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Case Study Report

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Executive Summary

Designing a facility for the production of Brio World Speedy Bullet Train was the major objective of the case study, along with establishing a plant layout and any material and machine handling. Increasing productivity is the most crucial technique to improve a facility's output and efficiency. The Bill of Materials, work methods, station procedures, process diagrams, time study standards, takt time, and workstation design all play a role in the product's design. The quantity of workers, the equipment, the line balance, the layout of the assembly area, the floor plans and layout drawings, the storage and warehousing operations, and the final design of the factory are all factors in the building of the facility. The facility's initial factory will operate for eight hours each day, five days per week, and fifty weeks each year, producing "50 carton packed" units every hour. The team's facility planning included three main components: fabrication, assembly, and materials, equipment, and storage. In order to ensure that the facility could retain both high worker satisfaction and optimal production, the principles of Lean and 5S were integrated in the Shipping and Receiving and Implementation Plan sections. The implementation plan includes a training phase so that employees will feel at ease at work in addition to outlining the necessary actions to ensure that the facility is created. Continuous improvements were taken into account while keeping the facility's longevity in mind, paying particular emphasis to the advantages of replacing wood materials and using cellular production. It is hoped that this case study will have an impact on the design of other stringed instrument facilities and the most effective management techniques for them.

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Introduction

A toy train may seem like an ordinary kids toy product, however it is rather a much complicated structure which requires a number of operations to manufacture, assemble and ship. The current model of the toy train is composed of different material parts like plastic, wood and metal, each with its own different shaped alignments, adding more complexity in the operation.

Figure 1: BRIO Speedy Bullet Train

BRIO is a global company that was founded in 1884 in Osby, Sweden as a small family-run business. It has grown to have subsidiaries in Germany, France, Japan and distributors worldwide. BRIO has been a supplier to the Royal Court of Sweden since the 1940s and is now owned by Ravensburger, a leading manufacturer of puzzles, games, and children's books in Europe. This project is a case study on the Brio World Speedy Bullet Train. The plant operates 8 hours a day, 5 days a week, and 50 weeks per year. The study requires data for facilities planning, including inventory policy, production volume, shipping & receiving, and manufacturing processes for the components of the bullet train. The project will involve designing the plant layout and material handling for Brio Ltd (US). The plant layout and material handling will be designed considering factors such as the processes of manufacturing plastic parts using an injection molding machine, carving wooden parts, contorting metal loop and hook pieces and the assembly and packaging of the final product. The report will focus on the fabrication of the bullet train and the assembly process. The project requires the preparation of process sheets, floor plans, and layout diagrams for each station or process involved in the manufacturing of the bullet train.

Fabrication

Bill of Materials

The bill of materials is a list of all the required parts to create a product. This will help in tracking what needs to be purchased and what requires manufacturing. In order to organize the BOM the group followed a 4-digit code that. 1000 if the product is manufactured, 2000 if the product is purchased and 3000 if they are indirect materials. (View appendix for full bill of materials).

Product Structure Tree

The diagram presented below shows a visual breakdown of all the assembly parts from the Toy Train. The toy train is divided into three main components which are the main train, the coal compartment and the packaging.

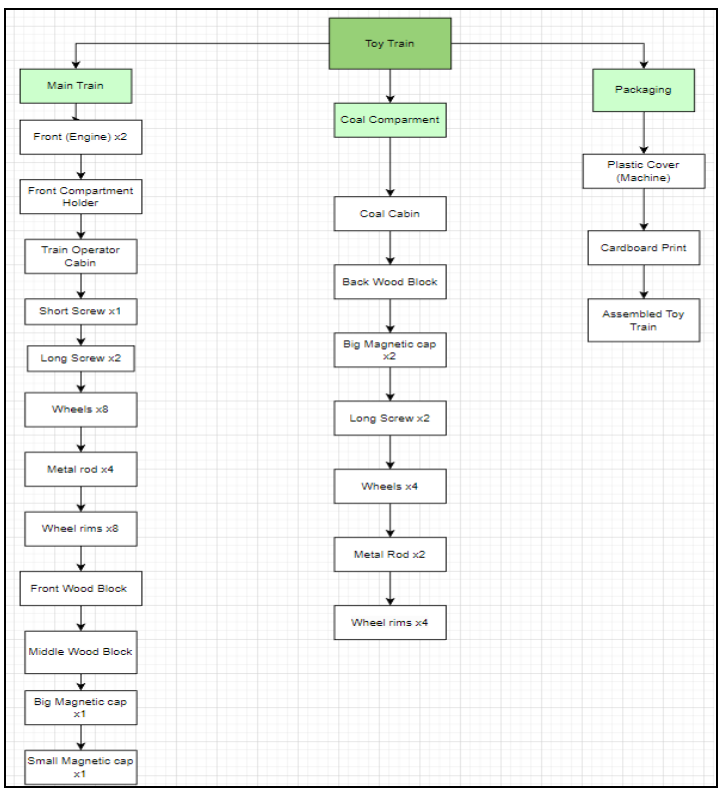

Figure 2: Product Structure Tree

Material Specifications

The production process of this Toy Train product requires raw materials such as custom wood blocks, plastic pieces and small metallic parts. Majority of the product is made of wood, the other portion of the train is made up of custom plastic parts and an arrangement of small metallic parts.

1. Wood

Table 1: Train Parts made of wood

Part Number	Part Name	Dimensions
1002	*Train Operator Cabin*	*3.6 cm x 3 cm*
1009	*Front Wood Block*	*4 cm x 1.5 cm*
1010	*Middle Wood Block*	*4 cm x 1.5 cm*
1011	*Coal Cabin*	*4.2 cm x 3 cm*
1012	*Back Wood Block*	*4 cm x 1.5 cm*

The wooden components listed above are made in house by employees, each wood block will be cut, shaped and painted to specifications. After each part is made, it must be sorted into their associated part bins.

2. Plastic

Table 2: Train Parts made of plastic

Part Number	Part Name	Dimensions
1000	*Front (Engine)*	*10 cm x 1 cm*
1001	*Front Compartment Holder*	*12.5 cm x 3 cm*
1003	*Wheels*	*D = 2 cm, T = 0.5 cm*

The plastic components listed above are developed using the mold injector which will shape the plastic sheet into the required shape.

3. Metal

Table 3: Train Parts made of metal

Part Number	Part Name	Dimensions
2000	*Long Screw*	*2.5 cm x 0.25 cm*
2001	*Short Screw*	*2 cm x 0.25 cm*
1004	*Wheel Rims*	*D = 1 cm*
1005	*Metal Rod*	*L = 2.5 cm*
1006	*Small Magnetic cap*	*D = 0.25*
1007	*Big Magnetic cap*	*2 cm x 0.25 cm*
1008	*Hook*	*2 cm x 0.25 cm*

The metal components listed above are made in house by employees, metal rods will be cut to size specifications, hooks and caps will be produced by a metal pressing machine for decreased variability in quality.

Forecast

Demand & Sales Projections

The following elements should be taken into account when calculating sales forecasts for the BRIO World Fast Bullet Train:

1. *Market Size and Potential:* Perform market research to identify the target market, the size of the prospective market for the product, and any trends that may have an impact on sales.
2. *Competition:* Examine the opposition and note how the BRIO World Fast Bullet Train varies from its rivals, taking into account any distinctive selling qualities that can boost sales.
3. *Production Capacity:* Establish the BRIO World Fast Bullet Train's production capacity, the type of process automations, if raw materials and components are readily available, and make sure it can fulfill demand taking into account the budgetary constraints in terms of purchasing machines.
4. *Marketing and Sales Strategy:* Create a marketing and sales strategy that includes distribution methods, advertising, and promotions to assist boost sales.
5. *Price Strategy:* Choose a pricing strategy that will optimize sales and profitability for the product.

Due to the COVID-19 pandemic and other limitations a quantitative and/or qualitative analysis could not be performed to determine the sales or demand projections. Nonetheless, a very small-scale qualitative analysis was carried out using articles and resources found online. Toy train sales growth can vary depending on a number of variables, including market need, consumer preferences, and competition.

The global toy train market was estimated to be worth USD 1.43 billion in 2019 and is projected to increase at a CAGR of 4.0% from 2020 to 2027, according to a report by Grand View Research, Inc. (Grand View Research, Inc., 2020). According to a different study by Persistence Market Research, throughout the projected period of 2021–2031, sales of electric toy trains are anticipated to grow at a CAGR of more than 11%. (Persistence Market Research, 2021). The market for wooden toys, which includes wooden toy trains, is anticipated to reach

$15.63 billion by 2026, rising at a CAGR of 3.0% from 2019 to 2026, according to a report by Allied Market Research (Allied Market Research, 2019). So therefore we can calculate for the purpose of this report that the average annual growth is:

- For the market for toy trains worldwide: 4.0%
- More than 11% of toy train sales were electric.
- 3.0% for the market for wooden toys worldwide

Hence, the three growth rates have an average of about 6.67%. It's crucial to keep in mind that these estimated compound annual growth rates (CAGRs) may not accurately represent the growth rates that actually occur.

