

CREATION AND ANALYSIS OF CHECKLISTS
TO IMPROVE RACQUET STRINGING PERFORMANCE IN TENNIS WAREHOUSE
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EXECUTIVE SUMMARY

Tennis Warehouse has a need to increase the supply of strung racquets and man hours to complete these strung racquets over the course of a year. That is, the demand can be increased by up to 4 times its average load during certain hectic parts of the year (professional tournaments, holidays, and competitive seasons). Not meeting this demand can lead to upset customers, unnecessary waste and replacing of rushed items and shipping costs, and a discouraged customer service representative workforce. The objective of this project is to use a set of checklists to address this problem and attempt to increase the amount of time allocated to stringing racquets by eliminating wastes, retraining employees, and providing a safe and efficient workplace for employees to work in.

The checklists were created in accordance with national standard safety procedures, ergonomic justification, and lean manufacturing and process improvement tenants. Each checklist took into account the amount of time each check would save in a mock simulation. This simulation took into account many factors including the amount of time it would take to retrain an employee on certain aspects, the amount a broken part (racquet or string) would cost, the amount of time and money an injury or sickness would cost the company, and the time it takes for an employee to complete a part (string a racquet). Best assumptions were made in discussion with employees about other aspects, such as defective parts per month, the amount it takes for set up and shut down of a work station, and time spent on running through these checklists.

The simulated improvements made as a result of the checklist turned to address up to three quarters of the increased demand. Although this is a rough estimate based on the few assumptions were made, this simulation proves to provide a massive improvement to the problem of increased demand. It also serves to provide a justification for Tennis Warehouse's use of checklists as a possible tool to use in the future to satisfy demand.

The overall results served to back up and provide extreme evidence of checklist effectiveness not only in a retailer like Tennis Warehouse, but possibly has uses in other fields such as medical, automotive

manufacturing, and construction. Recommendations for Tennis Warehouse are to use the provided checklist as an example and not only utilize them in everyday operations, but to record the effects over a couple months to evaluate their value further.

INTRODUCTION

Tennis Warehouse Inc. (commonly called TW) currently controls the retail market in the tennis industry in the world. In being the largest and most successful tennis related product retailer in the world, TW focuses on employee as well as customer satisfaction. Not only does TW provide an open working atmosphere, but focuses employees by putting customers as their number one priority. One of the major tenants of the company is based on the phrase “Give 'em the Pickle” which is primarily based on trying to give the customer what they ask for even if it seems as if the customer is taking advantage of the company. This includes giving discounts, t-shirts and other promotions on a continuous basis when customers ask for them. This keeps customer satisfaction at a high and promotes repeat purchases and business.

TW shares a building with other warehouses such as Running Warehouse, Riding Warehouse, and Arts Cyclery. TW itself is separated into two sections, the customer service floor and the warehouse. The customer service floor is responsible for the stringing of racquets and the answering of phone calls while the second floor is concerned with all warehouse, invoicing and shipping responsibilities. The project will be primarily focused on the employees on the customer service floor and the interaction between the warehouse and the customer service floor concerning the input and output of strung racquets. This is because during certain times of the year, the demand of strung racquets is increased by a factor of 3 and this can place a burden on employees and hiring new employees can cost the company unnecessary employment costs.

Stringing racquets can have an effect on the body as it involves repetitive movement, standing, looking downward, and having long periods of sustained movements. Turning times of increased demands of the company, the employees are susceptible to even longer periods of stringing racquets. In order to fix this problem, there are two things that need to be addressed. How the company is meeting demand now verses how they could be meeting demand, and how the company is dealing with employee comfortability (ergonomics) and how it could be improved. This would involve implementing of new

methods of the layout of the customer service floor; different heights of the racquet machines to fit employee specifications, and the addressing the process of getting racquets strung and out to customers the quickest. Using company layout diagrams, ergonomic design and human factors, and statistical time to completion variations, the experiment will result in recommendations for improvements to reduce costs and improve efficiency.

Of course there are some limitations to the experiment. The company limits access to specific sales numbers, the demand during certain periods of the year (not definite, but usually during tennis tournament times), and amount of product available. There are also limitations to on site testing and disruption of operations is a main concern for a fast paced business like Tennis Warehouse. To address this, a checklist will be made and estimations based on real data collected from the warehouse and its website will be used and calculated to arrive at a rough estimate of how much time these checklists will take to implement and how many time/money it would save the company. This will translate over to how many man-hours saved and thus, how many racquets the company can improve (roughly) by the use of checklists.

Lean Manufacturing and Maintenance

There are many different approaches to making a process faster. Lean manufacturing is commonly associated with

- 1) Waste reduction
- 2) Integrated supply chain
- 3) Enhanced customer value
- 3) Value creating organization.

However, there are characteristics that are commonly related to lean manufacturing that relate to this project. These are a

- 1) Committed management
- 2) Winning employee commitment
- 3) Empowering employees
- 4) Optimized equipment reliability
- 5) Measurement systems
- 6) Communication across all lines
- 7) All processes and work flows defined
- 8) Team based organization
- 9) Continuous improvement
- 10) Flatter organization structure (less middle-level management)
- 11) Measures of performance used, balanced production
- 12) Quality and the first and every time. (Smith & Hawkins, 2004)

Applying this to TW, areas that require addressing are optimized equipment reliability, measurement systems, and balanced production. That is, there is noticeably boxes of defective machine parts on the customer service floor that need to be fixed as well as certain machines that do not perform as well as

others. Also, there is no measurement system for the appropriate height for a worker and no standard for measuring overall worker performance. There is racquet timing which is designed to keep workers on the right pace, however there is no amount of times a person is timed per certain working periods which can cause the learning curve to be stagnant at a below average level.

“It is essential to establish specific goals for achievement in relation to the plant's strategic and operations plans both short and long term. Targets must be set for maintenance performance in terms of equipment up time, maintenance cost, overtime, work-force productivity and supervisor's time at job sites.” (Smith & Hawkins, 2004) The specific goals are as follows:

**Table 2-3
Maintenance Goals**

Indicator	Ultimate Goal
Backlog—Ready	2 to 4 weeks
Total	4 to 6 weeks**
Stores service (average)	95% to 98%
Materials delivered to job site	Above 65%
Stores turns per year	2 to 3
Preventive maintenance man-hours (includes PDM)	30% or greater
Unscheduled man-hours	Under 10%
On-the-job supervision	Above 65%
Schedule compliance	Above 90%
PM schedule compliance	Above 95%
Overtime	5%
On-the-job wrench time	Above 55%
% of planned work	Above 90%
Emergency maintenance labor hours	Under 2%
PPM routines/corrective WO (actions)	6:1 (without RCM)

* To be achieved by year-end.
 ** Excluding major overhaul (shutdown or outage).

