<u>TX Facility Design Proposal</u>

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ISyE 350
Prof. Radwin

Bad News Badgers

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1. Executive Summary

This report outlines our proposal to shift WiScooter's operations to a new facility in El Paso, Texas in order to meet the rapid increase in demand for personal electric scooters and to roll out three new scooter models. This new facility will have a footprint of 240,000 square feet at a cost of $0.75 per square foot per year, flexible lines, a larger production floor, and a combined assembly and manufacturing space to enhance efficiency and increase production volume significantly. While our proposal may be capital intensive and risky to WiScooter, we believe that in the medium to long term it is a good strategic move to take advantage of changing market conditions, especially the large increase in demand for smaller scooter models. We outlined our initial process by making a Gantt Chart, Activity Network Diagram, Aggregated Resource Table. We then considered four alternatives to the one we ultimately selected and rigorously discussed and ruled them out in a systematic way after a pairwise ranking algorithm followed by two Pugh Iterations. We ended up choosing a hybrid solution because the combined benefits of changing the facility layout and making the production lines flexible were better than only pursuing one aspect to change. Our current production at the Wisconsin facility is approximately 480 units per day and we aim to produce 800 units per day by the end of the first year after beginning operations in Texas, calculated by averaging current demand over the first year. We understand that we will need to ramp up production into the future as demand continues to increase at an increasing rate and have the capacity in this new facility to do so. Our proposal outlined here is comprehensive. We hope to provide further details in the future on our strategic move of shifting WiScooters operations to Texas in order to address the concerns of Professor Radwin.

2. Project Definition

2.1 Project Charter

WiScooter Inc., a dynamic electric scooter manufacturer based in Madison, Wisconsin, specializes in producing high-quality e-scooters for ride-share companies. Facing rapid growth and an expanding product line, WiScooter is poised to relocate its operations to a new, larger facility in El Paso, Texas, to meet increasing demand across the U.S. and explore international markets. This strategic move aims to enhance manufacturing capacity, streamline assembly processes, and optimize warehousing solutions, ensuring WiScooter's continued success and innovation in the mobility industry.

WiScooter's primary aim is to increase production capabilities, ensuring that the supply meets the escalating demand for the company's sought-after e-scooters, while also preparing for a strategic expansion into new markets. The addition of three cutting-edge SKUs to WiScooter's product range is central to this growth strategy, which will be underpinned by thorough market research, seamless integration into current production lines, and dynamic marketing initiatives for a robust market entry.

Emphasizing cost-effectiveness in production is key. The company is set to enhance efficiency and maintain the highest standards of quality in its El Paso facility by incorporating advanced manufacturing technologies, improving supply chain logistics, and employing lean manufacturing principles. This approach is designed to reduce wastage and decrease production costs, aligning with WiScooter's commitment to affordability and quality.
The scope of this venture includes evaluating WiScooter's existing and future operational needs, designing the layout for the new facility in El Paso, and planning to meet projected demands over the next decade. Selecting the right machinery, quantifying necessary resources, and developing a Value Stream Map to detail the production process from receipt of raw materials to shipping of the finished product are critical components of this planning phase. The plan is developed with an eye towards sustainability, cost reduction, and enhancing the work environment for staff.

2.2 Resources

In the heart of El Paso, Texas, WiScooter Inc. is set to anchor its operations in a vast 240,000 square foot facility. At a competitive lease rate of $0.75 per square foot annually, this expansive area is designed to house the full spectrum of WiScooter's operations, from manufacturing and assembly to warehousing and administrative functions. The facility is meticulously equipped with the latest machinery and tools essential for producing a diverse range of five SKUs, with a particular emphasis on integrating automation and robotics to bolster efficiency and precision.

The warehouse component of this facility is a model of logistical efficiency, featuring state-of-the-art storage racks and material handling systems. These are complemented by advanced inventory management systems, all working in tandem to ensure maximum utilization of space and streamlined logistics. On the technological front, WiScooter taps into the potential of computer-aided engineering labs. These CAE labs are hubs for innovative design, simulation, and analysis, playing a crucial role in the development and refinement of WiScooter's e-scooters.

When it comes to financial investments, WiScooter is fully committed. Investments encompass not just the lease and potential construction or renovation of the El Paso facility but also extend to the procurement of cutting-edge equipment and technology upgrades. Moreover, the company has allocated funds to cover all initial operational expenses, which include materials, utilities, and payroll as the facility gets up and running. Additionally, there is a dedicated budget for training and development programs, ensuring that the workforce is adept and ready to meet the demands of the new setup.

At the helm of this project's oversight is Professor Radwin, who offers invaluable insights, feedback, and ultimately the final word on the project's deliverables, ensuring that each step aligns with WiScooter's strategic goals. Supporting the initiative is a team of industrious industrial engineering students, with TA Deepak providing expert guidance, together weaving the fabric of what is poised to be a new chapter in WiScooter's story of innovation and success.

Table 1: Aggregate Resource Table
Time throughout the semester allocated and utilized

Tasks	Lab Time(hrs)	Time with TA (hrs)	Time with Professor (hrs)	Lecture Time(hrs)	Meeting Time(hrs)	Personal Time(hrs)
Team Formation	1	0	0	1	0	0
Team Ground Rules	3	0.25	0	1	0.25	1
Project Charter Development	4	3	0.25	1	3	0
Activity Network Diagram	4	3	0	0	0	3
Voice of the Customer	0.25	1	1	0	1	0
CTQ Tree	1	1	0	0	1	0
Value Stream Mapping	2	1	0	0	1	4
Brainstorming	2	1	0	0	1	0
Facility Layout Ideas using Affinity Diagramming	1	1	0.25	3	1	0
Design Concepts and Decriptions	3	1	1	1	1	0
Utlized Pairwise ranking to weight each design criterion	2	1	0	1	1	0
Utilized the Pugh Matrix to compare alternative design ideas	2	1	0	2	1	0
Mid Semester Design Proposal	5	1	1	0	2	3
Proposal Presentation	2	1	1	1	3	1
FMEA Analysis	7	2	2	0	2	1
Final Design Report	5	0	1	0	3	3
Final Presentation Preperation	2	0	1	1	4	3
Resource Demand	46.25	18.25	8.5	12	25.25	19
Resource Capacity	48	48	10	16	60	25
Capacity Utilization	96%	38%	85%	75%	42%	76%

2.3 Project Schedule

To ensure the project progresses in alignment with our academic schedule, we meticulously planned our milestones and deliverables in the beginning of the semester. We accomplished this through the development of a detailed Gantt Chart in *Figure 1*, which serves as our roadmap, delineating key dates and activities essential to the project's success. Accompanying the Gantt Chart is our Activity Network Diagram in *Figure 2* , a visual representation that illustrates the sequential flow and interdependencies of project tasks. It highlights the project's critical path, marked as A-B-C-J-F-G-H-K-L-M, spanning a period of 60 days. This duration aligns with the semester's timeline, ensuring our goals are both realistic and achievable within the stipulated period.

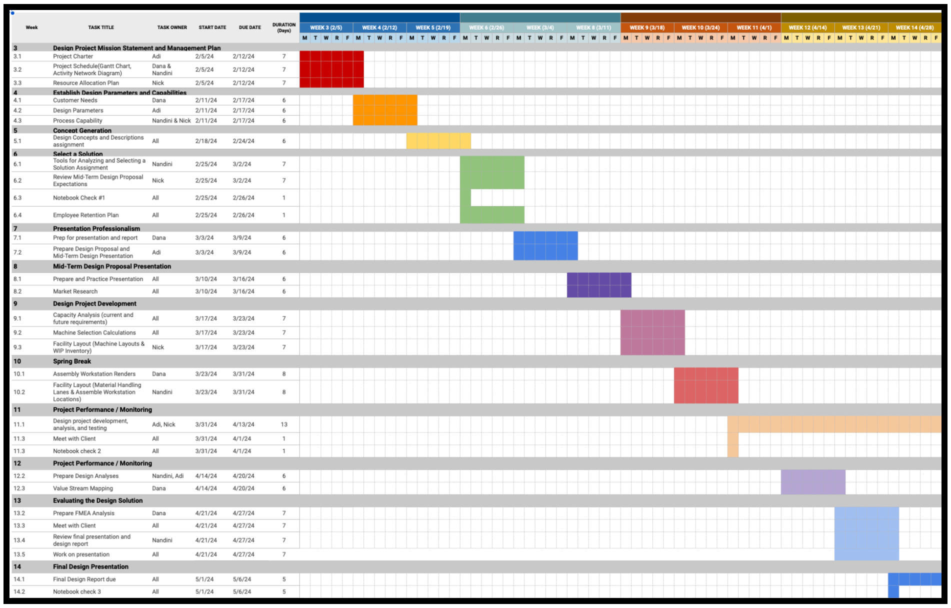

Figure 1: Gantt chart

The Gantt Chart of our important dates, milestones, and deliverables

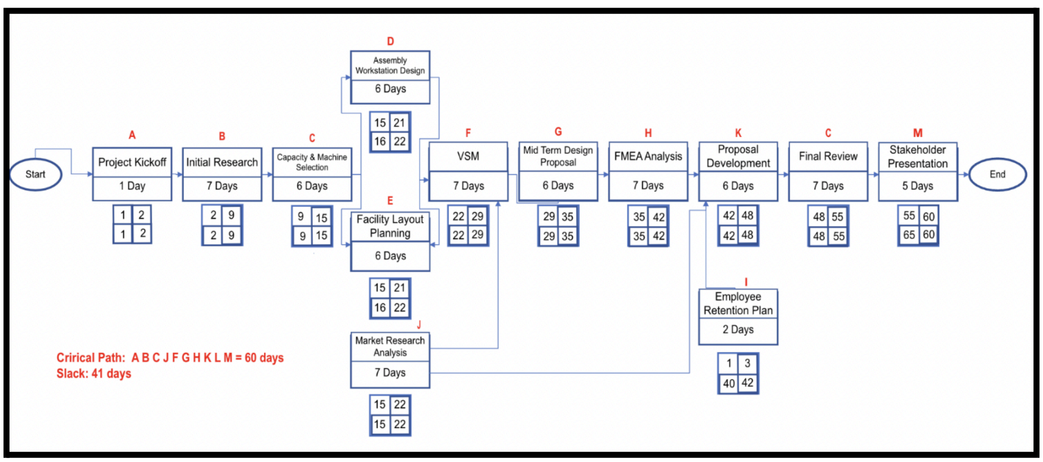

Figure 2: Activity Network Diagram

A visual representation of sequential relationships of tasks. The critical path is 60 days.