Units Produced Annually: 50*7.25*5*50=90,625 units annually

Sales equal 90,625 times (1 plus Growth Rate) where n denotes how many years have passed since 2023. With the help of this formula, we can determine the sales for each year between 2023 and 2027 as follows:

- 2023: 90,625 sales (given)
- 2024: 90,625 x (1 + 0.0667)^1 = 96,670 sales
- 2025: 90,625 x (1 + 0.0667)^2 = 103,118 sales
- 2026: 90,625 x (1 + 0.0667)^3 = 109,996 sales
- 2027: 90,625 x (1 + 0.0667)^4 = 117,332 sales

Thus, based on the assumed growth rate of 6.67%, the expected sales for each year from 2023 through 2027 are:

Table 4: Production/Demand Forecast

Year (s)	2023	2024	2025	2026	2027
Trains Produced	90,625	96,670	103,118	109,996	117,332

What Parts Should be Produced vs. Bought

The Brio World Speedy Bullet Train is a popular toy that requires various parts to be produced in order to function properly. While some of these components can be manufactured in-house, it can be more cost-effective to purchase them from suppliers. The choice of whether to manufacture or purchase a component necessitates a thorough examination of a number of variables, including the part's strategic value and the production costs, capacity, manufacturing challenges, and bottlenecks. The different parts of the Brio World Speedy Bullet Train, such as the screws, hooks, magnetic caps, wheels, and wooden train blocks, will be examined in this report to determine whether they should be manufactured in-house or purchased from vendors. By taking into account these variables, we may decide more intelligently which components ought to be produced internally and which ought to be bought from other sources.

Screws:

- Cost of production in house vs cost of buying
  - We can compare the price of producing screws internally vs the price of purchasing them from a source to determine which option is less expensive. Porter and Van der Linde's (1995) study found that, especially for small and medium-sized businesses, purchasing from a supplier is frequently more affordable than producing on-site. While purchasing in bulk from a supplier frequently results in reduced costs due to economies of scale, the cost of equipment, labor, and raw materials needed for in-house manufacturing can be expensive. Hence, purchasing the screws from a provider would probably be preferable.
- Capacity
  - The quantity of screws needed to produce the Brio World Speedy Bullet Train will determine how much space is needed for inventory. Space must be set aside for equipment, raw materials, completed goods, and storage if the product is manufactured internally. Nevertheless, if you purchase from a supplier, all that is needed is storage space. Hence, purchasing screws would take up less space than manufacturing them internally (Kessler & Christensen, 2019).

- Difficulty
    - Depending on the size and kind of screw needed, manufacturing screws can be a complicated and time-consuming procedure. Kim and colleagues' (2018) research suggests that producing screws internally can be challenging and may call for specific tools and knowledge. Achieving consistent quality and accuracy with in-house production may also be difficult. Hence, purchasing the screws from a provider would probably be preferable.
- Bottleneck
    - Equipment failures, material shortages, and other challenges can cause bottlenecks in internal production, which can impede progress, drive up prices, and create problems with quality control (Shah et al., 2018). Hence, purchasing screws from a supplier can lower the probability of bottlenecks.
- Strategic Importance
    - The strategic significance of making screws internally vs purchasing them will depend on the company's overarching strategic objectives. In-house production may be more strategically advantageous, according to a study by Langley and Holcomb (1992), if the business wants to have more control over the supply chain, shorten lead times, and have more design freedom. Yet, if the business wishes to concentrate on its core strengths, cut expenses, and boost productivity, purchasing from a supplier can be more smart.

As a result of cheaper costs, less space requirement, lower difficulty, and fewer bottlenecks, it would probably be preferable to purchase screws from a supplier as opposed to producing them internally, according to the study and information provided. The choice, however, ultimately depends on the strategic aims and goals of the business.

Wheels:

- Cost of production in house vs cost of buying
    - Compared to purchasing wheels from a provider, manufacturing wheels in-house has many advantages. Buying from a supplier could appear more convenient, but it can be more expensive because of things like delivery costs and the provider's

price. On the other hand, when you manufacture the wheels locally, you have complete control over the product's quality and can guarantee that it adheres to your exact specifications. In the long term, you can also save money by avoiding supplier markups and delivery fees. Additionally, internal production enables more adaptability and flexibility in addressing shifts in demand and design specifications. Therefore, manufacturing wheels internally is preferable to purchasing them from a provider.

- Capacity
  - Although buying from a supplier might seem like a simpler choice, it might be expensive due to delivery costs and the provider's fee. The need for equipment, raw materials, and finished goods to be stored in inventory can be countered by the flexibility to customize the manufacturing process, which also increases production speed and efficiency. For the Brio World Speedy Bullet Train, making the wheels in-house is preferable to buying them from a supplier.
- Difficulty
  - By manufacturing wheels in-house, businesses may keep better control over the quality of the final product, react quicker to changes in demand, and perhaps even lower costs over time. The advantages of in-house production might make it a viable endeavor for organizations trying to increase their efficiency and competitiveness, even though it could entail some investment in resources, training, and equipment.
- Bottleneck
  - Although producing wheels internally can be difficult, there are a number of benefits over getting them from a provider. While bottlenecks in the production process can be brought on by issues like equipment breakdowns and material shortages, they can also happen when buying from a supplier. However, by creating your own wheels, you have more control over the production process and are better able to respond to any potential problems. In the long run, this may lead to higher-quality products and lower costs.
- Strategic Importance

    - Strategically, manufacturing wheels in-house provides an advantage over getting them from a source. It enables improved supply chain management, quicker lead times, and more design flexibility. Internal production increases knowledge, creativity, competitiveness, and lowers overall costs. Outsourcing non-core tasks has the risk of reducing flexibility, increasing lead times, and losing control over quality and design. Therefore, firms looking to control their supply chain, innovate, and cut costs may choose to consider in-house production as a strategic alternative.

According to the research and data presented, it may appear like buying wheels from a supplier is the superior choice because it is less expensive, requires less space, is easier, and has fewer bottlenecks. However, the study by Langley and Holcomb (1992) suggests that in-house production may be more advantageous strategically if a company wishes to have more control over the supply chain, reduce lead times, and have more creative freedom. Thus, the organization's strategic goals and priorities ultimately determine whether to create wheels internally or to buy them.

Magnetic Caps:

- Cost of production in house vs cost of buying
    - Depending on the company's knowledge and resources, making magnetic caps in-house is more cost-effective than purchasing them. According to a study by Kim et al. (2013), outsourcing might be more cost-effective if the business lacks the required knowledge or tools. But, if the business has the necessary knowledge and tools, making the magnetic caps in-house might be more economical. Hence, a cost study relevant to the organization will determine whether to produce in-house or purchase.
- Capacity
    - Internal manufacture of magnetic caps might necessitate more room for equipment and inventory storage, which could have an effect on other production steps. Porter and Van der Linde's (1995) analysis suggests that outsourcing the manufacturing of magnetic caps would not necessitate the addition of equipment

or inventory storage space. Despite this, in-house production may be the superior choice for a company looking for increased supply chain control, innovation, and cost savings because it fosters experience and creativity, which lowers long-term expenses. Therefore, companies should balance the advantages of in-house production against the expenses and physical constraints.

- Difficulty
    - In-house production of magnetic caps has a number of benefits over outsourcing or getting products from a source. It enables businesses to have more control over the production process, improving quality and allowing for greater flexibility. Eliminating supplier markups, transportation costs, and lead times can also result in cost savings. Additionally, producing locally can lower the risk of supply chain interruptions and open up opportunities for innovation and new product development. On the other hand, in some circumstances, acquisition or outsourcing may be suitable. However, before making a choice, businesses should thoroughly consider the advantages and disadvantages of each strategy. In the end, manufacturing in-house gives firms more control, cost savings, and chances for innovation, making it a good alternative for enterprises with the required resources and skills.
- Bottleneck
    - Outsourcing could result in longer lead times, quality control issues, and potential communication bottlenecks that can cause production delays and affect other stages of the process. On the other hand, producing in-house allows the company to have full control over the production process, enabling them to ensure quality, consistency, and timely delivery of the magnetic caps.
- Strategic Importance
    - The function of the magnetic caps in the Brio World Speedy Bullet Train determines its strategic significance. Producing them internally could provide the business more control over the part's quality and availability if it's a crucial component. Outsourcing, however, can be a better choice if the component is not essential to the toy.

Even if the company lacks the skills or resources to efficiently manufacture the product, producing magnetic caps in-house is preferable to outsourcing to a supplier. This is due to the possibility that outsourcing could lead to increased lead times, poor quality control, and communication problems that could delay production and have an impact on other process stages. Additionally, by producing internally, the business is able to maintain total control over the manufacturing process, enabling them to guarantee the quality, consistency, and prompt delivery of the magnetic caps. This offers the organization chances to enhance its manufacturing procedures, acquire new knowledge, and promote innovation.

Hooks:

- Cost of production in house vs cost of buying
  - Producing hooks internally vs purchasing them from a supplier is more cost-effective depending on a number of variables, including the company's experience and equipment. It is important to evaluate the price of producing hooks internally versus buying them from vendors when determining the costs of labor, raw materials, and equipment upkeep. Doing an internal production of hooks or purchasing them from a provider can be more cost-effective, according to a cost-benefit analysis.
- Capacity
  - The in-house production of magnetic caps may increase the space required for equipment and inventory storage, which may decrease the amount of space available for subsequent manufacturing stages. The business should consider its manufacturing capacity and space restrictions before making a decision.
- Difficulty
  - The complexity of the manufacturing process and the company's experience will decide how difficult it is to create magnetic caps. The company should evaluate its capacity to manufacture the caps internally, taking into account the equipment, supplies, and labor. If you outsource the production of magnetic caps to a supplier, there may be longer lead times, quality control problems, and communication problems that delay the process and have an impact on other phases. Therefore, rather than depending on outsourcing to a supplier, it is advised

that the organization invest in gaining the necessary knowledge and tools to create magnetic caps itself.

- Bottleneck
    - Production snags could result from outsourcing hook production to a supplier. Projects may be delayed and their completion deadlines may change as a result of outsourcing, which can demand extra labor and managerial resources. Outsourcing might also lead to longer lead times, poor quality control, and communication problems that could delay production and disrupt other phases of the process. Therefore, rather than depending on outsourcing to a provider, it is advised that the business invest in gaining the necessary knowledge and tools to make hooks itself.
- Strategic Importance
    - If manufacturing hooks in-house is advantageous for the business will depend on how strategically important they are to the Brio World Speedy Bullet Train. To maintain quality control and guarantee consistency, it could be required to make hooks internally if they are essential to the toy's operation or design.