Figure 1: Maintenance Goals
(Smith & Hawkins, 2004)

Notable percentages relevant to TW's line of work are goal percentages of overtime, unscheduled man-hours, schedule compliance, preventative maintenance man-hours, and backlog-- ready and total. These are goal percentages that could affect employee ergonomics. For example, a large percentage of unscheduled man hours can lead to overwork of employees and overall can cost the company profits and increase downtime. Keeping within the 'ultimate goal' category can reduce costs and increase overall employee satisfaction and optimize efficiency.

Demand Management

In demand management, there are different subjects to address. These are sales "...planning / forecasting, order promising, distribution center demands (or branch warehouse demands), inter plant demands, and service or spare parts demand." (Landvater, 1997). The main focus for Tennis Warehouse to manage the increase demand during certain time periods of the year are order promising and sales planning/forecasting. Although sales planning/forecasting would be a nice way to predict demand and adjust worker availability, sales numbers and products vary and are not readily available to experiment on. Therefore, what can be adjusted is order promising. TW prides itself on its 2 day delivery for certain orders and inexpensive shipping charges. However, when demo racquet orders or tennis racquet orders come in and it is promised 1-2 day shipping there are delays in the orders coming mostly from the stringing of racquets. TW has two options in this case, either promising less or delivering more. Increasing the speed of racquet stringing using ergonomics or production layout planning- using this experiment- is delivering more. To promise less, there needs to be an available to promise calculation which can be calculated given the amount of customer orders. There are limitations to the availability of the information needed to complete this calculation so the primary focus of this experiment will be to delivery more.

Just-In-Time

In order to meet customer demand, a strategy that is used is called Just-in-Time Strategy. This strategy consists of seven key principles like

- 1) Produce to exact customer demand,
- 2) Eliminate waste,
- 3) Produce one-at-a-time,
- 4) Continuous improvement,
- 5) Respect people,
- 6) No contingencies,

7) Long-term emphasis. (Wantuck, 1989).

TW does a good job at Just in time production as they use a pull system. This pull system is simply defined as “pulling items only as you need them” (Smith & Hawkins, 2004). TW does this by bringing in racquets in carts and bringing them back down to shipping in carts as well. This minimizes on floor products and maximizes floor space while giving the warehouse ideas of how many racquets are on backlog.

In doing this, TW allows to focus more on the quality at the source. The seven principles of quality at the source are

- 1) Perfect parts every time
- 2) Operator responsibility
- 3) A new customer definition
- 4) The new Q&S Tool Kit
- 5) Stop and fix the problem
- 6) Visibility management
- 7) Machines always ready. (Wantuck, 1989)

TW addresses all the seven principles of quality equally and to a great degree. There is an emphasis on quality when stringing racquets which is echoed when frequently checked for quality by supervisors (visibility management). Quality at the source or “Jidoka” is closely related to “Poka Yoke” or mistake proofing. (Smith & Hawkins, 2004) Mistake proofing is done at TW by teaching employees how to check their racquets for misweaves (errors during racquet stringing) and asking supervisors for help when stringing racquets.

Maximizing Production

There has to be a tradeoff between quality control and production. (Quality verses quantity argument) The trend in goal setting is towards maximizing production. This often results in excess product inventory from overproduction. (Smith & Hawkins, 2004). TW is guilty of overproduction as when

surplus employees are present, the employees string demo racquets. These racquets can stock pile and when they are not sent out for demo, they are taking up space in storage and eventually sold at a lower than retail price. This can cost the company profits as well as unnecessary employment costs.

Work Environment

What about work environment? TW prides itself in its employee friendly work environment and has even received awards honoring it as the most employee friendly work environment in San Luis Obispo. According to Just-In-Time for America, "... a stable work environment must have stability through lifetime employment, highly qualified hires, extensive training, pay for capability, job flexibility, and address surplus workers." (Wantuck, 1989) What stands out that TW needs help addressing are surplus workers. TW has a high turnover rate as it mainly hires college and high school employees. These employees lifetime of employment varies but is unlikely to exceed greater than 4 years. In order to avoid over hiring surplus workers, TW must have enough backlog to keep surplus workers occupied without having dissatisfied customers.

Working Ergonomics

Tennis Warehouse employees in the customer service department spend at least half their time standing depending on the amount of phone calls coming in that day. Non phone trained employees (called "String only" employees) spend 100% of their time standing which can lead to general soreness and even injuries. Working in a standing position on a regular basis can cause "... sore feet, swelling of the legs, varicose veins, general muscular fatigue, low back pain, stiffness in the neck and shoulders and other health problems." ("OSH Answers Fact Sheets.",2015). Employees are responsible for setting their own schedule and limiting themselves on the stress they put on their bodies. However, during times of increase demands TW asks employees to work extra hours and thus requires more standing time. Adjusting for the demand and minimizing the effects of standing for expanded periods of time is the goal of the experiment and would save TW money in the long run.

If recovery is complete in 60 minutes it would take only four minutes to drop from 100 percent fatigue

to 75 percent fatigue; but it would take 42 minutes to drop from 25 percent fatigue to no fatigue (Chester & Rys, 2001). In other words, for fatigue recovery, a number of short (five-minute) breaks are more beneficial than one 15-minute break. Using the short-break approach, more recovery is accomplished over three breaks and less fatigue is created during the shorter work periods (Chester & Rys, 2001). Applying this study to TW, the workplace allows one 10 minute break per 4 hours. This, for a phone worker, does seem like an acceptable study however for a non-phone trained worker 10 min every 4 hours seems a little low a rest. This is because a phone worker is allowed to sit and rest the body every couple of minutes to answer a phone call while a string only employee stands for the full shift.