3. Project Goals and Objectives

3.1 Customer needs and design parameters

The scope involves evaluating WiScooter's current and projected operational requirements, designing a new El Paso facility layout, and preparing for projected demand. This will encompass selecting suitable machinery, resource quantification, and developing a Value Stream Map from raw material receipt to finished product shipment, all while emphasizing meeting our client's priorities. Currently, WiScooter faces capacity challenges due to rapid growth in the U.S. and planned market expansion abroad. To address these issues and support anticipated demand for existing and new products, our solution is to create a final prototype of a flexible manufacturing system within a dual-purpose fabrication and assembly space, thereby enhancing factory space efficiency and increasing production capabilities.

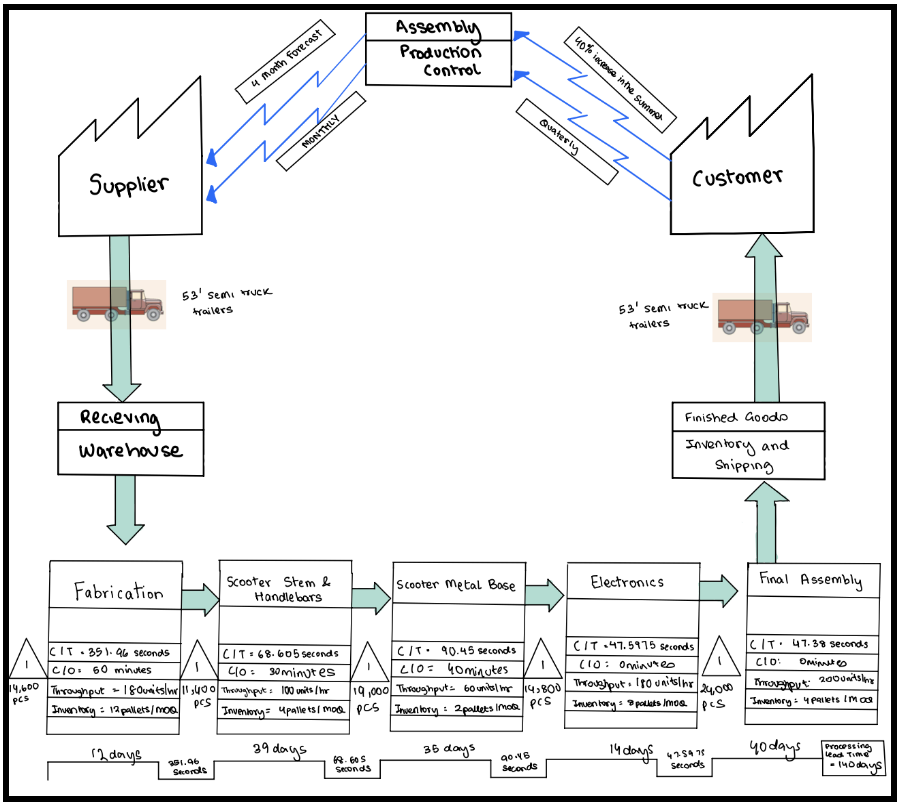

Figure 3 - Value Stream Map (VSM) of the current facility

Figure 3 depicts a Value Stream Map (VSM), which is a diagram used to analyze and design the flow of materials and information required to bring a product or service to a consumer. Here, we represent how each segment of the manufacturing flow contributes to the overall efficiency and effectiveness of the operation. This map is not only a blueprint for our current operations but also a strategic tool for identifying potential areas for improvement and innovation.

In the current facility, the supply chain process begins with the supplier, who is responsible for providing the raw materials necessary for production. Following this initial stage, the Assembly Production Control takes over, managing the assembly process based on forecasts and actual orders to ensure efficiency and timeliness. The next step involves the Receiving Warehouse, where materials sourced from suppliers are received and stored until needed. Fabrication is a crucial phase where various parts of the product, such as scooter stems, handlebars, metal bases, and electronics, are manufactured. During this stage, several important measures are taken into consideration, including Cycle Time (C/T), which is the total time from the beginning to the end of a process; Changeover Time (C/O), which is the time required to change a production line or equipment from making one product to another; Throughput, which refers to the amount of material or items passing through a system or process; and Inventory, which is the number of parts or products on hand. Following fabrication, the Final Assembly stage occurs where the various fabricated parts are assembled into the final product. The process culminates in the

Finished Goods Inventory and Shipping stage, where the final product is stored before being shipped to the customer.

Voice of the Customer

In this section, we will delve into the heart of our project - the alignment of our design parameters with the customer's needs. The Voice of the Customer articulates the necessity for a scalable production model capable of launching three new electric scooter models, addressing the growing market demand while maintaining cost efficiency. Through a detailed examination of the Critical-to-Quality Tree, we will explore how increased production, inventory management, and scalable manufacturing form the cornerstone of our design parameters. Our objective is to ensure that each design choice closely corresponds to WiScooter's strategic goals, enabling us to meet market demands swiftly without compromising on efficiency or cost. WiScooter's main objective is to introduce three new small personal electric scooter models in order to meet the future demand of this booming market at a relatively low cost. Measuring average monthly production will be a solid indicator of our projected performance. This would be a good proxy for annual revenue. Our customer, WiScooter, also wants to enter the market quickly to take advantage of the recent surge in demand. There needs to be enough space to meet production targets and inventory requirements, and since we are planning to move to TX, we will essentially be starting from scratch. While we have a high degree of freedom in our overall approach, we are constrained to one facility in one location. We realize that this alternative carries significant risks to WiScooter and a high degree of uncertainty.

We will need to design and construct a new plant from the ground up and its production lines. We understand that this new plant in TX will need to be significantly better than the current one and superior to the other alternatives for it to be attractive to WiScooter. If we cannot make our plan worth it after analyzing it fully, it would be helpful to let WiScooter management know that it is infeasible under the current constraints.

We also need to focus on minimizing costs when we introduce the three new models. This can be achieved by analyzing each aspect of the value stream map rigorously. The customer desires low lead times, low cycle times, high throughput, low labor costs, low maintenance costs and low capital costs. We plan to take all variables into account when putting our plan together and understand that new problems and questions will arise throughout the process.

Critical-to-Quality Tree

Our project's success hinges on identifying and fulfilling key quality factors. This visual tool breaks down the customer's requirements into specific, actionable attributes that our design must possess. The three critical client requirements are market demand, introducing new SKU's, and maintaining cost effective production. From ensuring proper inventory management to the creation of high variability assembly lines, each branch of the CTQ Tree will guide us to understanding our client's priorities. This analysis will help us pinpoint the essential quality characteristics that our scooter manufacturing process must meet to satisfy both our immediate and long-term objectives: meet market demand, introduce new SKU's, and maintain cost effective production.

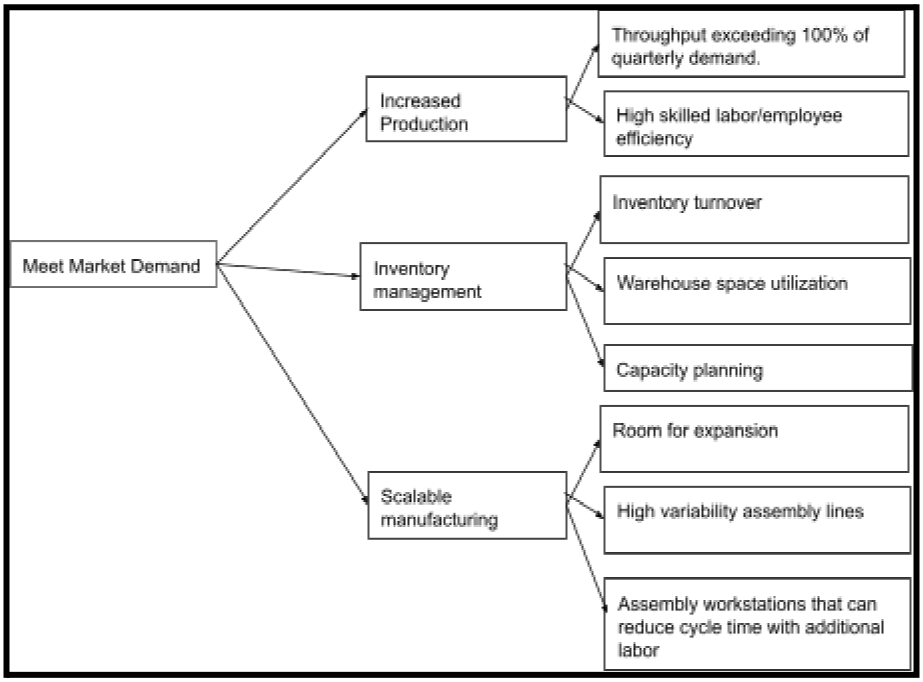

Figure 4 - Meet Market Demand

To fulfill the critical requirement of meeting market demand, our production process will be meticulously optimized to align with quarterly market demand projections, aiming to exceed them when possible. The success of this objective hinges on maximizing labor efficiency, which involves not only hiring highly skilled workers but also providing continuous training to enhance their productivity.

A key measure of our progress will be inventory turnover rates, which will inform us about the adequacy of our inventory management strategies and warehouse space utilization. This measure is pivotal, as it reflects our ability to supply products without incurring storage excesses or shortages. Effective capacity planning will also play a crucial role, providing us with the flexibility to scale up production while maintaining room for expansion. With a focus on creating highly variable assembly lines, we aim to build a production system that can easily adapt to varying product demands. The implementation of assembly workstations designed to reduce cycle times with additional labor will be tested rigorously. By systematically evaluating these measures, we can pinpoint areas for improvement, ensuring that our process is both agile and robust enough to handle current and future market trends.

While we strive for high labor efficiency and optimal inventory turnover, we must acknowledge the limitation of accurately predicting market fluctuations, which could lead to discrepancies between production levels and actual demand. Another potential limitation is the scalability of warehouse space, which might require us to explore innovative storage solutions or expansion to new locations. The results from our test plans on cycle time reductions and capacity planning will feed into a continuous improvement loop, informing future designs that may include advanced predictive analytics for better demand forecasting and modular warehouse designs for scalability.