Making the Brio World Speedy Bullet Train on-site could be preferable to buying hooks from a vendor. Even though purchasing from a supplier could appear convenient, over time, it might lead to a lowered level of quality control and higher prices. Businesses may guarantee that the items fulfill their standards and prevent potential supply chain delays by manufacturing the hooks in-house. Additionally, manufacturing within a company gives organizations more flexibility and control over the production process, allowing them to react swiftly to changes in demand or product requirements. Producing internally can result in significant cost savings and increased efficiency over time, even though it may initially involve more labor and resources.

Train Blocks (Wooden & Plastic):

- Cost of production in house vs cost of buying
    - It might be more practical to manufacture your own railroad bricks than buying them from a source. In-house production has costs, such as labor, materials, and overhead, but also gives them more control over the manufacturing process and

guarantees that the products satisfy their requirements. As prices are determined by the seller's price, transportation costs, and the amount required, buying from a supplier might lead to reduced quality control and higher costs. Furthermore, depending on the source, the cost of wooden railway bricks might vary significantly, making it challenging to calculate expenses precisely. Businesses can prevent potential supply chain interruptions and ensure that external influences do not have an impact on their manufacturing processes by producing internally. Even if buying from a supplier could seem more cost-effective at first, doing so can have long-term financial consequences. Therefore, while choosing between internal and external sourcing, it is crucial for firms to thoroughly weigh their options and take into account the advantages of in-house production. Overall, domestic production can have a number of benefits and is a realistic choice.

- Capacity
  - Production of railway blocks internally may provide advantages in terms of capacity. In-house production gives companies more control over the manufacturing process and allows them to tailor production capacity to their demands. Reduced capacity may be the outcome of external sourcing depending on things like delivery time and quantity ordered. Additionally, firms can reduce the risk of manufacturing delays and supply chain interruptions that could have a detrimental impact on capacity by doing their own production. Despite potential worries over inventory space, effective planning and storage can maximize space utilization. When choosing between internal and external sourcing, businesses should carefully weigh the benefits of internal production, especially in terms of capacity.
- Difficulty
  - Producing railway blocks in-house can be difficult because it calls for a particular level of expertise, experience, and specialized tools. The blocks must be precisely and consistently cut, shaped, sanded, and finished in order to obtain the appropriate quality and functionality. Businesses without prior experience in this field or without access to the required tools and equipment may find this

particularly challenging. Nevertheless, despite these difficulties, in-house manufacturing has a number of advantages versus buying from outside sources. For instance, firms can verify that the blocks satisfy their unique specifications and standards since they have more control over the manufacturing process. The difficulty of manufacturing may appear to be a substantial barrier, but it can be overcome with the right instruction, direction, and investment in the required tools and equipment. Therefore, while choosing between internal and external sourcing, firms should carefully consider the benefits of in-house production, especially in terms of quality control and cost-effectiveness. Despite the difficulties, businesses can ultimately reap major benefits from in-house production by streamlining their manufacturing procedures and ensuring the highest standards of product quality and functioning.

- Bottleneck
    - When railway blocks are made in-house, production can become sluggish if the company is not set up to handle the additional manufacturing processes. Projects may be delayed and their completion dates may change as a result of the additional labor and managerial resources needed for in-house production. However, it enables more quality control and production process management. On the other hand, buying from a supplier could mean lower quality control and higher costs. As a result, companies should assess their capacity for in-house production and take into account any potential bottlenecks as well as the advantages of more control and quality assurance.
- Strategic Importance
    - Depending on the company's strategic goals and priorities, it may be preferable to create railway blocks in-house rather than purchasing them from a vendor. Producing the blocks internally can be the best choice if the business values having control over the production process and wishes to guarantee the blocks' quality. Yet, purchasing from a supplier might be a preferable choice if the business wishes to concentrate on cost effectiveness and on-time delivery.

Despite worries about potential bottlenecks, producing train blocks internally is a more advantageous alternative for the construction of the Brio World Speedy Bullet Train. While it's true that specialized tools and equipment are needed to produce train blocks, the savings from producing them internally can offset the cost of doing so. Furthermore, manufacturing in-house gives companies more control over the production process and ensures that the products satisfy their standards. On the other hand, because prices are determined by the seller's price, delivery costs, and the amount required, buying from a supplier may lead to reduced quality control and higher costs. Businesses can reduce these risks and ensure that external influences do not have an impact on their manufacturing processes by producing internally. Therefore, while choosing between internal and external sourcing, it is crucial for firms to thoroughly weigh their options and take into account the advantages of in-house production. In the end, manufacturing in-house has many benefits and should be taken into consideration as a feasible option, especially if it is in line with the organization's strategic goals.

Manufacturing Process

Types of Machines

1. Wood Parts

A tool used to make exact copies of an existing wood object is a 3D wood carving duplicator machine. The input for this machine is painted wood blocks. It functions by transferring the old artwork's contours on a fresh piece of wood by tracing them. A router is used by the machine to carve out the contour of the original item, and a sanding drum is used to remove any sharp edges. When a new piece of wood is being created, the machine captures the movements of the previous piece as the operator moves it along its surface. With the same curves, angles, and features as the original, the new piece is guaranteed to be an identical replica using this procedure. Then, the sanding drum removes any roughness or irregularities, leaving a faultless duplicate.

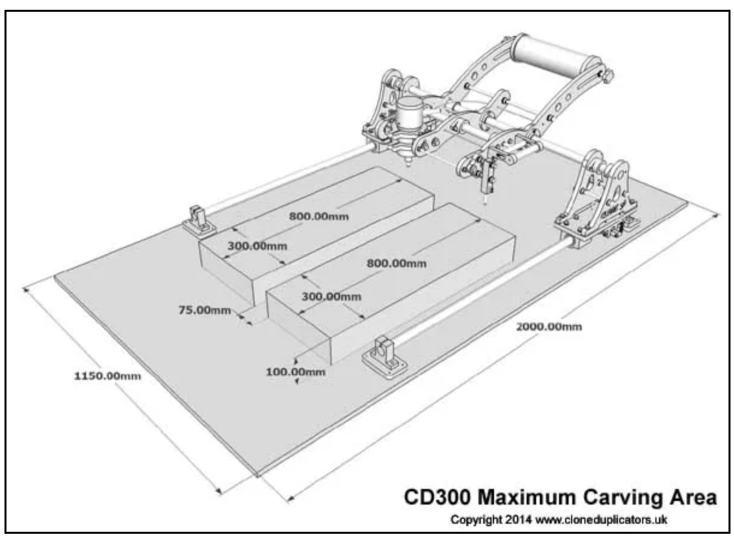

Figure 3: 3D Carving Machine with Parts

2. Plastic Parts

A manufacturing tool called an injection molding machine is used to make plastic objects by injecting molten plastic into a mold cavity. The input for this would be plastic pellet pieces. The apparatus consists of a hopper for melting and mixing the plastic material, a screw or plunger for injecting the melted plastic into the mold, and a cooling system for setting the plastic in the mold. The actual mold, which is frequently made of metal, is manufactured to produce a completed object that has a particular shape and dimension. It is common practice in sectors including automotive, packaging, and consumer goods to employ the injection molding technique to create a wide variety of plastic parts, from small and basic to massive and sophisticated. Because of its precision and reproducibility, the machine is a popular option for high-volume production runs and can be operated manually or automatically.

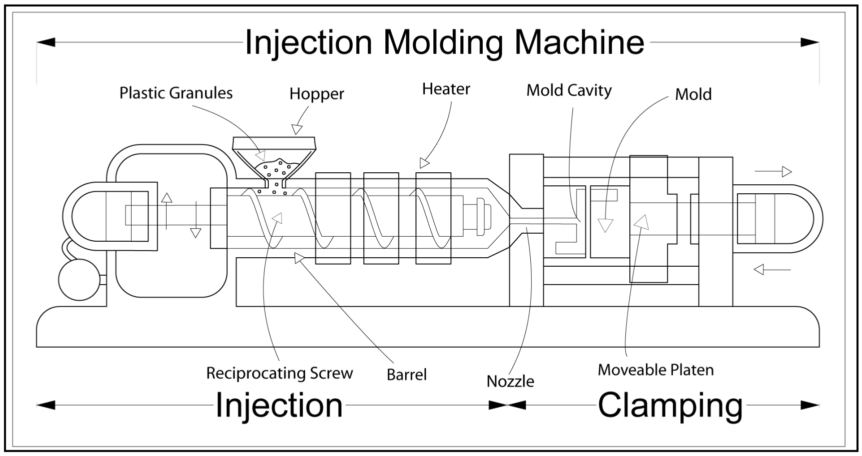

Figure 4: Injection Molding Machine with Parts

3. Hook Parts

A hook maker machine is a tool used to create hooks from wire in a variety of sizes and shapes. Wire is fed into the machine through a spool or coil as the machine's input. The wire is then straightened, cut to the required length, and bent using a variety of tools and dies into the shape of the hook. Additionally, the machine is capable of threading, cutting, and polishing the hook to the required standards.

Figure 5: Hook Maker Machine with Parts

4. Cap Parts

The production of metal caps is done with the machine below. It produces metal caps by processing metal sheets or coils via a number of manufacturing steps. Metal coils or sheets are first fed into the machine and run through a succession of rollers and cutting tools to start the operation. A press or a set of dies are then used to stamp or draw the metal into the shape of the cap. The cap is then cut to the proper length and width.

Figure 6: Cap Maker Machine with Parts

Flow Process Chart

The ordered steps of the production process, such as transportation, delay, inspection, and storage, are shown in the process flow chart below. This diagram has shown to be a very useful tool for pinpointing crucial phases that raise the product's worth, increase customer pleasure, and guarantee high-quality output. The team can quickly discover inefficiencies, boost productivity, and streamline the manufacturing process using this chart, leading to a more dependable and economical production method. The chart also encourages team members to collaborate effectively and to share their views and suggestions for continuous improvement.