Creating a Checklist in Industry

Looking into recently made checklists, there have been extensive checklists for various industry operations. The Texas Department of Insurance created one of the most thought through checklists for general use at the moment. Checklists include "... worksite general, health & safety training, walkways, noise, electrical, hand tools and equipment, and environmental conditions." ("General Industry Self-Inspect Checklist.", 2015). This is very helpful as it will give a general idea of what to include in a standard checklist and how checklists are used in industry today. An example would be the "Health & Safety Training" checklist that makes sure all employees are trained, attend safety meetings, have adequate training resources, have documented training in required subjects, have refresher training annually, and have instruction on procedures to report unsafe and defective equipment as well as unsafe acts. ("General Industry Self-Inspect Checklist", 2015)

Basic Methodology

The problem in Tennis Warehouse according to background research of the operations and literature review of industrial engineering concepts is that fact that Tennis Warehouse does not have a checklist or training manual of any kind for new employees. A checklist could be helpful in emphasizing procedures in Tennis Warehouse that can increase production, promote human factors and worker ergonomics, and lessen the training time and defective parts.

To fix this problem, Tennis Warehouse will be explored and the daily operations of a worker will be observed and summarized. Productivity will be measured via stringing racquet times with a highly controlled experiment. Ergonomic and human factor issues and lean production issues will also be observed. Using some of the literature review, a checklist will be created to increase productivity, lean production issues, and human factor and ergonomic issues. Then, going back to Tennis Warehouse employees will be calculated again but take into consideration the new checklist and its factors. What will be measured before and after the checklist are times stringing racquets and assumed frequency in error of ergonomic, human factor, lean production procedures. The results will then tell whether or not the checklist served as a reliable tool in the workplace and a recommendation will be made to Tennis Warehouse to implement this checklist to new employees.

Division of Checklist

Initially, the checklist was to be consisted of one long extensive checklist. Upon discussing with employees and further exploration of Tennis Warehouse operations, it was decided that three checklists were to be made. One addressing the training of new employees, one addressing the safety and ergonomics of operations and one addressing the general facilities/ machinery. This was to ensure that supervisors as well as managers had a chance to separate and address different concerns at a particular time. For example if there was an influx of new employees like during the summer, then the training checklist likely used more often or in a greater capacity to prevent the most lost.

Layout of Prospective Checklist

The checklist is made to provide a quick and easy look at the main functions that can be addressed to prevent waste. What will be provided to the client in completion is the checklist provided with reasoning behind each check and accompany assignment values that according to discussion with employees and supervisors. Each check will have an evidence of effectiveness, or a reason for the employers to check. This will be related to a tenant of industrial engineering, either lean manufacturing, ergonomics, and human factors.

Creation of All Checklists

Visualization of the Structure and Layout of Tennis Warehouse

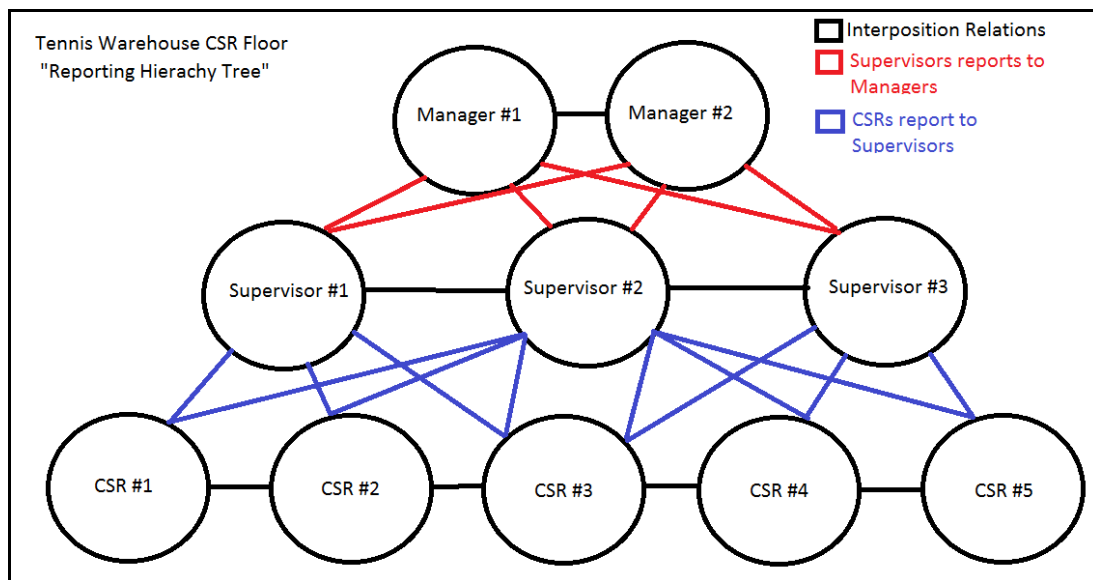


Figure 2: Reporting Hierarchy Tree

Creating the training checklist identified the major causes of loss time in the workplace and addressed them. When creating a checklist, one must take into consideration the structure and layout of the workplace. The Hierarchy Tree (Fig. 2) was created in an attempt to visual the structure of how the customer service floor functions. In Tennis Warehouse's case the assumption is that there are 15 customer service representatives, 3 supervisors, and 2 managers. The customer service representatives report to each supervisor who then reports to the manager in terms of authority, all while maintaining a

relationship amongst each other. This type of structure reflects the team like structure that is crucial in the success of lean production where all employees can ask each other questions and work together to create a to solve problems and accelerate production.