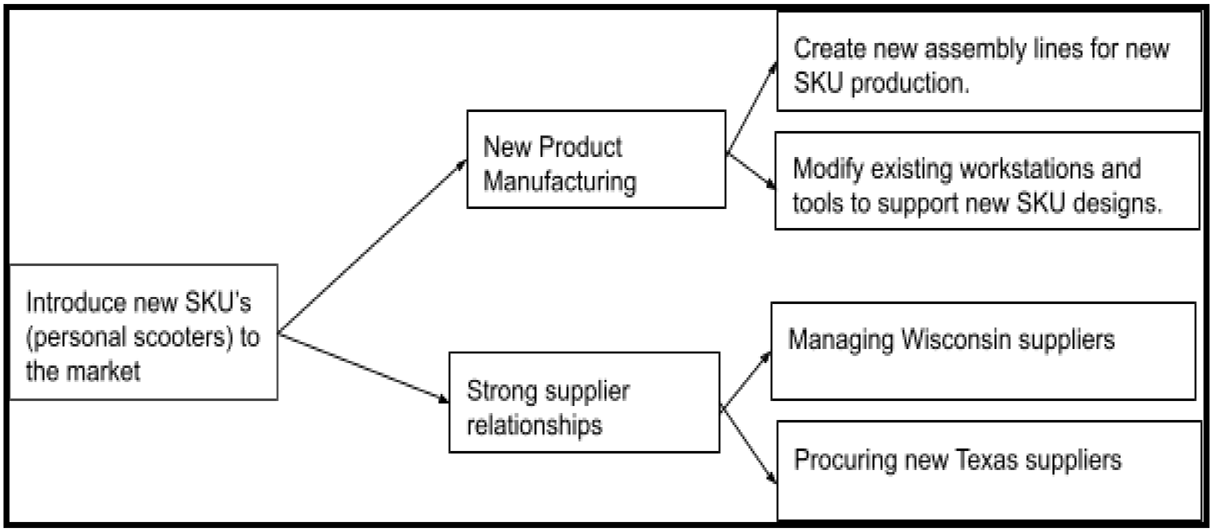

Figure 5: Introduce New SKUs

The introduction of new SKUs (Stock Keeping Units) is a vital component for maintaining market competitiveness and addressing the evolving tastes and preferences of consumers. To ensure seamless integration of new products, our manufacturing system will feature assembly lines specifically designed for flexibility and rapid reconfiguration. This adaptability is crucial for the quick rollout of new scooter models and the efficient use of assembly space. In terms of metrics, we will monitor the time from concept development to market launch, the quantity produced in initial batches, and the speed of assembly line reconfigurations as benchmarks for this objective. Establishing strong supplier relationships is a foundational element in this process, which will involve not only managing existing partnerships but also procuring new suppliers that meet our standards in Texas. These relationships will be crucial when introducing new products, as they will allow us to quickly adapt our supply chain to the demands of new SKUs. Our test plan must account for the complexities introduced by new product designs, particularly as they pertain to the integration of new parts and materials. Future testing will include small-scale rollouts and trial production runs to ensure that our process design can be scaled up effectively.

As we aim to introduce new SKUs rapidly into the marketplace, we confront the limitation of ensuring that our production lines can flexibly adapt to new product designs. The need to maintain strong supplier relationships introduces a dependency, which could affect our ability to control the end-to-end production timeline. Our test plans will need to assess the feasibility of creating and modifying assembly lines for new products, considering factors such as the integration of novel technologies or materials. The outcomes will have significant implications for future designs, potentially leading to the implementation of more modular and adaptable production systems or the development of closer, more collaborative supplier partnerships.

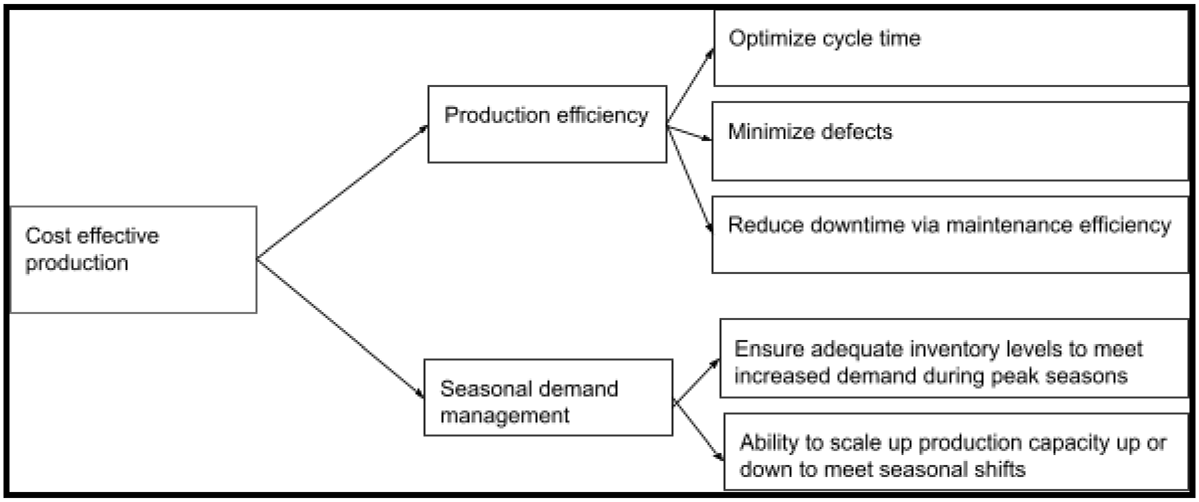

Figure 6: Maintain Cost-Effective Production

Maintaining cost-effective production is a complex challenge that involves optimizing every aspect of the manufacturing process to improve the bottom line without compromising quality or the client's critical needs. We will pursue production efficiency by working to optimize cycle times and minimize defects. A crucial part of our strategy includes reducing downtime through improved maintenance efficiency, ensuring that our machinery operates at peak performance with minimal interruptions. Seasonal demand management is another aspect of our approach, requiring us to ensure that inventory levels are adequate to meet peak season demands without resulting in overproduction during off-peak periods. This delicate balance will be achieved through a strategic combination of just-in-time inventory practices and a keen ability to scale production capacities to match seasonal market shifts. Our measurement of cost-effectiveness will extend beyond simple cost per unit metrics to include a holistic view of overall equipment effectiveness and waste reduction percentages.

With the goal of maintaining waste effective productions, we must also be aware of limitations such as potential raw material cost volatility and the unpredictability of equipment maintenance needs. These factors could affect our ability to maintain the planned cost per unit and overall equipment effectiveness. Additionally, managing seasonal demand is complex, with the risk of either overproducing or underproducing if our predictions are inaccurate. Our test plans will include monitoring these metrics against industry benchmarks and conducting scenario analysis to anticipate and mitigate these challenges. The results from these tests will be crucial for future designs, prompting us to consider advanced inventory management systems and predictive maintenance technologies to stay ahead of potential issues and optimize production efficiency.

3.2: Design evaluation criteria and relative weighting

Through brainstorming, the design criteria that we utilized to select design options and evaluate are the following: cost, meeting demand (throughput), revenue increase, time to implement, effect on workers, risk, inventory level, layout efficiency, supplier lead time, and penetration of new market. We determined these based on their importance to achieve the client's goals.

The chosen criteria were selected for their alignment with both the client's immediate needs and long-term strategy. By focusing on cost, we ensure the solution is economically viable. Throughput aligns production with market dynamics, safeguarding against demand fluctuations. Market penetration encapsulates the design's adaptability for future expansion, making these criteria not just relevant, but essential for the client's success. Revenue potential emphasizes the design's contribution to growth, while implementation speed reflects our commitment to timely delivery. Worker impact is prioritized to foster a productive and satisfying work environment. Risk consideration ensures resilience, and inventory management prevents capital tie-up. Layout efficiency and supplier lead time directly correlate with operational agility.

4. Design Concepts and Problem Analysis

With a clear grasp of what our client needed, we kicked off our brainstorming, aiming to devise design solutions that would rise to the occasion. We were on the lookout for designs that could not only support a higher scooter output but also swiftly introduce new models to the market, all while keeping a close eye on cost-effectiveness. Our team dove into a three-stage creative process: we first generated a wide array of ideas—around 40 to 50—prioritizing the quantity over quality at this stage. Then, we sorted these ideas into related groups using affinity diagrams, which helped us see the bigger picture. Next, we pinpointed criteria to evaluate these groups, ensuring our designs were on the right track. Finally, we narrowed our options down to four solid design ideas through a combination of multi-voting, pairwise ranking, and Pugh matrix analysis, each method giving us a fresh perspective on the best path forward.
We started brainstorming by spending half an hour each, jotting down every idea that came to mind. We worked separately but shared our thoughts in one document, covering everything from how we could keep our employees safe to different ways we could move materials around in the new facility. The ideas we came up with were really different from each other, some simple and some more complex. Once we hit a total of fifty ideas, we brought them all together and started seeing which ones seemed to click with each other. Our goal was to shape these ideas into a rough sketch of what we needed in a production facility that could handle all kinds of scooter models. But we noticed some ideas didn't include important stuff that we and our TA thought were key, things that other factories use and work well. So we had a good look at what was missing and made sure to add those in. After that, we all voted to choose the best ones, narrowing down all our brainstorming to the four design approaches we thought would work best.

During our brainstorming session, we initially came up with four potential design approaches. After discussing with our client, it became clear that not all of these ideas would realistically meet the project's deadlines or the client's expectations. With this insight, those designs were discarded prior to additional weighting and ranking in order to save time and also put more focus on the designs we felt had the best chance of success in this case. The affinity diagrams of the design can be seen in *Table 2* below.