⚪ : An operational process
⇨ : A transportational process/material flow
▽ : A storage/ Inventory
D : A delay
☐ : An inspection

Note: The Flow Process chart can be found under the Appendix.

Production Rate and Available Time

The production plant is operating 8 hours a day, 5 days a week, and 50 weeks in a year. In addition, the plant produces 50 "carton boxed" units per hour. Using this information, the production rate and available time can be determined as following,

Production Demands

- Production rate = 50 units per hour X 8 hours per day X 5 days per week X 50 weeks per year
- Production rate = 100,000 units per year
- Available time = 8 hours per day X 5 days per week X 50 weeks per year
- Available time = 2000 hours per year

Actual Production Capacity

- Production rate = 80% efficiency * 5 stations * hourly production rate 212sec - (scrap) - (expected delays) - (storage) = 424.5 = 424 units daily
- Production rate = 106,000 units per year
- 6,000 units to be stored as a contingency plan in case of an unplanned production closure or delay
- The proposed factory is capable of meeting all demands considering the worker utilization, efficiency, scrap, defective material, storage.

Considering part, shipment, manufacturing, maintenance, and other related delays in production, and the amount of scrap parts produced, the required amount of production may vary to meet the demands mentioned above. Therefore, a more comprehensive analysis of the actual production schedule will be analyzed later in this report.

Operations Process Chart

We have designed an operations process diagram for the Brio World Speedy Bullet Train as part of our group project. From the loading of passengers and goods to the train's arrival at its destination, the chart outlines the train's operation step-by-step. We created this diagram to help explain the different steps involved in operating the train and to emphasize the crucial components that make it a dependable and effective means of transportation. Key performance indicators are also provided so that we may assess how well the train achieves the required results. In general, this chart is a useful resource for all parties involved in the Brio World Speedy Bullet Train's operations, including assemblers, operators, and management.

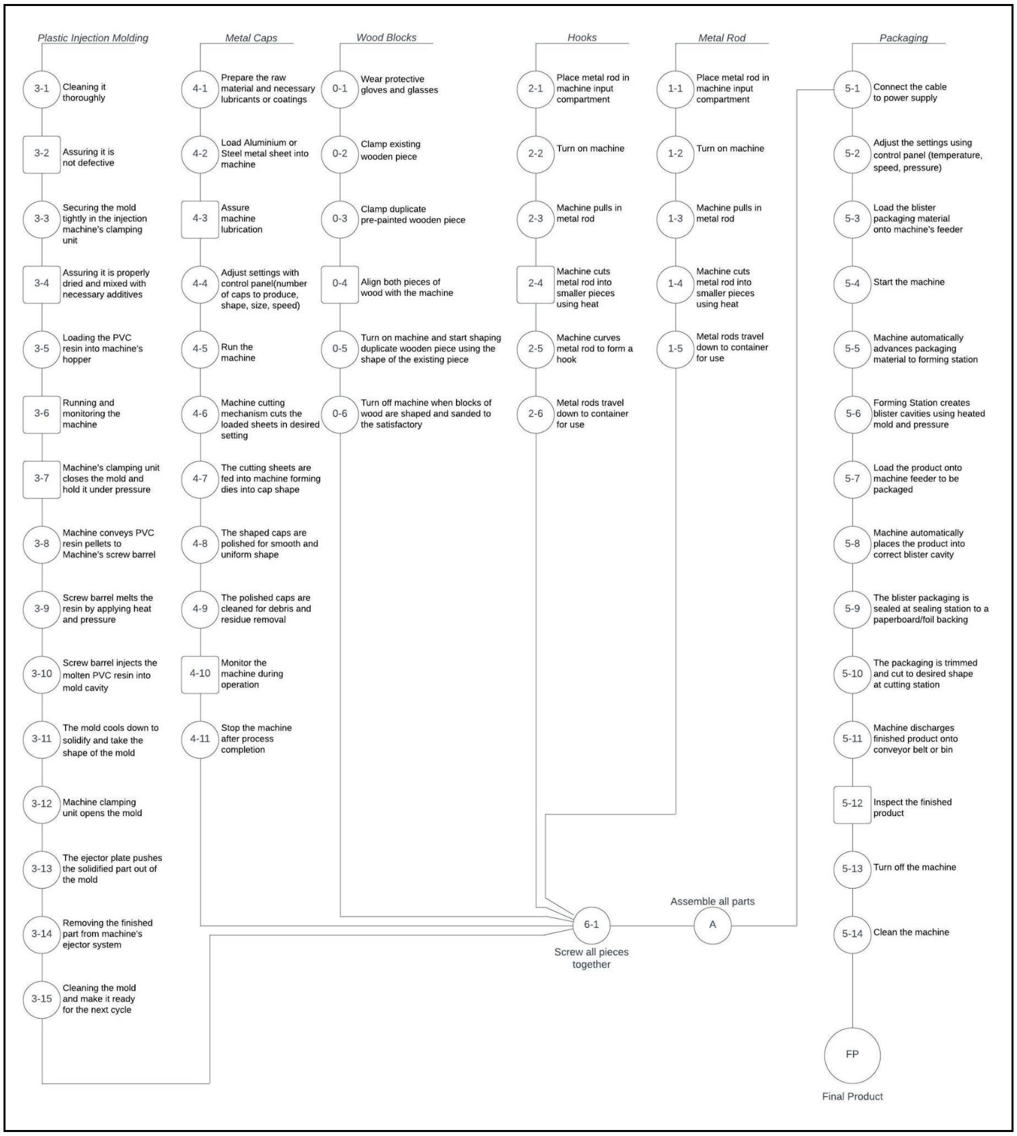

Figure 5: Operations Process Chart

1. 3D Wood Carving Machine Steps
    a. Start 3D wood carving machine process
    b. Wear protective gloves and glasses
    c. Clamp Existing wooden piece
    d. Clamp duplicate pre-painted wooden piece
    e. Align both pieces of wood with the machine
    f. Turn on machine and start shaping duplicate wooden piece using the shape of the existing piece

g. Turn off machine when blocks of wood are shaped and sanded to the satisfactory standard
h. End 3D wood carving machine process

2. Metal Rods/Hooks Machine
    a. Metal Rod Manufacturing
        i. Start metal rod manufacturing process
        ii. Place metal rod in machine input compartment
        iii. Turn on machine
        iv. Machine pulls in metal rod
        v. Machine cuts metal rod into smaller pieces using heat
        vi. Metal rods travel down to container for use
        vii. End metal rod manufacturing process
    b. Hooks Manufacturing
        i. Start hook manufacturing process
        ii. Place metal rod in machine input compartment
        iii. Turn on machine
        iv. Machine pulls in metal rod
        v. Machine cuts metal rod into smaller pieces using heat
        vi. Machine curves metal rod to form a hook
        vii. Hook travels down to container for use

3. Metal Cap Manufacturing Machine
    a. Prepare the raw material and necessary lubricants or coatings
    b. Load Aluminium or Steel metal sheet into machine
    c. Machine Preparation
        i. Assure machine lubrication
        ii. Adjust settings with control panel(number of caps to produce, shape, size, speed)
    d. Run the machine

e. Machine cutting mechanism cuts the loaded sheets in desired setting with variety of methods (ex: laser cutting, shearing, punching)
f. The cutting sheets are fed into machine forming dies into cap shape
g. The shaped caps are polished for smooth and uniform shape
h. The polished caps are cleaned for debris and residue removal
i. Monitor the machine during operation
j. Stop the machine after process completion

4. Plastic Mold Injector Machine
    a. Preparation of the mold
        i. Cleaning it thoroughly
        ii. Assuring it is not defective
        iii. Securing the mold tightly in the injection machine's clamping unit
    b. Preparation of the PVC resin
        i. Assuring it is properly dried and mixed with necessary additives
    c. Setting the machine parameters such as temperature, pressure and injection time using machine's PLC control and touchscreen interface
    d. Loading the PVC resin into machine's hopper
    e. Running and monitoring the machine
    f. Machine's clamping unit closes the mold and hold it under pressure
    g. Machine conveys PVC resin pellets to Machine's screw barrel
    h. Screw barrel melts the resin by applying heat and pressure
    i. Screw barrel injects the molten PVC resin into mold cavity
    j. The mold cools down to solidify and take the shape of the mold
    k. Machine clamping unit opens the mold
    l. The ejector plate pushes the solidified part out of the mold
    m. Stop the machine
    n. Removing the finished part from machine's ejector system
    o. Cleaning the mold and make it ready for the next cycle

5. Packaging Machine

a. Preparation of Machine
   i. Connect the cable to power supply
   ii. Adjust the settings using control panel (temperature, speed, pressure)
b. Load the blister packaging material onto machine’s feeder
c. Start the machine
d. Machine automatically advances packaging material to forming station
e. Forming Station creates blister cavities using heated mold and pressure
f. Load the product onto machine feeder to be packaged
g. Machine automatically places the product into correct blister cavity
h. The blister packaging is sealed at sealing station to a paperboard/foil backing
i. The packaging is trimmed and cut to desired shape at cutting station
j. Machine discharges finished product onto conveyor belt or bin
k. Inspect the finished product
l. Turn off the machine
m. Clean the machine

Assembly

Procedure

1. Attach metal rod into the wooden block
2. Attach wheels onto the sides of the metal rod
3. Attach hooks into the wooden block
4. Attach magnetic caps to the wooden blocks
5. Align top of wooden train block to bottom of wooden train block
6. Screw top and bottom parts together
7. Align holes of plastic parts together
8. Screw top plastic part with middle and bottle plastic part
9. Align assembled plastic portion with wooden blocks
10. Screw wooden blocks to the plastic portion

11. Hook train blocks together
12. Attach train blocks together with the magnetic caps
13. Place fully assembled train in the plastic casing
14. Place plastic casing in cardboard box

