	1.195
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.550

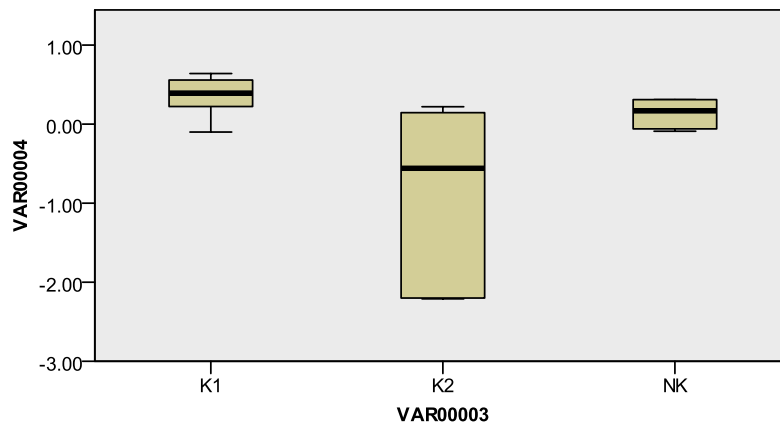
1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

VI. Motivating Potential Score

VI. Motivating Potential
Score (MPS)

	Before	After	Delta
K1	87.11	58.67	0.33
K1	198.44	72.25	0.64
K1	204.44	96.30	0.53
K1	170.00	103.70	0.39
K1	145.38	89.19	0.39
K1	32.84	36.11	-0.10
K2	66.67	103.70	-0.56
K2	167.90	156.99	0.07
K2	31.11	100.00	-2.21
K2	35.56	113.33	-2.19
K2	232.22	181.33	0.22
NK	121.33	117.33	0.03
NK	60.30	41.83	0.31
NK	60.00	65.33	-0.09
NK	36.30	24.89	0.31

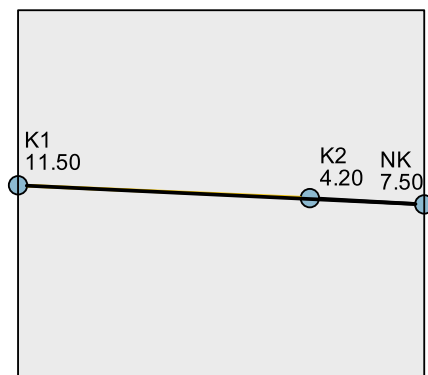
Independent-Samples Kruskal-Wallis Test



Total N	15
Test Statistic	7.361
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.025

1. The test statistic is adjusted for ties.

Pairwise Comparisons of VAR00003



Each node shows the sample average rank of VAR00003.

Sample 1-Sam...	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
1-2	-3.300	2.995	-1.102	.270	.811
1-0	7.300	2.703	2.701	.007	.021
2-0	4.000	2.882	1.388	.165	.495

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

VITA

Amanda Morse, the daughter of Ronald and Cheri Morse, was born in December 1985 residing Tickfaw, Louisiana and is succeeded by one sister, Ann Megan. In the fall of 2004 she began her undergraduate studies at Randolph-Macon College in Physics with a minor in Mathematics. She graduated with the degree of Bachelor of Science in May 2008. During her stay at Randolph-Macon College, the author received the distinguished honor of becoming a member of the Lambda Alpha Sigma and Sigma Pi Sigma Honor Societies. Amanda was selected as a Society of Women Engineers Scholarship Recipient. The author was awarded the Randolph- Macon College Watts Physics Scholarship given to an outstanding Physics major. Amanda also received the Randolph-Macon College Physics Department Distinguished Service Award. She served as the chapter Vice-President for the Society of Physics Students. During college she also served as a tutor and mentor for the Randolph-Macon College Higgins Academic Center. The author began graduate studies in Engineering Science at Louisiana State University in 2011, and then transferred to the Industrial Engineering Department under the direction of Dr. Isabelina Nahmens. During her stay at Louisiana State University, the author received the distinguished honor of becoming a member of the Alpha Pi Mu Honor Society. Amanda also became a member of the Institute of Industrial Engineers. The author continues to work with the Institute of Industrial Engineers and the Society of Women Engineers today.