Table 2: Affinity Diagramming of Preliminary Designs

1. **Transportation and Supply** a. Intra-facility shuttle transportation b. Smaller packaging c. Larger order size d. Transportation bays suited for method of transportation, i.e. trucks
2. **HR and Workforce Management** a. Provide corporate housing close to the site for workers to reduce their commute b. Hire more people, or less but more skilled c. Cross training d. Worker benefits to promote steady employment and production e. Implement a schedule for other employees to support the production line when we have less production line workers f. Cut workers benefits g. More overtime
3. **Manufacturing and Production Optimization** a. Flexible production line b. Scalable production c. Production line that can produce different SKUs d. Intra-facility shuttle transportation e. Automated machinery (AGV in warehouses) f. Purchase more machines
4. **Inventory and Warehouse Management/capacity planning** a. Separate/combined manufacturing and assembly space b. Combined fabrication and assembly c. Separated space between fabrication, assembly and inventory, distribution. d. Sufficient inventory for set time period, Seasonal inventory management e. Kanban system f. Backorder management strategies g. Purchase initial fleet h. Regional distribution model i. Take as much capital as we can to start j. Lower price per unit k. Higher price per unit
5. **New product development** a. Scrap the previous 2 models and only produce the new 3 b. Scrap 1 of the 2 previous models and only produce 4 total c. Scooter recycling for parts d. Smaller parts (battery, motor, etc). e. Marketing campaign f. Cheaper raw materials (ex. metal) or using alternative materials such as carbon fiber or carbon steel. g. Implement college student discount h. A flexible line that can produce different SKU's
6. **Efficiency and quality control** a. Sustainable energy to power the plant b. Quality control checkpoints at manufacturing line
7. **Suppliers** a. New supplier, wisconsin = far when in texas, texas or wisconsin supplier b. More frequent orders c. Use different metal alloys d. Secure partnerships with ride sharing companies to secure more orders

4.1 Specific design solution options considered

At this point in the design process we narrowed our selection down to four distinct alternatives, each with their own benefits and drawbacks.

4.1.1)*Keep the current WI facility*: *Scale up current operations*
Our first was to simply scale up the current operations in WI into the new 240,000 sq ft facility in El Paso, TX which would have a lower cost and a higher production volume. This is not necessarily a bad option, but we believe we could do better if we innovate and change the layout and/or processes in our new facility.

4.1.2) *Automated machinery (AGV in warehouses) and purchase more machines*
Our second option was to automate machinery, which would have a large upfront cost, but reduce labor costs, increase efficiency, increase quality, and increase volume. Incorporating state-of-the-art manufacturing techniques sounds good on paper, but we scrutinized this strategy. We determined that there are perhaps better ways to increase production to meet demand and introduce new models to the market without only increasing the sophistication of our production methods.

4.1.3) *Combined fabrication and assembly spaces*
One of the standout alternatives was to restructure our manufacturing and production lines for flexibility, which would allow us to quickly roll out the three new scooter models. Initially, we were all on board with this idea. However, after a discussion with our client, we wanted to ensure we hadn't missed any potential improvements. This led us to conceive an idea that could revolutionize our operations by merging the assembly and manufacturing zones into one expansive production floor in the Texas facility. The challenge here was to design this combined space carefully to prevent overcrowding and inefficiency.

4.1.4) *Flexible Manufacturing Line*
In our pursuit of a more adaptable production environment, we focused on the concept of a flexible manufacturing line. This dedicated line is designed to be versatile, allowing us to swiftly shift our manufacturing focus depending on demand fluctuations across different scooter models. The inherent flexibility means that if one model sees a surge in demand, we can promptly increase its production without significant downtime or reconfiguration. Such agility in our manufacturing process ensures we can respond rapidly to market trends and customer preferences, ultimately improving efficiency and meeting demand in real-time. This streamlined approach positions us to maximize productivity and maintain competitiveness as we cater to an evolving marketplace.

4.2 Comparative analysis and solution selection

We used the preceding list of design criteria to determine the importance weighting of each criteria. These decisions were informed by meeting with the client to gauge their opinion on which criteria is of highest importance to them and use the pairwise ranking method to establish the weightings for each design by assigning numerical values on a 1-to-10 scale, relative to its contribution towards achieving your goals. This process concluded with the following pairwise ranking matrix and associated weights with each criteria. The highest ranked design criteria based on the client's priorities is meeting demand, followed by penetration of new markets and cost efficiency.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1.		**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**10**
2			**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
3				**4**	**5**	**6**	**7**	**8**	**9**	**10**
4					**4**	**4**	**7**	**8**	**9**	**10**
5						**6**	**7**	**8**	**9**	**10**
6							**7**	**8**	**9**	**10**
7								**7**	**7**	**10**

8									**8**	**10**
9										**10**
10										

Figure 7: Pairwise Ranking Matrix
A pairwise ranking of the design criteria

Table 3: Weighting of Design Criteria

Design Criteria	Tally (Weight)
1. Cost	8
2. Meeting Demand (Throughput)	10
3. Revenue Increase	1
4. Time to Implement	4
5. Effect on Workers	2
6. Risk	3
7. Inventory Level	7
8. Layout Efficiency	6
9. Supplier Lead Time	5
10. Penetration of New Market	9

After we determined our four mutually exclusive alternatives, we qualitatively compared them in a Pugh Matrix to objectively select the best option given our weightings. We discussed each comparison in detail and voted on whether to score it better, the same, or worse for each key criteria. Our results are shown in *Figure 8* below:

Key Criteria	Weight	Keep the current WI facility	Automate Machinery	Combine Fabrication and Assembly Spaces	Flexible Production Line
Meeting Demand (Throughput)	10	(-)	(+)	(-)	B
Penetration of New Market	9	(-)	(-)	(-)	B
Improve Cost per Unit	8	(-)	S	(-)	B
Inventory System (+) = better	7	(-)	(-)	S	B
Layout Efficiency	6	(-)	(-)	(+)	B
Supplier Lead Time	5	S	S	S	B
Time to Implement	4	(+)	(-)	(+)	B
Risk (-) = worse	3	(+)	(-)	(+)	B
Effect on Workers	2	(-)	(+)	S	B
Revenue Increase	1	(-)	S	(-)	B
Sum of Positives (+)		2	2	3	0
Sum of Negatives (-)		7	5	4	0
Sum of Sames (S)		1	3	3	0
Positiives - Negatives		-5	-3	-1	0
Weighted Sum of Positiives (+)		7	12	13	0
Weighted Sum of Negatives (-)		43	29	28	0
Weighted Sum of Sames (S)		5	14	14	0
Weighted Positiives - Weighted Negatives		-36	-17	-15	0

Figure 8: Pugh Matrix Iteration 1

This iteration made clear that out of the four alternatives in question, the flexible production line is the optimal one to pursue under these criteria and weightings. We were pretty satisfied as a group with this outcome but wanted to introduce a hybrid option between the flexible system and the combined assembly space to see if we can do better. After filling in the missing comparisons to the hybrid system, we obtained the results in *Figure 9* below:

Key Criteria	Weight	Keep the current WI facility	Automate Machinery	Combine Fabrication and Assembly Spaces	Flexible Production Line	Hybrid: Flexible and Combined
Meeting Demand (Throughput)	10	(-)	(+)	(-)	B	(+)
Penetration of New Market	9	(-)	(-)	(-)	B	S
Improve Cost per Unit	8	(-)	S	(-)	B	(+)
Inventory System (+) = better	7	(-)	(-)	S	B	S
Layout Efficiency	6	(-)	(-)	(+)	B	(+)
Supplier Lead Time	5	S	S	S	B	S
Time to Implement	4	(+)	(-)	(+)	B	(+)
Risk (-) = worse	3	(+)	(-)	(+)	B	S
Effect on Workers	2	(-)	(+)	S	B	(-)
Revenue Increase	1	(-)	S	(-)	B	S
Sum of Positives (+)		2	2	3	0	4
Sum of Negatives (-)		7	5	4	0	1
Sum of Sames (S)		1	3	3	0	5
Positiives - Negatives		-5	-3	-1	0	3
Weighted Sum of Positiives (+)		7	12	13	0	28
Weighted Sum of Negatives (-)		43	29	28	0	2
Weighted Sum of Sames (S)		5	14	14	0	25
Weighted Positiives - Weighted Negatives		-36	-17	-15	0	26

Figure 9: Pugh Matrix Iteration 2

This iteration made clear that out of the five alternatives in question, a hybrid solution, which includes both Integrating Flexible Lines and Combined Spaces is the optimal one to pursue under these criteria and weightings. It has many positive effects that come from our previous two best alternatives, only with the added drawback of a negative effect on workers. The production floor could be chaotic and overcrowded, with many more variables for the workers to manage. We value the workers' quality of life minimally when making this decision. The team agreed that this hybrid alternative is the one which we will further pursue.

5. Design approach

Our final prototype is of a flexible manufacturing system and a combined fabrication and assembly space. Our idea of a combined fabrication and assembly space serves to maximize the space utilization of the factory. We plan to achieve this through the 'double-horseshoe' design seen in Figure 10.

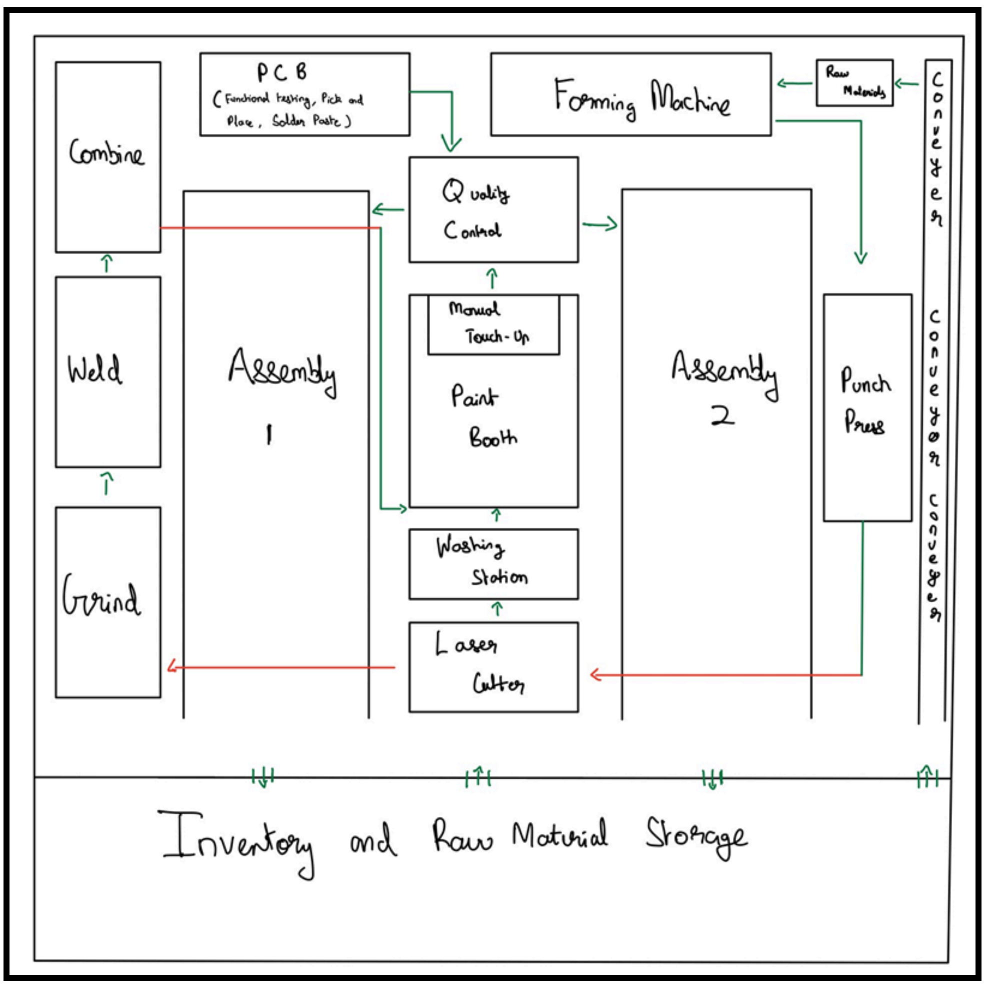

Figure 10: Preliminary 'Double-Horseshoe' Facility Layout

The fabrication process for each SKU has 4 main processes before heading to QC for assembly: Stem & Handlebar Production, Metal Base Production, Paint and Printed Circuit Board (PCB)