Table 5: Operations Processes Table

Operation no.	Operation information	Equipment used	STD. mins/operation (≅)(mins)	No. of Machines
Locomotive assembly				
1	Reach & grab all locomotive system parts from respective bins and place in assembly area	none	0.5	0
2	Assemble locomotive carriage and attach wheel system	screwdriver	2	0
Wheel assembly (front)				
3	Reach & grab all wheel system parts from respective bins and place in assembly area	none	0.5	0
4	Assemble wheel system	none	2	0
Wheel assembly (back)				
5	Reach & grab all wheel system parts from respective bins and place in assembly area	none	0.5	0
6	Assemble wheel system	none	2	0
Back carriage assembly				
7	Reach & grab back block with respective wheel system parts and place in assembly area	none	0.5	0
8	Assemble locomotive carriage and attach wheel system	screwdriver	2	0
Packaging				
9	Place assembled product into packaging machine	none	0.5	1
10	Packaged product is placed in box	none	1	0

Standard time = 191 mins = 3.18 Hrs (time required for 1 complete unit) Assuming cutting, injection mold and removing spurs are done at 3 different stations at the same time

# of operators = desired rate * SM/E

$$Takt\ Time\ = \frac{Total\ daily\ operating\ time}{Total\ daily\ production\ requirement}$$

Total daily operating time = 8 hours per day = 480 minutes per day

Total daily production requirement = 70 units per hour = $70\ \times\ 8\ =\ 560\ units\ per\ day$

$$Takt\ Time\ = \frac{480}{560} =\ 0.857 min$$

The plant must produce a part every 0.857min or every 51.4 seconds.

High-Level Process Chart

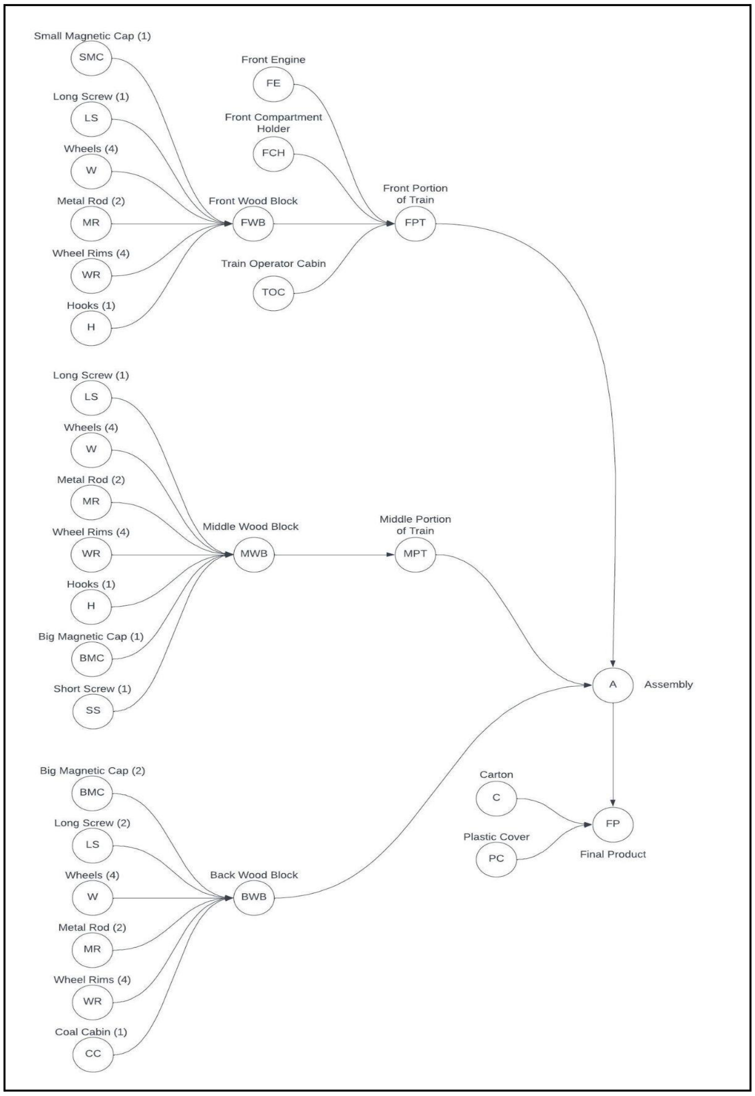

Figure 7: High Level Process Chart

For the assembly process there are several sub-assemblies and sub-sub-assemblies, each employing the use of different assembly techniques. The front portion of the train sub-assembly is made up of two sub-sub-assemblies. The first one includes 6 parts that need to be assembled; small magnetic cap, long screw, wheels, metal rod, wheel rims, and hooks. The front engine, the front compartment holder, and the train operator cabin make up the second sub-sub-assembly. An injection molding machine will be used to make the front engine and compartment holder. In contrast, the train operator's cabin will be physically carved from wood using a band saw before being mechanically sanded. Next, the middle portion of the train sub-assembly is made up of one sub-sub-assembly which includes 7 parts that need to be assembled; long screw, wheels, metal rod, wheel rims, hooks, big magnetic cap, and short screw. The back portion of the train sub-assembly includes 6 parts that need to be assembled; big magnetic caps, long screws, wheels, metal rod, wheel rims, and the coal cabin. The wheel rims, wheels, and hooks will be attached manually to the wooden cabin and main body using glue and the metal rod. The screws will be used to attach the front engine, front compartment holder, and train operator cabin to the body of the train. The 3 parts are then put together and placed into a machine for packaging alongside the carton box and plastic.

Line Balancing

In order to determine the Precedence Time Standard (PTS) chart we have utilized the obtained values in the MOST tables sheet and changed the TMU values for each task to seconds. Below table indicates the calculated values and dependence of each Task on others before starting it:

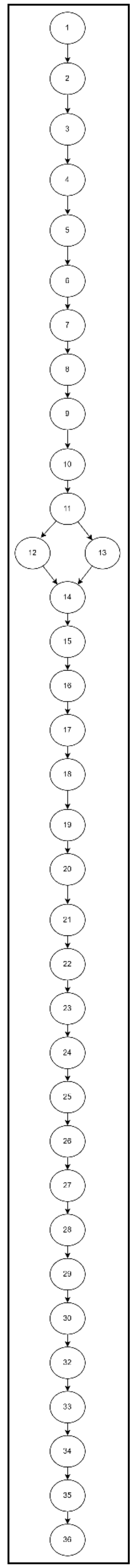
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Figure 8: Precedence Matrix

Table 6: *Precedence Time Standard (PTS)*

Task	Activity	Predecessors	Task Time (s)
1	Get front engine	-	1.08
2	Press the front engine parts together	1	1.44
3	get magnetic caps	2	1.44
4	screw the magnetic cap	3	3.24
5	Get main train parts	4	1.44
6	Press them together	5	1.44
7	Get screwdriver and position 1 screw	6	1.8
8	screw the holder to the wooden block	7	13.68
9	put screw driver to the side	8	0.36

10	get hooks	9	1.08
11	screw the hooks into the wooden base	10	27.36
12	Get rods from bin	11	1.44
13	get wood wheel blocks from bins	11	1.44
14	put rods through block	12,13	5.76
15	get wheel from bin	14	4.32
16	put wheel on rod	15	12.96
17	get rim from bin	16	4.32
18	put rim on wheel	17	12.96
19	Get assembled front engine	18	1.08
20	Get assembled wheel block	18	1.08
21	Get	19,20	1.8

	screwdriver and position screws		
22	screw the wheel block to assembled front engine	21	27.36
23	put screw driver to the side	22	0.36
24	put assembled front to the side	23	1.08
25	get coal blocks	24	1.44
26	Get screwdriver and position screws	25	1.8
27	screw the wheel block to coal block	26	27.36
28	get magnetic caps	26	1.44
29	screw the magnetic cap	27,28	6.48
30	Get rods from bin	29	1.44
31	get wood wheel blocks from bins	29	1.44

32	put rods through block	31	5.76
33	get wheel from bin	32	4.32
34	put wheel on rod	32	12.96
35	get rim from bin	34	4.32
36	put rim on wheel	35	12.96

The calculation below was necessary in order to complete the line balancing:

Total Time = 212.04 s

Takt Time = 51.42 s

Theoretical Number of stations = $\frac{\Sigma t}{Takt\ Time} = \frac{212.04}{51.4} \simeq 5\ stations$

Table 7: *Line balancing*

Workstation	Task in order	Assigned task #	Task time (s)	Idle time seconds (CT - WsT)
1	1	1	1.08	(51.42 - 1.08) = 50.34
	2	2	1.44	48.9
	3	3	1.44	47.46
	4	4	3.24	44.22
	5	5	1.44	42.78
	6	6	1.44	41.34
	7	7	1.8	39.54

	8	8	13.68	25.86
	9	9	0.36	25.5
	10	10	1.08	24.42
2	11	11	27.36	51.4 - 27.36 = 24.04
	12,13	12	1.44	22.6
		13	1.44	21.16
	14	14	5.76	15.4
	15	15	4.32	11.08
3	16	16	12.96	51.4 - 12.96 = 38.44
	17	17	4.32	34.12
	18	18	12.96	21.16
	19,20	19	1.08	20.08
		20	1.08	19
	21	21	1.8	17.2
4	22	22	27.36	51.4 - 27.36 = 24.04
	23	23	0.36	23.68
	24	24	1.08	22.6
	25	25	1.44	21.16
	26	26	1.8	19.36
5	27,28	27	27.36	51.4 - 27.36 = 24.04
		28	1.44	22.6
	29	29	6.48	16.12

	30	30	1.44	14.68
	31	31	1.44	13.24
	32	32	5.76	7.48
	33	33	4.32	3.16
6	34	34	12.96	51.4 - 12.96 = 38.44
	35	35	4.32	34.12
	36	36	12.96	21.16