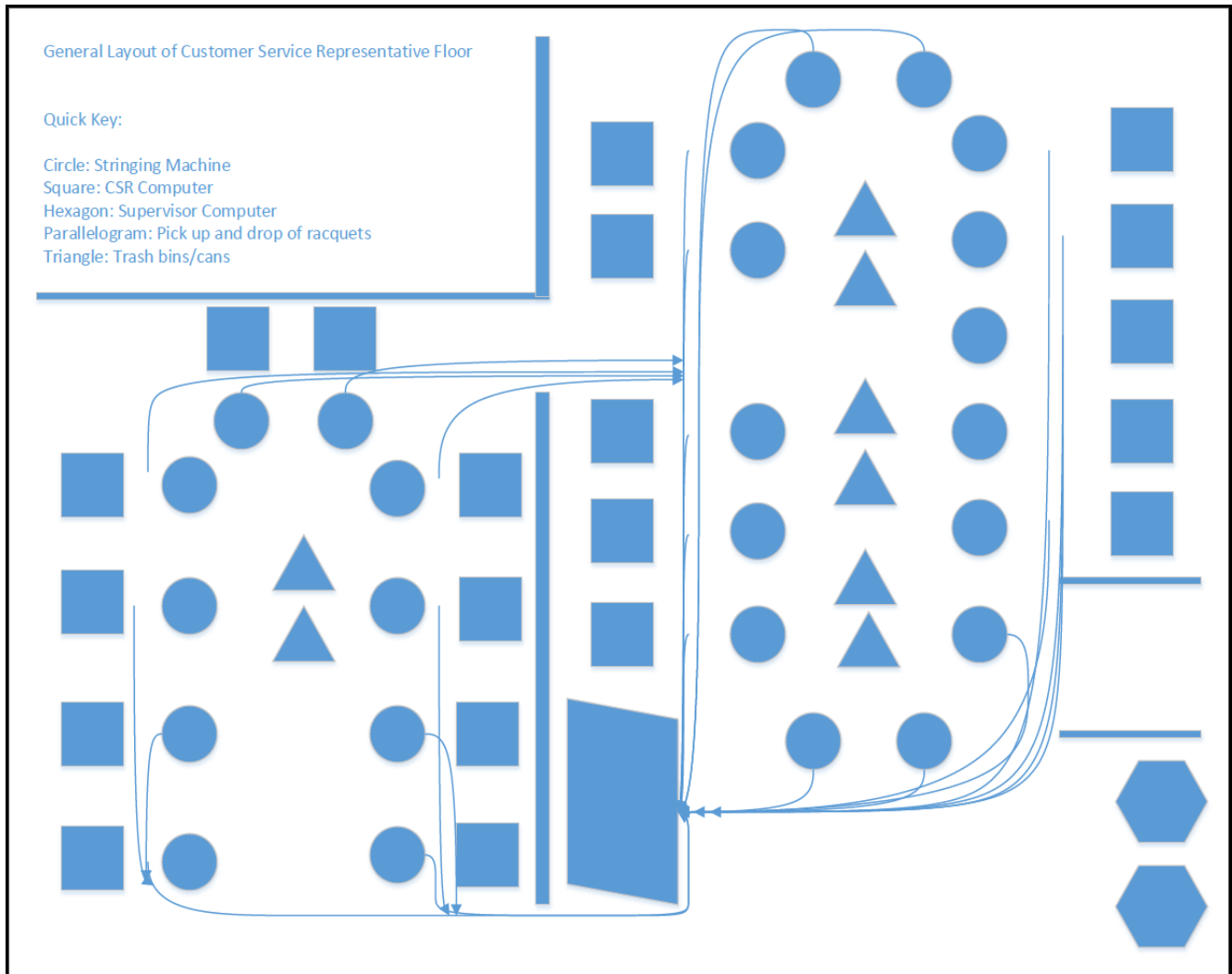


Figure 3: General Layout of CSR Floor

The general layout of the CSR floor keys in to a much of the time and hours spent between picking a racquet, walking to workstation, setting up the workstation, and submitting the racquets and picking a new one. Referring to the general layout of the CSR floor (Figure 2), one can see that the distance covered between racquets can lead to wasted time that could be otherwise put into production of strung racquets. This factors mainly into the one of the 7 wastes of lean manufacturing, transport. This is

taken into consideration when creating the checklist for training new or retraining old employees.

The Checklists and Reasons for Each Check

Table 1: Checklist 1; Safety and Ergonomics

Monthly Basic Safety and Ergonomic Checklist

Y	N	C	All Employees On CSR Floor	Evidence of Effectiveness (Why Check?)
			1. Are the aisles clear for safe passages of employees?	Aisles not being clear can lead to injuries, tripping, falling, phones falling, racquets falling, and damage to products and/or employees.
			2. Are the machines raised/lowered to a comfortable level for the operator to work? *Varies by user ~arms bent 90 degrees from torso	Machines not at the right height can cause significant strain in the lower back, arms, and neck area. This can cause inflammation of the joints, muscle pain, and significant musculoskeletal fatigue that can cause time off, and may cost the company in terms of insurance.
			3. Are all necessary first aid kits restocked, up to date, and readily available?	First aid kits are commonly used as employees deal with machines and sharp objects that may cause minor cuts or bruises.
			4. Are all employees aware of emergency exits and entrances?	Employees who are trained for safety precautions are less likely to be injured or be in panic in case there is an emergency.
			5. Are all employees wearing closed toes shoes?	Closed toes shoes prevent falled sharp or heavy objects that are used to string racquets from hurting employees.
			6. Are all work areas clean and orderly?	Clean and orderly areas can not only quicken string times but can prevent injury and health issues.
			7. Are all fire extinguishers and emergency procedures taught/ acknowledged to employees?	In case of fire, all employees must be taught the proper procedures of handling a fire including where the fire extinguisher is.
			8. Is there a good balance between standing and sitting during shifts longer than 4 hours?	Study shows that a good balance between standing and sitting is the least impactful way to work. This increases blood flow throughout the body and decreases the amount of stress on certain joints and muscles.
			9. Are all employees in good and healthy condition when working? I.E. If someone is coughing, is he/she being accounted for.	Making sure that employees are all healthy and all contagious employees are contained (masked or sent home) can promote an environment of health.
			10. Are all machines and work areas sanitized for daily used?- Wiped down computers and machines, vacuumed floors, dusting top of fans.	Sanitized machines kill germs and can prevent sickness from occuring or spreading in the workplace.
			11. Are there signs designating emergency exits, entrances and safety precautions to remind workers of hazards?	Signs can remind workers of certain precautions even if they have been trained. Can prevent further injuries from occuring.
			12. Make sure phone wires and tennis strings are not tangled in a way that could be harmful to workers.	These wires/strings can cause workers to trip and fall during busy times and if workers are not paying attention.
			13. Make sure phones and racquets and accessible to prevent reaching and repetitive movements.	Overreaching and repetitive movements are common causes of injury in the workplace and can cause employees to take time off, making objects more accessible can help prevent this.
			14. Are breaks frequent to prevent repetitive stressful movements?	Overreaching and repetitive movements are common causes of injury in the workplace and can cause employees to take time off, breaks can help prevent this.
			15. Are stretches encouraged to be performed periodically?	Stretches can lossen tight muscles and prevent injuries especially if employees are trained to stretch periodically.
			16. Are employees safe in handling chemicals (glue, rubbing alcohol) when maintaining racquets?	Mishandling of volatile materials can result in damaging of product and more importantly can injury employees.