Production. Stem & Handlebar and Metal Base Production share a laser cutting process as well as the paint and manual touch up processes. This facility layout allows us to optimize part flow and maximize layout efficiency by having all of the common processes in the middle of the factory while individual processes are conducted on the side. The layout also features two identical assembly lines which take the completed fabrication parts once they have passed through the Quality Check station.

The material flow is indicated by green and red arrows. Green arrows represent material flow on the ground while red arrows indicate three overhead conveyors. These conveyors are used to transport parts in and out of the laser cutter as well as from the combination station to the paint booth.

In Figure 11, we can see a facility layout, completed in Visio, showcasing all the features mentioned in the initial layout above. It has machines in black and red, black reflecting the ones needed to set up for the initial, while red denoting the final amount of machinery required at the end of the 10 year period. A Visio file of the facility layout has been included in our submission for closer perusal.

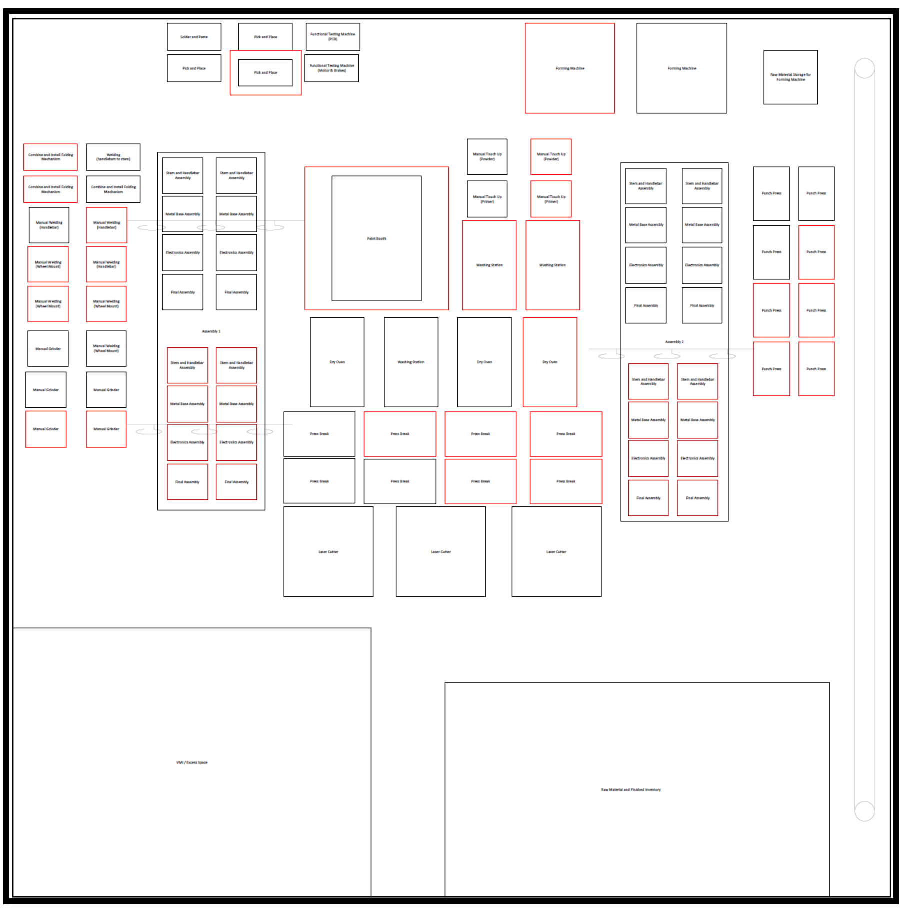

Figure 11: 'Double-Horseshoe' Facility Layout

We found that despite the increased demand till year 10, due to the size of our facility, there was still ~30,000 sq.ft of unused space. After thorough brainstorming we have come up with a few ideas that the client can implement such as: Vendor Managed Inventory (VMI), Testing and Innovation Lab or Scooter Repair/ Return Center.

Setting a VMI space in the facility would allow WiScooter to bring vendors with high lead times to Texas such as Electronic's Plus, Motor Gears and Tom's Spare Parts to the facility. Not only will this drastically improve their supply chain efficiency, but it will also reduce inventory holding costs and the stock is managed by the vendor.

Meanwhile, a Testing and Innovation Lab would allow WiScooter to further bolster their goal of penetrating the new market by empowering them to continuously improve the designs of their current offerings as well as explore new products to manufacture keeping them at the forefront of technology. Setting up such a lab would also allow WiScooter to test their current product offerings rigorously thereby upholding higher safety and regulatory standards than before.

Finally, a Scooter Repair/ Return Center would give WiScooter the opportunity to better connect with their customers and offer quality customer service for their product offerings, commercial and personal. Additionally, they can also implement a scooter refurbishment program where they take in old scooters and transform them to a like-new state, turning a profit on them while also lowering a strain on their scooter manufacturing process by feeding the growing demand.

Our design will also include a Barcode (RFID) system linked to a Manufacturing Execution System (MES) to allow for multiple SKU production on the same line with minimal impact on throughput. [2] Each individual part will be assigned with a RFID indicating the SKU and unit it is to be produced for. This will allow the MES to track the transition of individual products from raw materials to a finished scooter. This approach will not only enhance our understanding of the production process's consistency but, more significantly, it will enable stations to precisely identify the specific SKU into which the part is being manufactured. The laser cutter, paint booth and manual touch up station are three processes which see variation in the different SKUs. An example of the RFID on a metal base can be seen in *Figure 12* below.

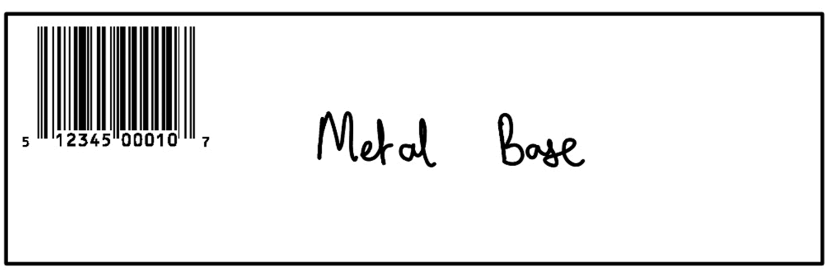

Figure 12: Example of RFID Sticker on Metal Base

This design will also allow us to minimize the impact of downtime. In a situation wherein a particular machine experiences machine failure or downtime, an individual line setup would halt production for that particular SKU. However, in our proposed design, since we have a flexible manufacturing system capable of handling all SKUs, we can redirect parts to other functioning machinery while the equipment undergoes maintenance. [3]

Our key objective with the flexible production line is to empower stations to produce all 5 SKUs. To accomplish this, certain machinery in the current process will have to be modified. The stations that need to be modified are the Laser Cutter, Paint Booth and Tubular Steel Fabrications stations. Moreover, the changeover time for these stations need to be reduced so as to allow seamless transitions from the production of one SKU to another.

Paint Booths

With regards to the paint booths we plan to retrofit the existing equipment, and purchase new paint booths, to have dedicated spray guns for all SKUs. Each paint booth will have 4 paint tanks and distinct spray guns for the four different colors required. This change will remove any need to clean and change our paint tubes to switch over to a different paint color. This will allow us to drastically reduce the changeover time.

Laser Cutter

The stem of the scooter sees a variation in length between the different SKUs. While SKU 3,4 and 5 use a 36” stem, SKU 1 and 2 use a 28” and 32” stem respectively. Our RFID system will be able to identify the length the tubular steel is meant to be cut at and seamlessly execute the process.

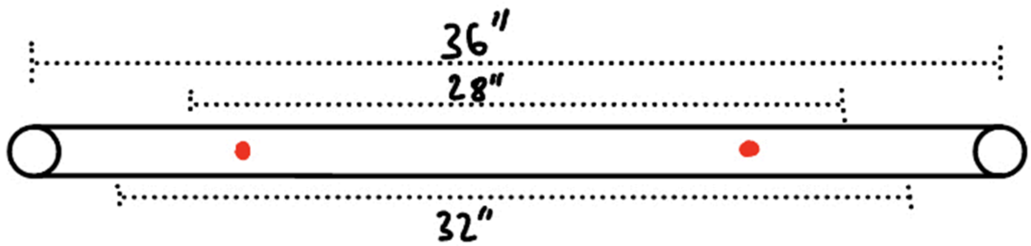

Figure 13: Handlebar Dimension by SKU

Tubular Steel:

To empower all the tubular steel fabrication stations to work on stems of all three specifications we need to take into account the fixtures used to hold the tubular steel in place. We therefore decided on designing an adjustable fixture that would be able to account for the variation in length. This adjustable fixture would need to ‘geo-lock’ our part regardless of its length. This can be done by placing our constraints (clamps or pins) within the shortest length. These constraint positions are marked on *Figure 13* by two red dots.