Table 6: Line Balancing Before and After

According to the Line Balancing table above, we have allocated the tasks to 6 workstations, so the Actual Number of Workstations is equal to 6. In comparison with the Theoretical Number of Workstations, which was 5, we require one more workstation.

$$\text{Efficiency}= \frac{\Sigma t}{Actual\ Number\ Ws \times Cycle\ Time} \times 100 = \frac{212.04}{6 \times 51.4} \times 100 = 68.8\,\%$$

Layout of Final Assembly Area

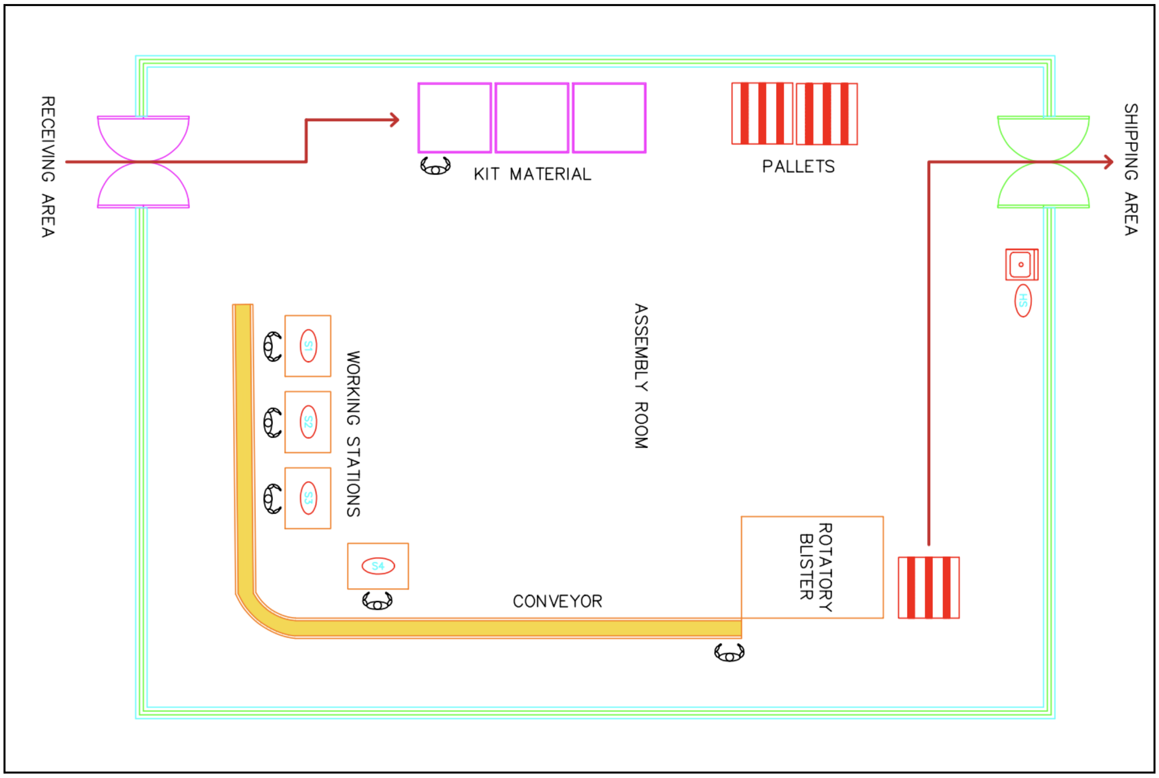

Figure 6: Assembly Room Layout

- The raw materials are received from the receiving department and then moved to the storage space located inside the assembly area.
    - This is due to the fact that the raw materials have to be rearranged into boxes by the material handling operator, and the plant is using FIFO rule where the first material in exists the plant first.
- After the material is rearranged by the material handling operator, the arranged containers are delivered to each station upon request or need.
- After this procedure, the assembly workers use the materials received and assemble the complete product in each station.
- Once the assembly is completed the workers place the complete train assembly onto the tracks of the belt located behind them.

- Later on, the packaging station receives the materials from the conveyor belt and uses the packaging blister machine to assemble the complete packaged product.
- Once the assembly is complete, a material handling operator collects and arranges the products onto racks of palettes.
- Another material handling operator using a forklift arrives and takes the pallets and delivers them to the shipping area storage space.

Materials, Machines, and Storage

Scrap

The production rate and the available time for the total production capacity and demand is determined to be 50 units per hour and 8 hours per day of production results in 400 units produced daily. Depending on this information and the scrap formula provided in the project outline, the estimated amount of scrap units produced can be calculated and the production rate can be altered to accommodate the amount of scrap units produced.

In addition, since the production facility will be obtaining the materials used to assemble the bullet train from suppliers instead of manufacturing the materials, the scrap rate will be significantly less in comparison to manufacturing all materials in the factory. Therefore, the scrap can only be produced by having the product misassembled, receiving defective materials, or faults in material handling. All three mentioned categories would yield a one percent chance to produce scrap material in each category. This percentage is an estimate, and a more accurate rate can be determined by using a simulation software, however the estimated amounts will be analyzed for this project since the production rate will be increased slightly to accommodate for additional inventory in case of any undesired event such as part delays, shipment delays, and defective units produced.

$$Total\ Units = Desired\ output\ /\ (1 - scrap\ 1)(1 - scrap2)...$$

$$Total\ Units = 400\ /\ (1 - 0.01) * (1 - 0.01) * (1 - 0.01)$$

$$Total\ Units = 412.244 \approx 413$$

As a result, it can be determined that the expected amount of daily defective units produced is (413 - 400 = 13). The production rate will be increased in order to accommodate for this difference as ($413 / 8 = 51.625 \approx 52$). Hence, hourly production rate is increased to 52 from 50 units produced per hour.

Quality Control

In addition to the scrap section mentioned above, the plant will be utilizing quality control procedures in order to minimize the amount of defective items built in the factory. In order to achieve this goal, there are several procedures and contingency plans placed inside all departments.

Manufacturing department is manufacturing the raw materials and these materials are stored in palettes inside the respective storage areas. These palettes denote a specific batch of items that are made during the manufacturing processes. In each particular batch, there is a tracking label for the materials and this information is stored in the computer for usage in the future. In case any raw material is being produced defective, this would affect the overall quality of the products. Therefore, any defective item can be tracked down using the label system mentioned earlier in order to minimize the errors that the factory may have with regards to sending defective items to customers.

In material handling, these items are scanned and placed in the respective stations in container bins. Since the parts are scanned, it is easier to track down the specific misassembly caused by each operator, and the manager can take decisive actions to track down and eliminate issues within the assembly facility.

In addition, there is another label that is placed on the complete and packaged products at the end of the production process where the packaging operator uses the labels on the product packaging. This helps managing when each product is produced and all defective items can be tracked down much more easily and quickly in case a recall is required.

Lastly, the management will be required to prepare task instruction sheets for all workers inside the facility which would help with worker training and can help increase the quality of produced products by eliminating any misassembly or misinterpretation of a specific job inside the factory.

Number of Machines

The facility will not only be receiving materials from suppliers and therefore the facility is determined to be utilized with appropriate types and numbers of machineries . For this reason the number of machines is determined to be cost effective and maintain efficiency. The plant will include two manufacturing rooms divided into three categories: metal parts, plastic parts and wooden parts manufacturing. To meet the requirement of 100,000 trains produced with an efficiency of 80% while counting 7 hour 45 min workday, a machine must have an adequate supply capacity of production to meet the requirements.

1. Wooden parts:

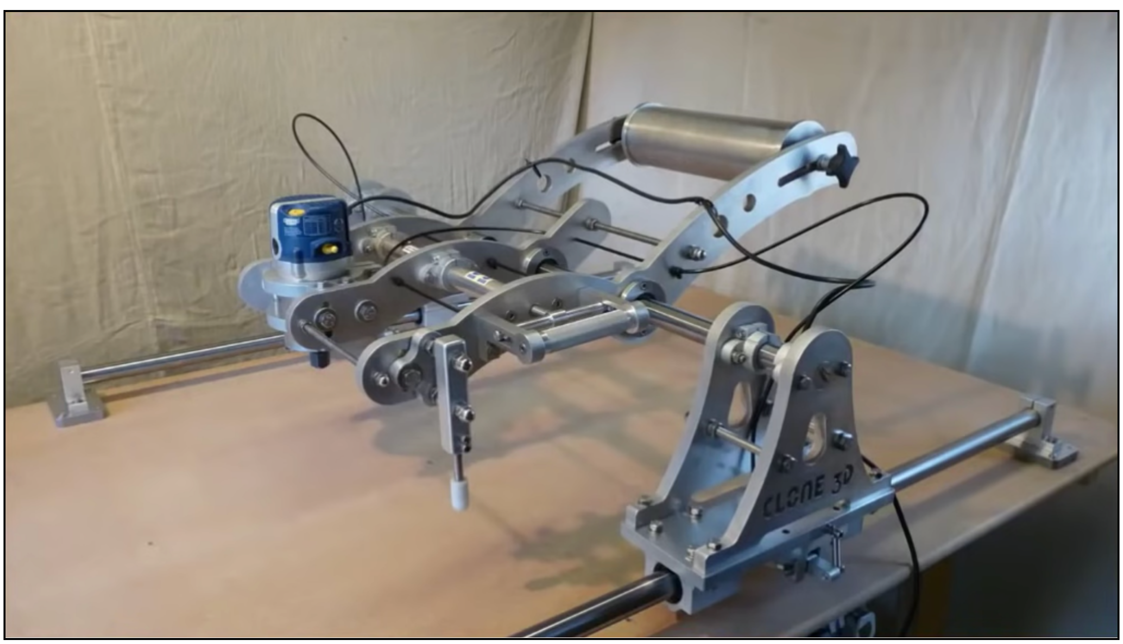

Figure 7: *CNC 3D Duplicator [1]*

There are a total of 5 different wood parts each of one quantity included in the train, therefore a total of 500,000 pieces of wood parts per year must be manufactured to meet minimum demand. To achieve this, a 3D CNC Duplicator machine will be used. This machine would require a big piece of wood that would be fed into the machine and the operator would cut it down to the required dimension of each part. The output of this machine is 200 pieces / hour [#] which results in an approx yearly production of 348,000 wood pieces per year which does not meet the minimum demand requirement, meaning at least two of these machines would be required in the facility. And, this machine would be required to run everyday during the manufacturing shift.