Table 2: Checklist 2; Training Assurance

Monthly Basic Employee Training Assurance Checklist				
Y	N	C	Training of "String Only" Employees	Evidence of Effectiveness (Why Check?)
			1. Are all employees near tennis stringing machines properly versed in handling of machines before stringing?	Improper handling of racquets and string can result in mishaping/breaking of racquets and breaking of string
			2. Are all employees trained to use the "swimming" method to pull string?	"Swimming" method can result in a speed increase of 3 minutes, without sacrificing quality. 5 seconds per string pull 34 pulls per racquet (varies)
			3. Are all employees using the "lock bar" to avoid deformation of racquets?	The "lock bar" locks the racquet in place which allows for no movement of the racquet and prevents breaking of racquets. Not "locking the bar" is the most common cause of loss of racquets.
			4. Are employees who are demo/racquet only who have 4-8 hours taking at least 3 racquets per hour?	Taking more than one racquet per trip to machine can eliminate the time it takes to walk over and select racquets. This would eliminate most of the transportation waste that occurs walking back and forth from the machines to the carts of racquets.
			5. Are all racquets properly labeled by the stringer?	Racquets being properly labeled by the stringer gives responsibility to the operators which can eliminate rework.
			6. Is on job training and one-on-one training properly managed?	Though there is a need for on job training, proper one-on-one training is needed to ensure less defective parts from the start and less time otherwise allocated toward customer service or racquet stringing.
			7. Are employees trained on how to handle defective machines?	Defective clamps, slipping head and throat securers, and levers falling off are common occurrences when operating these machines. Being able to address these without consulting a supervisor or other employee can save time and improve efficiency in the workplace.
			8. Are employees taught how to properly adjust machine heights?	Properly adjusting machines needs 2 people and can significantly increase set up time for operators.
			9. Are employees continuously tested and timed on stringing racquets?	Continuously testing employees promotes healthy competition between employees and faster stringing times. Est 2 min improvement
			10. Are employees times recorded to promote quicker paced stringing?	Recorded times and scoreboards can create a sense of friendly competition, and prompt employees to "time" when not asked to.
Y	N	C	Training of "String and Phone" Employees	Evidence of Effectiveness (Why Check?)
			1. Are employee thoughts about the amount of training given adequate?	If the employee feels like he/she has not received adequate training this can result in lower quality phone calls and frequent questions to supervisors.
			2. Are employees trained to ask questions when needed?	Asking questions, though not too frequently, can result in higher quality service, less defects and more happy customers
			3. Are employees trained on how to deal with tough customers?	Tough customers can result in loss of sales and bad reputation. Being able to deal with these customers is part of the CSR job and can promote lifetime customers and increased sales.
			4. Do customers know how to use the discount function?	CSRs ability to discount items at the discretion of a supervisor is one of the main functions of a CSR other than placing/cancelling/changing orders over the phone. Not using the discount function right or struggling with it over the phone can result in unhappy customers or unintended loss by the company.
			5. Do supervisors have a method to check on the progress of CSRs?	Progress checks such as racquets/hour or time on phones can give a good indication of how a employee is doing and improvements that can be made as far as stringing racquets or phone service.
			6. Are there enough supervisors to accommodate the amount of CSRs working available?	At times of increased phone calls, busy supervisors can result in long phone calls waits, unhappy customers, and delay the stringing of racquets.

Table 3: Checklist 3; Basic Maintenance and Facilities

Monthly Basic Maintenance and Facilities Checklist

Y	N	C	Machine Maintenance	Effectiveness of Check (Why Check?)
			1. Are machines, tables and computers wiped down at least once a week?	The abundance of dust in the open environment of the floor can lead to allergens, sneezing, and spreading of germs which increase the amount of sickness on the CSR floor.
			2. Are moveable parts (head and throat secures) cleaned often to prevent racquet slipping?	Slipping can cause broken racquets, string, and can cause a delay in stringing times.
			3. Do last employees tasked with cleaning areas before janitorial services do?	Between racquets on the last 10-20 minutes of a ending shift can be better spent cleaning up the csr floor, which can make the space in better condition for employees the next day.
			4. Are stringing machines cleaned of string at least every month?	Can promote a clean environment and attention to detail.
			5. Are point of contact between employees and machines cleaned daily during seasons of increased sickness (i.e. flu season)?	Machines that are not wiped down can lead to spreading of germs of employees. Sick days can lead to losing of man hours which can be important in days of increased demand.
Y	N	C	Computer Maintenance	Effectiveness of Check (Why Check?)
			1. Are computers shut down/ all programs closed before closing each day?	Programs being closed can allow the machines to reset properly and prevent bugs from happening. This also allows a standard procedure to be had when employees come in the morning to opening programs and teaches them how to navigate the data-base.
			2. Are all keys wiped down to prevent spreading of possible sicknesses?	Machines that are not wiped down can lead to spreading of germs of employees. Sick days can lead to losing of man hours which can be important in days of increased demand.

Each checklist (Tables 1-3) were made to be short, no more than 20 checks per list, in order to put a limit on how much time was spent on these monthly audits and prevent the lists from delaying operations further. The separation of these lists into three separate lists allows Tennis Warehouse to utilize each list on their own schedule and in different frequencies depending on their need.

After creating a general checklist and having a solid reasoning behind each check, there had to be some experimentation to determine how much money (racquets improved) each check would have on the company theoretically. This was done by establishing a key of loss and assigning numbers to the amount of loss the checks would prevent.

Key of Loss

Table 4: Key of Loss

Losses that can be salvaged	Key
Broken Racquets	BR
Broken String	BS
Customer Dissatisfaction	CR
Rework	RW
Transportation Time	TT
Delayed Production (stringing) time	DP
Setup Time	ST
Supervisor Attention	SA

The key of loss (Table 4) addressed much of the improvements that could be made and corresponds with the majority of checks listed. The next step in the process would be to assign physical number values to the key of loss. This would have to be done using some experimentation, as well as broad estimation on the impact of the loss on the company.