However, to effectively execute this adjustable fixture design we need to take into account the effect of different stresses on the part geometry. Placing both of our constraints closer to the middle might cause higher stress on the edges of the longest length of tubular steel, 36”, during the welding and grinding process. Tests should be conducted to ensure that these constraints do not alter the part geometry and dimensions beyond the specification limit.

Our team recognizes that there are certain commercial and safety risks with the design. Notwithstanding the initial investment required to set up the factory, retrofitting the new equipment and setting up the MES will require a sizable initial investment. However, we believe that the projected demand and increased sales will allow us to offset this large initial investment and place WiScooter in a great position to meet projected demand for the next 10 years. With regards to safety, workers will need to go through extensive training to get them familiarized with the new system and machinery. Standard safety mechanisms such as PPE, emergency stops and safety scanners will be implemented to ensure worker safety during production.

Capacity Analysis and Machine Selection:

Given our client's priority to meet demand, we took a demand centric approach to our capacity analysis and machine selection. We approached the issue of machines for the factory with a 10 year lens, since we were given a projected 10 year demand for all 5 SKUs. Using this demand we plan on implementing a triannual ramp-up for the facility in El Paso. We intend to only begin with machines enough for the first year's demand so as to prevent adding extra strain on the logistics of setting up a new facility. Once the facility has been running successfully for one year, we plan to continue with our triannual ramp up plan. Specifically, an initial setup and then an immediate ramp up at the end of year 1 followed by further machine introductions at the end of years 4 and 7. For each given period we decided our target throughput by taking the average demand year prior to the next ramp up, i.e. year 6 for the ramp up at year 4. However, accounting for variation in demand we chose to add one standard deviation of wiggle room in our throughput estimate. A sample calculation for the target monthly throughput for year 1 can be seen below in Table 4.

Table 4: Target Throughput for Year 1

Average Monthly Demand Year 1	Standard Deviation	Target Monthly Throughput
20563	2637	23200

Table 5: Machines Requirement

Machine	Option	Number of Machines at WI	Initial Number of Machines Required at TX
Laser Cutter (handle cars, stem, support bar, metal base)	Medium	3	3
Manual Grinder	1 Employee	3	3
Pick & Place Machine	Standard	1	3
Press Break	Manual	1	3

Punch Press	Manual	1	3
Dry Oven	Small	2	2
Manual Welding (handlebars)	Small	1	2
Manual Welding (wheel mount)	Small	1	2
Welding (handlebars to stem, stem to support bar)	1 Employee	2	2
Forming Machine	Standard	1	1
Functional Testing Machine (motor & brakes)	Standard	1	1
Functional Testing Machine (PCB)	Standard	1	1
Manual Touch-Up (powder coat)	Standard	1	1
Manual Touch-Up (primer)	Standard	1	1
Paint Booth	Small	1	1
Solder Paste Machine	Standard	1	1
Washing Station	Small	1	1
Combine & Install Folding Mechanism	1 Employee	1	1

We plan to ship all the existing machinery from the Wisconsin factory to the factory in El Paso so as to prevent incurring high fixed costs. A list of the existing machinery can be seen in Table 5 above. Table 6 below highlights the additional equipment needed throughout all 3 ramp ups.

Table 6: Machine Selection Across

Machine	Option	Ramp Up Year 1	Ramp Up Year 4	Ramp Up Year 7
Laser Cutter (handle cars, stem, support bar, metal base)	Medium	3	3	3
Manual Grinder	1 Employee	3	4	5
Pick & Place Machine	Deluxe	1	1	1
Press Break	Manual	5	6	8
Punch Press	Manual	5	7	8
Dry Oven	Small	2	2	3
Manual Welding (handlebars)	Small	2	3	4
Manual Welding (wheel mount)	Small	3	4	5
Welding (handlebars to stem, stem to support bar)	1 Employee	2	2	2
Forming Machine	Standard	1	2	2
Functional Testing Machine (motor & brakes)	Standard	1	1	1
Functional Testing Machine (PCB)	Standard	1	1	1
Manual Touch-Up (powder coat)	Standard	1	2	2
Manual Touch-Up (primer)	Standard	1	2	2
Paint Booth	Large	1	1	1
Solder Paste	Standard	1	1	1

Machine				
Washing Station	Small	1	1	3
Combine & Install Folding Mechanism	1 Employee	1	2	3

While we intend to use the same manner of machinery for almost all processes, we intend to upgrade our Paint Booth and Pick & Place machine. The new option has been highlighted in yellow, we intend to upgrade our Paint Booth from small to large and our Pick & Place Machine from standard to deluxe to better meet throughput and conserve space in the facility.

MOST Analysis:

We created a MOST table to estimate the cycle time for assembling (excluding manufacturing) the largest personal scooter model to give us a sense for the efficiency of our design compared to the current high cycle time of approximately 250 seconds. Our table is shown below:

Table 7: MOST Analysis

MOST Analysis		Tool Use Sequence/General Move								Precise Move Assembly							
Step Name	**MOST Action Type**	**A**	**B**	**G**	**A**	**P**	**B**	**A**	**Total TMU**	**A**	**B**	**G**	**M**	**X**	**I**	**A**	**Total TMU**
Weld Support Tube to Bar	Tool Use	1	6	6	3	45	3		64								0
Weld Support Tube to Chassis	Tool Use	1	6	6	6	100	3		122								0
Weld Support Tube to Rear Wheel Support	Tool Use	1	6	6	3	100	3		119								0
Paint Chassis with Powder Coat	Tool Use	3	6	6	6	30	6		57								0
Chassis Baked in Oven for 5 min	Automated	3	6	6	3	2800	6		2824								0
Concurrently, Brake Disk Heat Treated	Automated	[redacted]							0								0
Place Magnesium Wheel Rim Over Brake Disk	General Move	1	6	1	1	40	3	1	53								0
Place Tire over Magnesium Wheel Rim	General Move	3	6	3	3	40	3	1	59								0
Place Second Wheel Rim over Tire	General Move	1	6	1	1	25	3	1	38								0
Thread 4 Lug Nuts through each Spacer on Wheel Rim	Tool Use	3	6	1	3	30	3		46								0
Insert Battery Pack into Motor	Precise Move								0	6	1	1	6	200	6	1	221
Secure Motor in Place with Screws	Tool Use	1	6	1	1	200	3		212								0
Install Drive Chain Adjuster	General Move	6	6	1	3	30	3		49								0
Mount Rear Axle with Sprocket	General Move	1	6	1	3	45	3	1	60								0
Install Small Sprocket on Drive Shaft	Tool Use	6	6	1	1	60	3		77								0
Hook Drive Chain around Sprockets	Precise Move								0	6	3	3	6	100	3	1	122
Mount Rear Fender and Chain Guard	General Move	3	3	1	3	45	3	1	59								0
Tighten Axle	Tool Use	1	6	6	6	30	3		52								0
Automated Welding Machine Fuses Handlebars to Tube	Automated	1	6	6	3	30	3		49								0
Install Hatch to Secure Handlebars	General Move	1	6	1	1	60	1		70								0
Install Motor Control to Handlebars	Tool Use	1	6	1	3	24	1		36								0
Add Rubber Handlebars to Handlebar Shaft	Precise Move								0	3	3	3	6	100	3	1	119
Tape Support Shaft to Secure it	Precise Move								1	1	1	1	1	6	1	1	12
Hammer Hinge Pin into Support Shaft	Tool Use	1	6	3	3	60	3		76								
Cover Battery with Wooden Platform (4 Screws)	Tool Use	1	6	30	1	300	3		341								
									Total TMU:	**4938**							
									Total Seconds:	**177.77**							

Total TMU: 4838, Total Seconds: 178.

While this analysis is a very rough estimate of the true cycle time for assembly of a personal eScooter in our design, it is about a minute faster than the current cycle time. We conducted this analysis based on a video of the current assembly process, and translated that to our flow of materials in our design. It's approximately a 28% improvement, mainly due to the better flow of materials and the scale of our lines. If a process is backed up, we estimate that about 20% of the time another like will have availability to resume production. While the TMU values are rough estimates, the conceptual flow of material through the lines is undoubtedly more efficient than the current system though.

VSM of New Design

Our new Value Stream Map in *Figure 14* for the El Paso facility lays out a clear plan for how we plan to make scooters from start to finish. It shows each step, from getting the raw materials to shipping out the finished scooters, ensuring everything moves smoothly and quickly. This setup is designed to streamline our manufacturing process, allowing us to produce more scooters efficiently and meet rising customer demand.

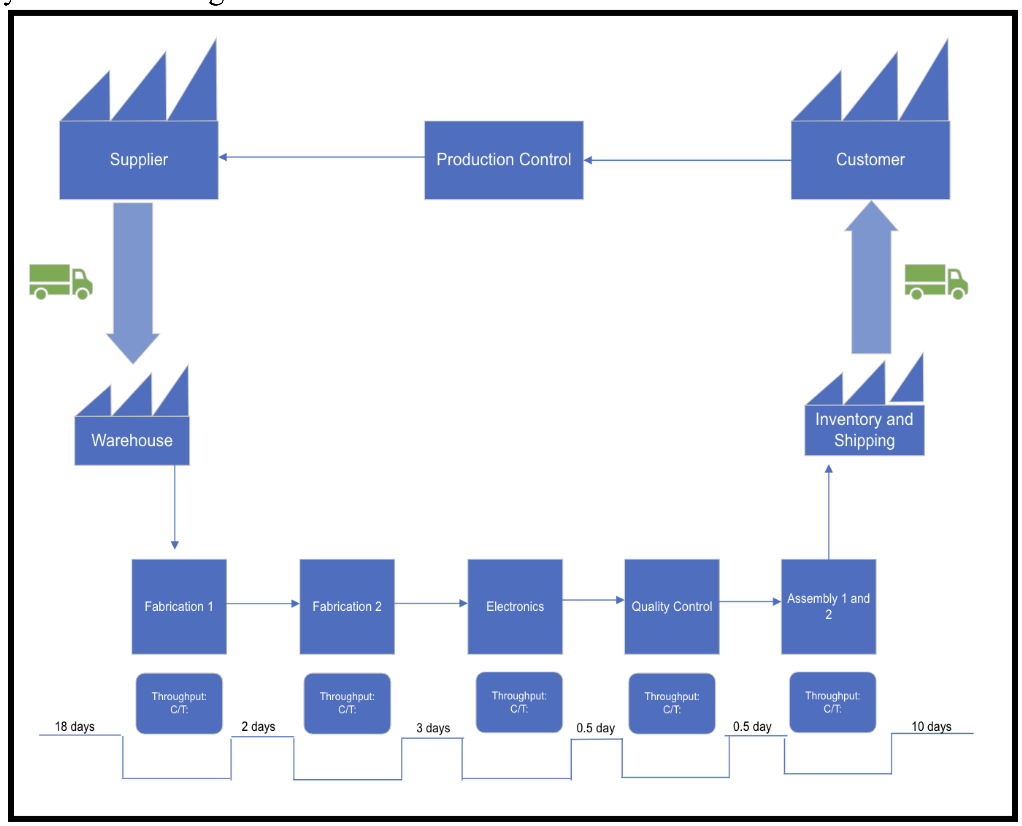

Figure 14: New layout VSM

The raw materials first go to Fabrication 1, then move to Fabrication 2, and proceed to the PCB functional testing. After testing, materials pass through Quality Control before moving to the Assembly stage. Once assembly is completed, the finished products are moved to Inventory, ready for shipping. The design of this VSM closely aligns with the layout of our new facility. This alignment minimizes the movement of materials and reduces handling times, which reduces the likelihood of errors.