2. Hooks:

Figure 8: *Rod/Hook Maker Machine [2]*

This train includes 2 hooks and 6 metal rods therefore a hook making and rod contouring process has to take place. A total of 8 parts are required per train, totalling 800,000 pieces of rod and hooks to be manufactured a year to meet minimum train demand. This is achieved by using a Hook making machine which has an production capacity output of 60 hooks/min [2]. This is considered as a very fast production rate as it is capable of producing 261,000 trains per year which is more than 2.6 times of required demand. Only one of these machines would be sufficient to be used. To avoid machine and operator from being idle, this machine will be utilized to be run for three working days a week to result in approx unit production of 130,000 trains per year.

3. Caps:

Figure 9: *Cap Maker Machine [3]*

There are a total of three different types of caps the final unit contains, totalling the total cap pieces to be 16 pieces. Therefore a total of 1,600,000 of caps will need to be produced to meet minimum demand requirement. This will be achieved by the use of a Metal Cap Making machine which has a production output of 800-1000 caps/hour [3] which is capable of producing 130500 trains per year, which meets the minimum production requirement, however it will be required to run everyday during the manufacturing shift.

4. Plastic parts:

Figure 10: *Mold Injector Machine [4]*

The train's main body and exterior includes plastic parts like engine, compartment holder and wheels totalling to 15 plastic parts per train. Each toy train would require 1,500,0000 plastic parts per year to be manufactured. All plastic parts can be manufactured using a single machine, Plastic Mold Injector, the specific model chosen for this facility has a production output of 50 sets per month and each set contains 1500 pieces [4] adding up to 75,000 pieces per month which totals to 900,000 parts per year resulting in insufficient production requirement. Therefore, two of these machines would be required in the plant to run at all times adding the yearly plastic piece production of 1,800,000 producing an adequate amount of units.

5. Packaging:

Figure 11: *Blister Packaging Machine*

The Blister packaging machine is a rotatory machine that has 8 stations, each with 4 molds in it making 32 molds per cycle packaging [5]. Although there are a lot of packaging molds per cycle compared with the assembly rate, it would be a great investment with the increasing sales and potential production increase. The packaging output rate for this machine is 32 packs in approximately 2.5 minutes which is far more than enough of required packaging.

Equipments and Assets

Along with all the machinery being operated at the plant, there will be equipment and resources present while some require movements across the facility, other would be static performing the required tasks. These equipments include:

• 1 Conveyor belt: to provide movement of assembled products in the assembly line

2 Forklifts: used in as material handling equipments to move finished pallets or totes across the facility

2 Electric Tuggers: used to distribute parts in the assembly room

Pallets: used to place and hold packaged carton boxes to be stored and moved to the truck

Totes: used in storing manufactured parts and stored in receding storage room

Carton Boxes: used to pack packaged final products to safely store and move without damaging the product.

3 Labeller machines: used in printing labels for parts for quality assurance purposes.

1 Batch Labeller machine: used in printing label for completed pallet for quality assurance purposes

Racks: different sizes of racks present inside the facility to store and utilize space for material handling and scheduling. More explained later in the report.

1 Computer: used to print or edit labels based on scheduling and perform other operations based tasks.

Machine and Equipments Space Utilization

The facility must have enough space to hold and occupy all machinery and equipment in such a way that it is utilized to operate smoothly without any interference or stoppages. Dimensions of these assets are very crucial in utilizing the space for the best use. Starting from the machinery, the Plastic Injector Molding machine has a size of 5 x 1.4 x 1.8m (LxWxH) [4] resulting in a floor area of 7 m^2 and two of these machines would add up to 14m^2 of floor area occupancy. The Metal Hook Making machine has dimensions 2.4 x 1.7 x 1.9m [3] resulting in a total floor area occupied by this machine to be 4.08 m^2. The Metal Cap making machine has dimensions of 2.6 x 1.54 x 3.8m [3] resulting in 4$m^{2.}$ of area being occupied. The CNC Wood machine has a dimension of 1.15 x 2 x 1m [2] resulting in occupying 2.3m^2 of floor area. The Blister Packaging Machine has dimensions of 112”x80”x90”[#] resulting in floor area of 8960 $inch^2$ converting to 5.78m^2.

In addition to the machinery, there are going to be equipment and assets present in the facility occupying their own space. One main equipment would be the tugger and the walkies. Both of these material handling equipment will be parked at their charging stations, at the shipping area, at the end of every shift.

Number of Employees

The total number of workers required to run the entire production is determined to be 19. This includes manufacturing machine operators, maintenance technicians, material handling operators, material handling officers and forklift drivers, assembly workers, and a factory manager. It is determined that only one supervisor or manager for the production would be required to manage and oversee the problems of the factory. The comprehensive analysis of the selection of employees is summarized below.

Manufacturing Machine Operators

Since all machines except one will be required to run everyday for production, one operator must be assigned to each machine. The number of manufacturing operators are as follows:

- Total of 8 employees in manufacturing:
    - 2 employees to operate both CNC Duplicator machines.
    - 2 employees to operate both plastic mold injector machines.
    - 1 employee to operate the cap maker machine.
    - 1 employee to operate the hook maker machine.
    - 1 employee to operate the blister packaging machine.
    - 1 full time maintenance mechanic.

Material Handlers, Shipping & Receiving

Material handlers are responsible for moving parts around from one room to another. In this plant receiving material handlers will be responsible for the movement of materials from manufacturing rooms to receiving storage racks and to organize each part to be moved to assembly room racks. The shipping material handlers will be responsible to move packaged boxes skids from assembly room to shipping storage area and organize it to be picked.

- Total of 5 material handlers
    - 1 Material handler in receiving room
        - Responsible for moving items to assembly room
    - 1 Receiver
        - Responsible for receiving screws and organizes all parts in receiving storage racks

- 1 Part distributor
  - Responsible for distributing parts in assembly room
- 1 Pallet maker
  - Responsible for putting packaged box in pallet
- 1 Shipper
  - Responsible for organizing packaged products and ship them safely

Assembly workers

In order to meet necessary production demands, it is determined that the number of stations required for the assembly process is 5. All workers are assigned to 1 station in the assembly department and all workers complete the same tasks and they receive the same materials. The workers are required to assemble the complete product and place the product onto the conveyor belt once assembled. Therefore the standard time to complete the assembly process for each of the stations is the same. This is due to the fact that all workers complete the same tasks in each station, and each station completes a complete assembly of the product.

As a result, the number of workers required for the 5 assembly stations is 5 which is calculated by the following formula. (+2 Hourly rate added to reflect scrap calculated earlier.)

$$Required\ amount\ of\ products\ assembled\ per\ day\ \leq\ \frac{(fully\ utilized\ production\ hours\ per\ day * 60)}{standard\ time\ /\ 60} *\ X$$

$$52\ *\ 8 \leq \frac{(0.8*7.25*60)}{212.04\ /\ 60} *\ X$$

Where "X" is integer and represents the number of workers/assembly stations required. Which equals 4.2245. This value is rounded to the nearest larger integer to represent the number of workers which equals to 5. As a result, the factory will have enough workers to meet the production demands required per daily performance, scrap and utilization.

Total number of **19 full time** employees present inside the plant.

Storage

Within the envisioned facility, there are three main storage facilities needed for manufacturing, fabrication, and assembly parts. The first portion will store the imported goods that were purchased as well as the raw materials used to make the injection molds. Receiving raw materials and storing them in the first receiving storage Following assembly, the items will be stored in an assembly area, and following inspection, the finished item will be kept in the third area. In the first segment, several storage techniques will be used to effectively store raw materials, purchased items, and components produced by injection molding machines. Pallets and boxes will be used to store the components that are removed from the injection molding equipment.

These containers will be positioned close to them to make it easy for staff to go between the inspection area and the storage area for the obtained things. Using this type of storage has benefits for the staff's well-being, organization, and reduced clutter. The components for the assembly will be arranged on a bin shelf. Because the materials are so little, a bin shelving system may easily organize and store them all while saving space. The raw materials, plastic pellets, will be stored using a carton flow storage system. Different coloured plastic pellets are required for the various portions of the bullet train; these pellets must be put into transparent plastic containers and stored on the carton flow system according to colour.This will make it straightforward to categorize the pellets according to color and arrange them in the proper rows.

A designated storage room has been set up next to the assembly line to ensure the quick and easy installation of the manufactured parts. All of the assembled parts that have not yet gone through the final inspection procedure are temporarily held in this second storage room. The various components are put together by the employees using the raw materials and bought items kept in the first area, and then they are brought to the assembly line for final assembly before being stacked on pallets. After the last assembly is finished, the pieces are packed up and put in the second storage space.

For the workers to readily store the assembled parts without having to walk far, the second storage room has been located strategically adjacent to the assembly line. As a result, the assembly procedure can be completed quickly and effectively without any unneeded pauses or disruptions. The assembled parts will be transferred from the assembly storage area to the third and final storage area when it is time for the final inspection. The third storage compartment has been set up exclusively for the purpose of storing the finished products once they have undergone the final inspection process.