METHODS/EXPERIMENTATION

Simulation and Testing of Checklist Effectiveness

The numbers assigned to each key of loss were determined mostly by consulting employees, and observations. There was, however, data taken to determine 1) the amount an average racquet unstrung cost and 2) the average time it takes to string a racquet. This data, reflected in Appendix A and B, was taken off Tennis Warehouse website as well as the in customer service floor resource center that was provided.

Table 5: Figure Calculation/Estimation

Loss that can be salvaged:	Key:	Amnt \$ /SHIFT (if applicable)	Reasoning
Broken Racquets	BR	fixed 180	Average of MSRP of racquets that require stringing (non-junior/used)
Broken String	BS	fixed 12	Average string cost of common multifilament string
Customer Dissatisfaction	CR	fixed 225	Customer dissatisfaction refunds do not exceed \$15 on average - store policy- special cases apply-
Rework	RW	fixed 225	Cost to restring racquet is \$15 *15
Transportation Times	TT	510	~5 min per racquet trip. 2 trips per racquet. Eliminate transportation on 2-3 extra racquets saves roughly 15 minutes per employee per shift. This amounts to \$34 dollars per shift.
Delayed Production (Stringing) Times	DP	67.5	Any loss of employee time is time that can be spent on employee stringing racquets. This is assuming that 15 employees are affected. 0.5 hours per shift x 15
Set-Up Times	ST	75	Set up times can take up to 15 minutes, for adjusting and maintenance on machines. 15x5=75 per shift
Supervisor Attention	SA	60	Supervisors on average consult 3/4 of the time and other times work on stringing racquets. In increased times of production, stringing time is sacrificed. Supervisors can string 4 racquets an hour. 15x4=\$60 per shift

Assumptions

- Shifts per day=2
- 15 employees per day
- Delayed production stringing times=.5 hours per shift
- 5/15 employees need set up time
- 15 min per racquet being strung

The amount of money is as seen in Table 5, with the reasoning behind each estimation of loss. The amount of loss for each broken racquet averaged to \$178.79 (Appendix A). For calculation’s sake, the number was rounded to \$180. Table 5 dictates in the “Reasoning” section the calculations behind the Loss Salvaged. The average for stringing times was determined to be about 12.358 minutes, however adding allowances for those times being the top skilled employees, set up times, walking distances,

tagging times, and caught miss-weave errors, the time was decided upon (and agreed upon by multiple employees) to be approximately 30 minutes. This time was factored into the final calculation of racquets saved.

As seen in Appendix C-E, each check on the checklist had a certain value assigned to it in terms of loss. This was determined by rough estimates of travel and effect on the company and under certain assumptions. Most of the assumptions that were made were that if a check were to not pass specification, the employees would undergo an immediate retraining. This idea is one promoted by the company and would reinforce the idea of an ever growing company focused on continuous improvement. The rest of the assumptions of failure were estimations based on supervisor and employee input. For example, “an estimated 2 racquets and 8 set of strings are broken each month due to lock bar error”. Although overestimates, these assumptions give a good look at the improvements that could be made when utilizing this checklist in the workplace and are best case estimates of improvements that these basic checklists can achieve. The amount of time that is spent applying to the checklist is also taken into consideration which is a general estimation of how much time each check would take and the operations that would be delayed as a result.

RESULTS AND DISCUSSION

Numerical Results Summary

Table 6: Safety and Ergonomic Checklist Results

Total Amount Saved:	59940	
Amount Lost Going Through Checklist	2835	(15 CSRs+ 3 supervisors) @ \$9/hr
Time Saved:	6660	hours
Racquets Improved:	13320	per month
Estimated Time/Racquet	0.5	hours per racquet

Table 7: Training Assurance Checklist Results

Total Amount Saved:	89604	
Amount Lost Going Through Checklist	2997	(15 CSRs+ 3 supervisors) @ \$9/hr
Time Saved:	9956	hours
Racquets Improved:	19912	per month
Estimated Time/Racquet	0.5	hours per racquet

Table 8: Maintenance Facilities Checklist Results

Total Amount Saved:	19206	
Amount Lost Going Through Checklist	1134	(15 CSRs+ 3 supervisors) @ \$9/hr
Time Saved:	2134	hours
Racquets Improved:	4268	per month
Estimated Time/Racquet	0.5	hours per racquet

Results Analysis

The results, succeeded in simulating an improvement of 3 times the demand of racquets (~217500 racquets per month reduced) while providing a monthly checklist solution. The number of racquets demanded per is assumed to be about 200 racquets per day * 30 days in a month, or 60,000 racquets a month. Assuming that this is quadrupled during times of increased demand to about 800 racquets per day. Using this checklist can reduce the load of racquets by at least 3 (~ 3.6) months. Looking back at the design, more solid numbers which would have required more extensive testing (noting every

defective part, miss- weave and the reasons behind them). Thus doing the most with the data that was taken, the design did hold up in improving the strung racquet production immensely.

There are non-monetary benefits to the checklist as well. This includes the happiness of employees as a safe, well trained, and smooth running workplace will lead to a decrease in turnover rate (more full time employees) and ease the hiring of new employees as the reputation of Tennis Warehouse as an employer would benefit.

As far as theory or design that can be changed, much of the racquet stringing issues and phone issues have been addressed. More specific training could be added to the training checklist in terms of phone etiquette and knowledge of products. Tennis Warehouse has already taken steps recently to improve the specific aspect using a new feature on their website called Tennis Warehouse University and level/promotion improvement within the customer service representative floor. Auditing these improvements and standardizing them in the form of checklists can definitely improve the amount of strung racquets improved.

Tennis Warehouse's recording of Tennis Racquet string times is very standardized and is the only experimental data taking that was done. The conditions are very controlled in the environment, type of racquet, and type of string used. The results are a very good indication of what the highest tier of racquet stringer's times are and continue to improve as the database of times gets updated. One thing that could have been improved would be the recording of frequency of tries of times. Employees are allowed multiple times to get timed and having more than one try may lead to a skewing of data in the long run.

Based on the result, predictions include the utilization of checklists in the form of a trial run. A legitimate problem that might arise would be the interruption of operations to the fact that it leads to dissatisfied customers or missed shipment dates. The use of this design should be limited to certain slow periods or ends of weeks (where shipment can be delayed till the next week as a result of no-weekend shipping) where the design could be tested in terms of effectiveness. Once applied and tried

thoroughly for effectiveness, the monthly checklists can serve to provide relief when certain tournaments are in full effect and demand for strung racquets are extremely high.