Market Research

The electric scooter market in Texas is experiencing consistent growth, influenced by broad trends of rising demand for sustainable and efficient urban transportation for teens and people in their 20s. Demand is driven by a couple of different factors including the need for fuel-efficient transportation, aversion to crowded public transportation, high price points of cars for young people, and the popularity of e-scooter-sharing services. Several players already operate in the Texas market, including major companies like Bird and Lime as well as smaller innovative firms such as Veo, which has introduced unique models like seated scooters. The competitive landscape evolves regularly but the majority of companies adopted one of two business models. They either offer a price per minute with additional fees or subscriptions as a service, or they sell scooters outright as a product [5]. We think it is probably best to model our business similar to Bird as they have experienced success recently. The market is expected to remain hot as it matures, and in the future we hope to differentiate ourselves.

Competition

The electric scooter market in Texas is experiencing consistent growth, influenced by broad trends of rising demand for sustainable and efficient urban transportation for teens and people in their 20s. Demand is driven by a couple of different factors including the need for fuel-efficient transportation, aversion to crowded public transportation, high price points of cars for young people, and the popularity of e-scooter-sharing services. Several players already operate in the Texas market, including major companies like Bird and Lime as well as smaller innovative firms such as Veo, which has introduced unique models like seated scooters [5]. The competitive landscape evolves regularly but the majority of companies adopted one of two business models. They either offer a price per minute with additional fees or subscriptions as a service, or they sell scooters outright as a product. We think it is probably best to model our business similar to Bird as they have experienced success recently. The market is expected to remain hot as it matures, and in the future we hope to differentiate ourselves.

Pricing

After doing some research on the prices per minute and per ride of the ride sharing scooter companies such as Bird and Lime, we think that a similar price of approximately $.30 per minute is reasonable for us. Also, the model of $1 to start the ride plus a fee of $.15 per minute could be more optimal for an area with a shorter average ride time [6]. Charging by the ride and giving a fixed time window doesn't make too much sense, as the desired riding time varies a lot within our target market. Finally, charging a subscription which lowers the fee per minute seems appealing (for example $5/month), and we will investigate this idea further once we collect a substantial amount of data on who our riders are, the distribution of their ride times, and whether they are likely repeat customers.

Forecasting

Our current production is intended to meet demand. Demand varies seasonally, so we predict summer demand is approximately 25% higher than winter, and spring and fall demand are roughly 10% higher than winter. We plan to take this into account when managing inventory, but the fine details should be worked out by WiScooter as more data comes in.

Employee Retention Plan:

In response to the challenging labor market and the escalating competition for skilled workers, WiScooter's employee retention plan is designed to attract and retain top talent, crucial for the success of our newly designed facility. Central to this strategy is the creation of a compelling work environment that not only offers competitive wages but also focuses on career development, job satisfaction, and work-life balance.

Understanding the financial motivations and needs of our workforce, WiScooter is committed to offering a starting hourly wage of $17, which is significantly above the Texas minimum wage of $7.25 and surpasses the average wage for manufacturing workers in Texas, which stands at approximately $15 per hour according to data from Indeed [4]. This competitive wage is complemented by the potential for raises and bonuses, reflecting our dedication to fair compensation that rewards the expertise and hard work of our employees. Alongside this, we will implement a comprehensive benefits package that includes enhanced health care options, retirement savings plans, and generous parental leave policies for both parents.

To further support our employees' career trajectories and job satisfaction, WiScooter will offer ongoing training and professional development opportunities. These programs are designed to help staff stay at the forefront of technological and industry advancements, ensuring they are well-equipped to meet the demands of their roles. Additionally, we will introduce options for cross-training and rotating workers across different teams and machinery to prevent job monotony and burnout, promoting a dynamic and engaging work environment.

WiScooter also prioritizes the creation of a supportive and inclusive work culture. This includes the establishment of cultural affinity groups and providing spaces and policies that respect and accommodate the diverse religious practices of our employees. By offering flexible scheduling options and dedicated spaces for prayer and meditation, we ensure that all team members feel respected and valued for their beliefs.

A significant aspect of our retention strategy focuses on fostering a community within the workplace. This includes hosting free lunch Fridays and monthly company social events, such as picnics or outings, designed to build camaraderie and enhance employee satisfaction. Furthermore, a two-way feedback system will be implemented, where employees not only receive bimonthly reviews but also have the opportunity to provide feedback to their supervisors, fostering transparency and ensuring that employee voices are integral in shaping the company's practices and allowing room for positive mentorship.

Finally, to sustain our workforce pipeline and enhance our attractiveness as an employer, WiScooter will engage in community outreach and form partnerships with technical schools and universities. These efforts will help in attracting future talent and maintaining our competitive edge in the industry. The following is a sample flier we plan to use to begin our recruitment:

Figure 15: Recruitment Flier

Through these comprehensive and strategic initiatives, WiScooter aims to create a workplace where skilled workers are not only attracted to join but are also motivated to stay, thereby ensuring the long-term success and sustainability of our operations.

6. Project execution

6.1 Challenges and obstacles

Navigating the complexity of project execution for the WiScooter facility upgrade presented an array of challenges that tested the resilience and adaptability of our team. One major hurdle was ensuring compliance with the budget constraints and tight scheduling demands outlined in our Project Charter. The challenge was compounded by the need to integrate diverse project activities, as depicted in the Activity Network Diagram (Figure 2), where tasks were categorized as parallel, sequential, or coupled. The critical paths identified, such as the parallel processing of Initial Research and Market Research Analysis and the coupling of Assembly Workstation Design with Facility Layout Planning, needed to be carefully managed to prevent bottlenecks.

Another significant challenge arose during the Capacity and Machine Selection phase. The requirement for machinery to precisely match our operational design goals was more complex than initially anticipated. This complexity not only prolonged this phase but also had a domino effect on subsequent critical tasks such as the development of the new Value Stream Map and the optimization of the facility layout. These elements were crucial for ensuring that the operational flow within the new facility would efficiently meet future production demands. Furthermore, aligning the intricate details of the facility's layout with the technology planned for deployment added another layer of complexity to our project execution strategy in terms of additional research required on the manufacturing machines used at the facility.

The project also faced challenges in maintaining engagement and clear communication among all team members and stakeholders. The multidisciplinary nature of our team meant that different members brought various expectations and expertise, which sometimes led to conflicting views on project priorities. Regularly scheduled meetings and updated communication channels were essential in managing these differences, ensuring that every team member remained aligned with the project's goals and deadlines. These strategies were pivotal in overcoming the obstacles we faced and were instrumental in steering the project back on track whenever deviations occurred.

6.2 Project implementation

The implementation phase was structured around the framework we created in our Project Charter. This document served as our guideline, detailing every critical aspect of the project from scope and budget to schedule and deliverables. Utilizing the Gantt chart (Figure 1) was particularly effective in providing a visual representation of our progress, facilitating better project management and allowing for real-time adjustments. A key milestone in this phase was the successful completion of the Capacity Analysis and Machine Selection. These tasks laid the groundwork for all subsequent planning and development phases and were critical in ensuring that the foundational infrastructure was suited for the advanced manufacturing processes we envisioned.

Post these milestones, we embarked on developing a new Value Stream Map and redesigning the facility layout. These tasks were informed by insights gained during the capacity analysis, ensuring that the facility's design was optimized for production efficiency and prepared for future scalability. Moreover, the integration of detailed analyses such as Failure Mode and Effects Analysis (FMEA) and Maynard Operation Sequence Technique (MOST) helped refine operational sequences and identify potential risks. These tools were essential not just for mitigating risks but also for ensuring that the facility design was robust, scalable, and capable of handling the anticipated operational challenges effectively.

The project is currently on track, with all phases progressing as planned. The strategic revisions and efficient management have ensured that we remain aligned with the original timeline, and we are projected to complete the project by May 6th.

6.3 Revisions

Throughout the lifecycle of this project, several revisions were necessary to respond effectively to both anticipated and unforeseen challenges. As project execution unfolded, real-time updates to our Gantt chart reflected the dynamic nature of our planning process. The initial floor plan was moved ahead due to an earlier-than-expected completion of the machine selection phase. This early completion allowed more time for refining the facility layout, which is crucial for the efficient flow of manufacturing processes.

However, the capacity planning phase was extended. The complexities involved in aligning the chosen equipment with specific production needs for the new scooter models were greater than initially anticipated. Extending this phase ensured that the facility would be fully capable of meeting future demands without compromising on efficiency or scalability. Additionally, certain tasks such as market research and the development of an employee retention plan were temporarily postponed. This decision was made to prioritize resources towards critical path activities, including finalizing the facility layout and conducting thorough FMEA. These adjustments were crucial in maintaining alignment with WiScooter's strategic objectives and ensuring that the project was completed to the highest standards within the constraints of our academic and project timelines.

7. Performance and test data

Implementation of a flexible manufacturing system in tandem with a combined fabrication and assembly space will empower WiScooter to meet all of its targets, satisfying projected demand and penetration of the new market. By maximizing part flow and efficiency in the fabrication process by grouping common processes and implementing an MES system to empower the stations to work on all SKUs, our design is able to effectively assist WiScooters' addition of 2 SKUs and increased production. Our design also provides critical quality control metrics through the MES system as well as avenues for innovation, VMI or refurbishment programs as a result of maximizing space efficiency. All of which further bolster our clients goals of meeting demand and penetrating the new market by making the manufacturing process more sustainable and efficient.

Based on our calculations in the capacity analysis and machine selections, we will achieve an initial throughput of 1,105 units /8 hr shift while accounting for individual defect rates, maintenance and machine downtime when we initially set up the facility. By our final ramp up at the end of year 7 we aim to achieve a throughput of 3,360 units / 8hr shift. Having calculated this ‘desired’ throughput directly from demand, this rate of production should more than sufficiently empower WiScooter to meet projected demand while also maintaining safety-stock. Additionally, we will conduct time studies and utilize the MES system data upon setting up the facility initially to discover other areas of improvement and also provide exact metrics on the line’s performance. Some such metrics could include: defect rate, SPC charts and cycle time.

One potential shortcoming of our design is the lack of acknowledgement that the initial setup and calibration of RFID systems could lead to temporary disruptions and extra training for workers who need to adapt to the new system. This might lead to initial struggles but if we have a strong worker education program and training modules then we can minimize the impact.

The ‘double-horseshoe layout’ provides a more organized flow of material and better space utilization in comparison to the current design of the Wisconsin facility. This can also be seen in the ability for the layout to reach higher throughput in the initial setup without the addition of much new equipment. The integration of RFID tracking and MES also help set a standard for production tracking and management and complement the flexible manufacturing ideology allowing for the lines to produce multiple SKUs instead of one at a time as it is currently done in Wisconsin. When looking at our CTQs the primary aims of our design were to empower the client to meet increasing demand, roll out new product offerings and produce the scooter in a cost effective manner, all of which are achieved by our design.

8.. Opportunities for improvement

Describe areas of improvement before and after the launch date. What aspects of the project need to be improved and what are the immediate and long-term plans. Include a Failure Mode and Effects Analysis (FMEA). Provide recommendations for improving (a)design of the system developed for this project, and (b) design of the whole system, including recommendations for changes in process and design of the other components of the whole system

8.1 FMEA Analysis

Table 8: FMEA Analysis

Item Process/Step	Potential Failure Mode	Potential Effects of Failure	Severity	Potential Causes of Failure	Occurrence	Current Controls	Detection	RPN	Recommended Actions
Customer Ordering	Order cancellation after order has been processed	Excess inventory, wasted resources, lower customer satisfaction	6	Unclear purchasing process, change in customer demand, delay in processing	5	Order confirmation system, customer service follow-up	4	120	Develop a more intuitive ordering system, implement real-time order tracking, enhance customer communication protocols.
Receiving	Receiving wrong materials	Production delays, increased handling costs, project timeline disruption	7	Vendor mislabeling, purchase order errors	3	Incoming inspection protocols	5	105	Increase frequency of vendor audits, improve purchase order verification steps
Tubular Steel Cutting	Inaccurate cuts due to equipment misalignment	Wasted material, potential for non-conformant final products	5	Equipment wear, incorrect setup	3	Regular maintenance, calibration checks, operator training	6	126	Automate cutting process, introduce laser-guided cutting systems for precision
Color Paint	Paint adhesion failure leading to peeling	Customer complaints, lower throughput	5	Inadequate surface preparation, incorrect paint mixture	3	Adherence to painting procedures, regular paint batch testing	4	84	Implement surface energy measurement, upgrade to higher-quality paint supplies
Touch-up & Quality Check	Overlooked defects due to inspection oversight	Higher defect rate, compromised product integrity	10	Inspection fatigue, lack of detailed guidelines	4	Detailed quality checklists, random quality audits	5	160	Introduce automated optical inspection, provide additional training for inspectors
PCB Functional Testing	PCBs passing with undetected failures	Subsequent product failures, customer safety incidents	9	Faulty test fixtures, incorrect test sequence implementation	5	Rigorous test procedure, routine test equipment checks	4	180	Employ automated test equipment with self-diagnostic capabilities, enhance test coverage
Scooter, Stem, and Handlebars Assembly	Improper torque application on assembly screws	Scooters may disassemble during use, leading to accidents	5	Bad training	4	Torque specification adherence, random post-assembly testing	3	120	Deploy smart tools with programmed torque settings, introduce a worker certification program
Scooter Metal Base Assembly	Weld failure resulting in structural compromise	Increased risk of injury due to base collapse	5	Inconsistent welding techniques, material impurities	4	Weld strength tests, in-process inspections	4	144	Implement real-time weld monitoring systems, standardize materials from certified suppliers
Weld Stem and Metal Base	Weak weld joints	Compromised product durability, potential safety hazards	5	Improper welding parameters, operator error	4	Weld inspection procedures, operator training	4	144	Introduce automated welding with quality feedback loops, periodic welder recertification
Machine Changeover	Extended downtime	Production delays, missed deadlines	10	Machines that are not maintained well	2	Changeover checklists, training sessions	6	60	Standardize changeover procedures, implement SMED (Single-Minute Exchange of Dies)
Electronics Assembly	Incorrect component placement	Nonfunctional electronics, potential recall	7	Component mislabeling, machine misalignment	3	Component verification system, assembly automation	5	120	Improve component traceability, enhance machine vision systems for placement verification
Final Assembly	Missing parts	Incomplete product, customer dissatisfaction	6	Inventory shortages	4	Final inspection checklist, assembly line monitors	3	84	Integrate parts verification system in the assembly line, apply IoT tracking for inventory
Packaging	Inadequate packaging	Damaged product during shipping, returns	6	Poor material quality, improper packaging technique	2	Packaging standards, random sample checks	7	84	Upgrade to robust packaging materials, provide specialized packaging training
Finished Product Shipped	Delay in shipment delivery	Customer dissatisfaction, order cancellation	6	Logistic inefficiencies, carrier delays	3	Logistics planning, carrier performance monitoring	5	90	Implement advanced logistics software, diversify carrier options, establish contingency plans
Inventory on the Floor	Excess inventory accumulation	Increased storage costs, reduced cash flow	4	Overproduction, forecasting errors	3	Inventory management system, regular audits	6	72	Refine demand forecasting, enhance just-in-time (JIT) inventory practices, regularly review inventory levels
Workplace Environment	Poor ergonomic design leading to worker injury	Decreased productivity, worker's compensation claims	7	Inadequate workplace design, insufficient ergonomic tools	3	Ergonomic assessments, staff training	4	84	Conduct regular ergonomic workshops, invest in ergonomic equipment, perform routine workplace safety audits

As part of our design process for the new WiScooter facility in El Paso, we conducted a Failure Mode and Effects Analysis (FMEA) on the current assembly process to identify potential risks and ensure robust design solutions. This analysis was crucial in helping us understand the key areas that could impact the quality and efficiency of scooter production. By evaluating the existing processes, we were able to suggest targeted improvements for the new facility design.

The FMEA revealed three main areas with the highest Risk Priority Numbers (RPN) as seen in *Table 8*, which guided our design considerations. The PCB Functional Testing process had the highest RPN of 180, due to issues like faulty test fixtures and incorrect test sequence implementation. To address this, we have suggested incorporating automated test equipment with self-diagnostic capabilities in our design. The second highest was in Quality Control, with an RPN of 160, where inspection fatigue and the lack of detailed guidelines were prevalent; our suggestion includes introducing automated optical inspection systems and enhanced training for inspectors. Finally, the Metal Base Assembly process, with an RPN of 144, highlighted problems with inconsistent welding techniques and material impurities. For this, we suggested standardizing materials from certified suppliers and implementing regular maintenance schedules. These suggested improvements are integral to our final design, ensuring that the new production layout minimizes risks and optimizes operational efficiency.

8.2 Suggested revisions and improvements

Before the launch of the new WiScooter facility in El Paso, it's crucial to address key areas that could significantly impact the success of the transition. Optimizing the supplier network is a priority. The differences in lead times for deliveries to Madison compared to Texas highlight an opportunity to decrease production delays by identifying local suppliers. Immediate actions include conducting a market search and initiating discussions to secure materials with reduced lead times. Additionally, developing a comprehensive logistics plan for the installation of new machines and equipment will ensure that the setup process is smooth and does not disrupt production. This plan should detail the timelines for equipment arrival, installation, and calibration, ideally outside of peak production periods to minimize impact.

After the launch, the focus will shift to continuous monitoring and feedback to quickly identify and rectify operational issues. Establishing a system for real-time feedback and regular production line audits will help in recognizing practical challenges at an early stage. Building strong relationships with local suppliers will also be vital for maintaining a stable supply chain and ensuring the availability of high-quality materials.

Following our FMEA analysis, we've outlined improvements for critical areas like PCB Functional Testing, Quality Control, and Metal Base Assembly. These improvements are now key parts of our broader strategy for the new facility. By focusing on these areas, we are making sure that the issues we found are addressed in the final design. This strategy is not just about fixing problems but also about making the whole manufacturing process stronger and more efficient at the El Paso facility.

To enhance the system's design, incorporating modular design elements would make it easier to reconfigure production lines quickly in response to changing market demands or product designs. Additionally, leveraging advanced automation technologies can reduce labor costs and increase production efficiency, which could include robotic assembly systems or AI-driven quality control systems.

Improvements to the whole system should focus on integrating more stages of production to reduce cycle times and minimize the risk of delays or defects. Enhancing the work environment by focusing on ergonomics and safety will lead to better productivity and lower worker injury rates. Implementing ergonomic workstations and advanced safety monitoring systems will contribute significantly to these goals.

By addressing these areas comprehensively before and after the launch, and continuously integrating insights from ongoing operations and the FMEA, WiScooter can ensure a successful transition to the new facility while maintaining high efficiency and quality standards in its manufacturing process.

9. Summary and Recommendations

In summary, we recommend the option to move to El Paso, TX in order to meet the client's goals of meeting increased demand and rolling out three new personal eScooter SKUs. We believe over the course of ten years we can comfortably meet increasing demand and roll out the three new SKUs. We have a high degree of confidence that our plan can succeed and with low risk. We recommend that WiScooter plan the construction schedule, installation of the machines, raise/allocate sufficient capital, and start to reach out to new suppliers before committing to our plan. If our design ends up becoming infeasible given the current financial status of WiScooter, the Bad News Badgers team is open to revising our solution.

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