CONCLUSIONS

This experiment serve to simulate the improvements of a checklist using real world data taken from Tennis Warehouse and its facilities. This was done using an accumulation of information received as a trained employee, asking multiple questions to supervisors, taking data of strung racquets and navigating the largest online tennis retailer's website. The standout result was that three simple checklists and the utilization of them can lead to not only an improvement of up to 3 times strung racquet demand, but can lead to a happier and more knowledgeable staff of employees. This did not address entirely the 4 times increased demand that Tennis Warehouse has a problem with, but significantly increased the supply of strung racquets without significantly overhauling operations or hiring more employees. This is based on the main beliefs of industrial engineering and centered on process improvement, lean manufacturing, ergonomics and human factors.

The project has taught me the importance of checklists and how much they can improve once put into effect. It has also gave me an in-depth look at some of the topics specifically in ergonomics and human factors in combination with lean manufacturing and process improvement which I would like to pursue as a career in the future as a safety engineer or related field. The project was based mainly on employee estimates, supervisor recommendations, and basic employee training which I was put through. If I had enough time, over the course of a couple years, the data collected could more accurately represent the improvements that could have been made specifically in the warehouse. It is recommended that the company do use the checklist and collect data on the improvements that are made in the long run. Then test the results over a longer period of time the effectiveness on the demand of tennis racquets in and out of the facility. It is then that the company can evaluate if the checklists were to be a permanent fixture in their operations or not.

Possible environmental impacts of this project would be reducing the man power hours and decreasing waste created when deforming and trashing products such as racquets and string. Social impact would be creating a divide amongst supervisors using the checklist and customer service representatives.

Right now there is an open relationship where customer service representatives and supervisors can ask each other questions and are more peers and co-workers than employee-supervisor. With the integration of the checklist, there is an increased sense of control given to supervisors that might be received badly by employees. With Tennis Warehouse being a successful company open to constructive criticism, continuous improvement, and a symbiotic relationship between all employees, I believe that by using a checklist, Tennis Warehouse can better promote a safer, more knowledgeable, and overall more seamless work experience.

APPENDIX A

Prices of Tennis Racquets from TW website

Adjusted, no jr. racquets, discounts not included MSRP only

Babolat Racquets	Wilson Racquets	Head Racquets	Prince Racquets	Dunlop Racquets	Asics Racquets
209.00	219.00	199.95	189.00	199.00	189
199.00	199.00	199.95	199.00	199.00	169
349.00	199.00	199.95	189.00	199.00	169
199.00	199.00	189.95	189.00	199.00	169
189.00	209.00	199.95	149.00	179.00	
199.00	209.00	225.00	149.00	179.00	
195.00	209.00	225.00	199.00	179.00	
189.00	209.00	210.00	99.00	179.00	
299.00	149.00	210.00	129.00	179.00	
349.00	199.00	189.95	179.00	179.00	
349.00	199.00	179.95	179.00	179.00	
399.00	199.00	179.95	199.00	179.00	
349.00	199.00	179.95	119.00	179.00	
299.00	199.00	169.95	199.00	179.00	
199.00	199.00	179.95	189.00	149.00	
199.00	199.00	190.00	189.00	149.00	
195.00	199.00	190.00	199.00	149.00	
189.00	99.00	169.95	199.00	149.00	
195.00	159.00	189.95	179.00	149.00	
199.00	159.00	189.99	149.00	149.00	
159.00	169.00	189.99	159.00	149.00	
189.00	189.00	189.99	159.99	169.00	
399.00	199.00	189.99	159.99	159.00	
195.00	189.00	89.99	159.99		
195.00	179.00	89.95	219.00		
149.00	189.00	169.95	219.00		
185.00	199.00	169.95	219.00		
189.00	189.00	169.95	219.00		
189.00	199.00	199.95	99.00		
189.00	189.00	199.95	99.00		
179.00	149.00	199.95	119.00		
179.00	139.00	189.95	119.00		
179.00	229.00	74.95	119.00		
179.00	199.00	84.95	139.00		
139.00	179.00	79.95	139.00		
139.00	229.00	69.95			
104.00	119.00				
104.00	199.00				
104.00					
89.00					

Boris Becker	Gamma	One String	Pacific	PowerAngle	ProKennex	Solinco	Tecnifibre	Volk
159.99	194.95	189.00	189.95	179.00	179.00	179.99	189.00	199.99
179.99	179.95	189.00	189.95	179.00	169.00	179.99	189.00	199.99
179.99	159.95	189.00	189.95	179.00	189.00	179.99	179.00	189.99
129.99	164.95	189.00	179.95	179.00	189.00	179.00	179.00	249.99
	184.95		179.95		199.00	179.00	169.00	199.99
	199.95		149.95		179.00		179.00	199.99
	84.95		149.95		179.00		179.00	169.99
	159.95				179.00		179.00	219.99
	84.95				169.00		179.00	189.99
	179.95				199.00		169.00	179.99
	199.95				149.99		169.00	179.99
					149.99		149.00	179.99
					129.95		159.00	199.99
					149.00		169.00	189.99
					149.00			199.99
					159.99			199.99
					159.00			159.99
					179.99			159.99
					129.00			189.99
					129.00			179.99
					149.00			199.99
					119.00			179.99
					119.00			159.99
					119.00			139.00
								139.95
								139.95
								169.99
								139.95
								159.00
								159.99
								109.99

APPENDIX B

Racquet Stringing Times

Racquet	Time (min)	Racquet	Time (min)
1	8.3833	41	13.7000
2	8.5000	42	13.7167
3	8.5333	43	13.7833
4	8.6000	44	13.9500
5	8.8000	45	14.0333
6	9.0167	46	14.0667
7	9.0667	47	14.1000
8	9.1833	48	14.1833
9	9.2500	49	14.2000
10	9.5000	50	14.2167
11	9.5167	51	14.2167
12	9.5167	52	14.2500
13	9.5333	53	14.3500
14	9.7000	54	14.3500
15	9.7000	55	14.4167
16	9.7167	56	14.4667
17	9.8000	57	14.5833
18	9.8333	58	14.6500
19	10.3000	59	14.7167
20	10.6167	60	14.7167
21	10.8833	61	14.7333
22	10.9667	62	14.7333
23	11.0000	63	14.8000
24	11.3667	64	14.8333
25	11.5333	65	14.8333
26	11.5667	66	14.8333
27	11.6000	67	14.8500
28	11.7667	68	14.8833
29	11.8167	69	14.8833
30	11.8333	70	14.8833
31	12.2333	71	14.9667
32	12.2667	Average	12.3580
33	12.3333	Total 625 racquets per month reduced	
34	12.4833	Approximately 200 racquets/day.	
35	12.5500	Can reduce racquets load by at least 3 days using checklists per month	
36	12.7833		
37	12.8667		
38	13.5000		
39	13.5333		
40	13.5667		

*Limit of 0-15 seconds, allowances added in final data

Racquet times of fastest recorded times of different employees

APPENDIX C

Full Safety and Ergonomic Checklist. Reasoning, loss prevented, salvaged values, assumptions of failure and time to check included.

Monthly Basic Safety and Ergonomic Checklist				
All Employees On CSR Floor	Loss Prevented	Estimated \$ Salv/Mo	Assumptions of Failure	Time To Check(hour)
1. Are the aisles clear for safe passages of employees?	DP * 2shift * 30 Days	4050	RETRAIN ALL	2
2. Are the machines raised/lowered to a comfortable level for the operator to work? *Varies by user ~arms bent 90 degrees from torso	DP * 2shift * 30 Days	4050	RETRAIN ALL	2
3. Are all necessary first aid kits restocked, up to date, and readily available?	DP * 1shift * 30 Days	2025	RETRAIN ALL-SHORT	1
4. Are all employees aware of emergency exits and entrances?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
5. Are all employees wearing closed toes shoes?	DP * 2shift * 30 Days	4050	RETRAIN ALL	0.5
6. Are all work areas clean and orderly?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
7. Are all fire extinguishers and emergency procedures taught/ acknowledged to employees?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
8. Is there a good balance between standing and sitting during shifts longer than 4 hours?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
9. Are all employees in good and healthy condition when working? I.E. If someone is coughing, is he/she being accounted for.	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
10. Are all machines and work areas sanitized for daily used?- Wiped down computers and machines, vaccumed floors, dusting top of fans.	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
11. Are there signs designating emergency exits, entrances and safety precautions to remind workers of hazards?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
12. Make sure phone wires and tennis strings are not tangled in a way that could be harmful to workers.	DP * 2shift * 30 Days	4050	RETRAIN ALL	1

13. Make sure phones and racquets and accessible to prevent reaching and repetitive movements.	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
14. Are breaks frequent to prevent repetitive stressful movements?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
15. Are stretches encouraged to be performed periodically?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
16. Are employees safe in handling chemicals (glue, rubbing alcohol) when maintaining racquets?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1

APPENDIX D

Full Training Checklist. Reasoning, loss prevented, salvaged values, assumptions of failure and time to check included.

Training of "String Only" Employees	*See Key of Loss Loss Prevented	Estimated \$ Salv/Mo	Assumptions of Failure	Time To Check(hour)
1. Are all employees near tennis stringing machines properly versed in handling of machines before stringing?	1 BR + 4BS	228	1 racquets, 4 strings broken each month	2
2. Are all employees trained to use the "swimming" method to pull string?	3 Min*15 CSRs * 2 shifts*30 days*\$9/60min	405	Retrain all	1
3. Are all employees using the "lock bar" to avoid deformation of racquets?	2 BR + 8BS	456	2 racquets, 8 strings broken each month	1
4. Are employees who are demo/racquet only who have 4-8 hours taking at least 3 racquets per hour?	TT * 2 shifts* 30 days	30600	Retrain all	1
5. Are all racquets properly labeled by the stringer?	RWs*10 days	150	1 racquet defect per CSR/ 3 days	1
6. Is on job training and one-on-one training properly managed?	SA*2 Shifts*30 days	10800	Retrain all	1
7. Are employees trained on how to handle defective machines?	ST*2 Shifts*30 days	4500	Retrain all	2
8. Are employees taught how to properly adjust machine heights?	ST*2 Shifts*30 days	4500	Retrain all	1.5

9. Are employees continuously tested and timed on stringing racquets?	2 min*\$ 9/60 min * 2 shift * 15 CSRs* 30 Days	270	All employees improve	0.5
10. Are employees times recorded to promote quicker paced stringing?	Quality check, negligible gain.	0 -		0.5
Training of "String and Phone" Employees				
1. Are employee thoughts about the amount of training given adequate?	.5SA*2 Shifts*30 days	5400	Job training insufficient for half employees	1
2. Are employees trained to ask questions when needed?	1BR+1BS	192	1 broken racquet and 1 broken string per month	0.5
3. Are employees trained on how to deal with tough customers?	CR*2 Shifts*30 days	13500	Retrain all	2
4. Do customers know how to use the discount function?	CR*2 Shifts*30 days	13500	Retrain all	1
5. Do supervisors have a method to check on the progress of CSRs?	DP*2 shifts * 30 Days	4050	Retrain all	2
6. Are there enough supervisors to accommodate the amount of CSRs working available?	DP*2 shifts * 30 Days	4050	Retrain all	0.5

APPENDIX E

Full Machine Maintenance Checklist. Reasoning, loss prevented, salvaged values, assumptions of failure and time to check included.

Machine Maintenance	*See Key of Loss Loss Prevented	Estimated \$ Salv/Mo	Assumptions of Failure	Time To Check(hour)
1. Are machines, tables and computers wiped down at least once a week?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
2. Are moveable parts(head and throat secures) cleaned often to prevent racquet slipping?	DP * 2 SHIFT * 30 Days	4050	RETRAIN ALL	1.5
3. Do last employees tasked with cleaning areas before janitorial services do?	20 min * 9/hr * 1hr/60 min *30 DAYS	90	RETRAIN ALL	0.5
4. Are stringing machines cleaned of string at least every month?	--			1
5. Are point of contact between employees and machines cleaned daily during seasons of increased sickness (i.e. flu season)?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
Computer Maintenance				
1. Are computers shut down/ all programs closed before closing each day?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1
2. Are all keys wiped down to prevent spreading of possible sicknesses?	DP * 2shift * 30 Days	4050	RETRAIN ALL	1

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