By setting up these three dedicated storage areas, the manufacturing and fabrication facility can ensure that the raw materials, purchased items, and assembled parts are all stored in an organized and efficient manner, reducing clutter, improving organization, and promoting a safer and more productive work environment. The last section is dedicated to storing the completed bullet trains that have passed inspection and are ready to ship. To manage finished items, a stacking frame system will be employed. The ability to store things in an ordered manner is one of the many advantages of adopting a stacking system. If the products on the lower shelves are going to be transported soon, they can be placed there to make it easier for workers to move them to the shipping area. Multiple shelves, on the other hand, will allow extra items that do not need to be dispatched to be stored in a fashion that does not disrupt the facility's operation.

Material Handling

In order to maintain the facility functioning as smoothly as possible while maximizing space usage, material handling requirements would be crucial to solve. Contrarily, a cross belt sorter would be perfect for small items that would take too long to sort by hand. The many elements of the Bullet train can be categorized using this type of automated material processing. Operators will have the choice to use sorted bins while building the product. It is touted to have high sortation rates and be able to sort more than 500 cartons per minute.

Figure 12: *Cross Belt Sorter [6]*

A barcode system can be used to track all items entering and exiting the plant and to maintain accurate inventory records. This system will make it possible to track inventories effectively and automatically, from raw materials to final goods.

The raw materials and commodities that have been acquired will be barcoded as part of the inventory management system as soon as they arrive at the facility. A set of four labelers will also be installed, three of which will be designated for labeling different types of materials, such as plastic, wood, and metal.

After the parts are put together, they will be stored and transported on pallets. Each pallet will also be labeled with a barcode to enable simple tracking of these pallets. This will make it possible for simplified and effective inventory tracking, lowering the chance of mistakes and increasing overall efficiency.

The manufacturing and fabrication plant may keep precise inventory records and guarantee that all commodities are accounted for throughout the production process by establishing a barcode system and using specialized labelers. This will increase production and efficiency while lowering the risk of mistakes and fostering a secure and well-organized workplace.

Finally, workers may use a forklift and an electric tugger if they need to move material pallets and bullet train parts respectively. Using electric tuggers, workers will be able to move everything efficiently, quickly, and without putting any physical strain on themselves and its compact design helps for easy movement inside a facility room. A pallet can rest on a forklift so that the merchandise can be pushed to a designated location by the operator. Two electric tuggers and two forklifts will be provided based on our decision .

Figure 13 : *Forklifts [7]*

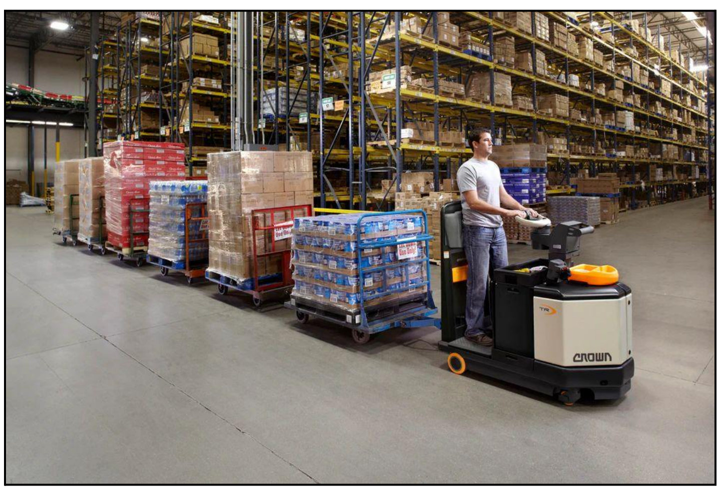

Figure 14: *Electric Tugger [8]*

Safety & Personal Protection

To safeguard the welfare of personnel and prevent workplace injuries, safety procedures and personal protective equipment (PPE) are crucial in assembly and manufacturing facilities. Hard hats, safety goggles, earplugs or earmuffs, respirators, gloves, and safety shoes are a few examples of PPE. Safety glasses defend the eyes from debris, dust, and dangerous chemicals, while hard hats shield the head from falling items. Loud noises pose a reduced risk of hearing loss when earplugs or earmuffs are worn. Gloves protect hands against cuts, punctures, and chemical exposure, while respirators screen workers' lungs from dangerous chemicals like fumes, dust, or vapors. Safety footwear shields the feet from hazards like falling items, slick floors, and electrical currents. To protect employees and uphold a healthy work environment, businesses must both provide and enforce the usage of PPE.

Moreover, eyewash and handwashing stations are present in every manufacturing room of the facility to ensure hygiene and most importantly provide aid in case of exposure to hazardous substances.

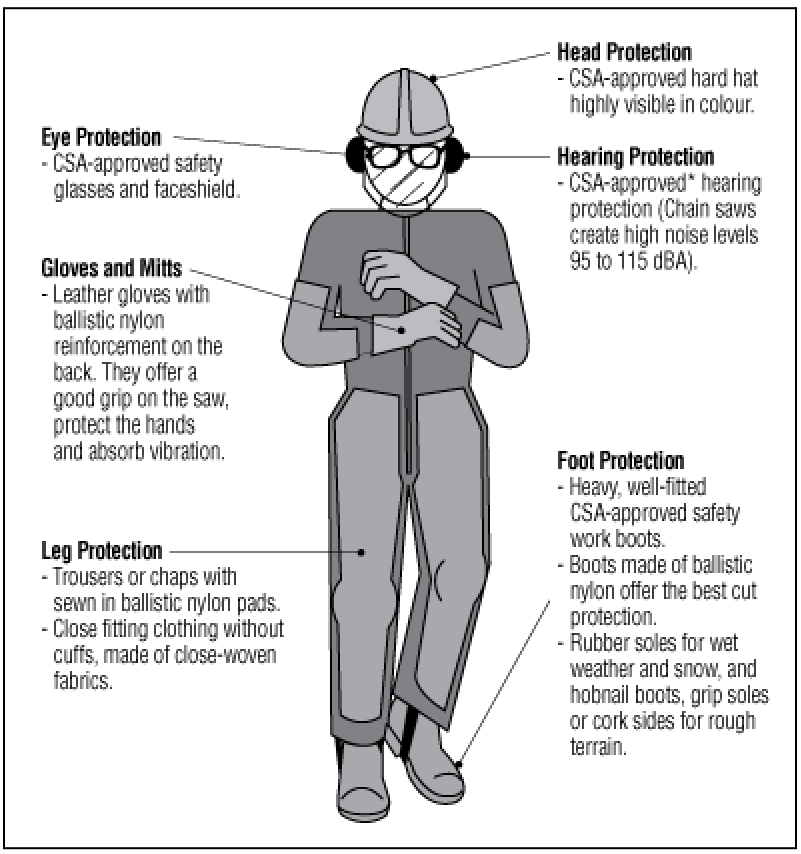

Figure 15: *Safety & Personal Protection Equipment*

Layout Planning

The Systematic Layout Planning model was developed by Richard Muther in 1995. It is a method that is used to professionally design the layout of a manufacturing facility to attain the maximum possible efficiency and productivity. It is a very structured method of optimization of space and resources within a facility. This is achieved by aiming to reduce the distance between the different workstations throughout the process of developing a product. The importance of SLP lies in the fact that a layout that is not made using proper analysis and calculations can lead to a wastage of resources both in terms of time and money, thus creating loopholes in the production process. This directly has a detrimental impact on the profitability of the business in the long run. A layout that has been planned and designed using Muther's SLP ensures the increased flow of materials and optimization of resources (Shiller, 2023).

Table 8: PQRST Chart

Product	Bullet Toy Train: Defining the physical components of the items used to prepare the product.
Quantity	This includes determining how many items of each product will be produced. - Flow rate: Amount of products that move in and out of the process. - Inventory level: A week's worth of parts will be received and manufactured prior to the assembly process to remain in inventory.
Routing	Each part is manufactured in its respective material-specific machine. Once the parts are completed, they are moved to the receiving storage area until further processing occurs. Following a predetermined schedule, the parts are replenished in the assembly room where they are assembled in a sequence. The assembly process takes place on a designated assembly line,

	guaranteeing conformity and compliance with established quality benchmarks set during the Product stage. After assembly, the finished products are packaged and prepared for shipping. They are then moved to the shipping storage area, awaiting distribution to the intended destination.
Supporting Services	As a major source of support, the plant manager is present on-site to ensure that the operations are taking place appropriately. He oversees the production process, identifies loopholes in the process, and comes up with solutions to keep the process going on smoothly. He also inspects the final product and guarantees the product conforms to the specifications and industry standards.
Time	7.25 Hours shift, 5 days a week, 50 weeks a year.

Activity Relationship

The engineering team organized the factory where the Brio World Speedy Bullet Train is made into five departments:

1. Receiving
2. Wood Manufacturing
3. Plastic/Metal Manufacturing
4. Assembly
5. Shipping

Each department has been assigned clear tasks and responsibilities in order to ensure a smooth and efficient production process from the receipt of raw materials through the shipment of the finished product. To further enhance the production process, an activity relationship diagram based on the proximity and importance of each department will be put into place. This graphic shows the interdependencies and links between several departments and their activities.

Tables 7 and 8 show the established values for these links, which were created by the renowned engineering and supply chain consulting firm Tompkins. By dividing the workload and resources among two or more departments, the use of these factors can help to eliminate bottlenecks and improve the production process. Using this activity relationship diagram, the production team can pinpoint areas for enhancement and make the necessary changes to simplify the process, increase efficiency, and save costs. With the help of this method, participants will work together more effectively, communicate more effectively, and the market-ready manufacturing process as a whole will be more concentrated on creating a high-quality and useful product.

Table 9: Closeness Rating

alue	Closeness
	Absolutely Necessary
	Especially Important
	Important
	Ordinary Closeness
	Unimportant
	Not Desirable

Table 10: Reasons for closeness rating

Value	Reason
1	Frequency of use high
2	Frequency of use medium
3	Frequency of use low
4	Information flow high
5	Information flow medium
6	Information flow low

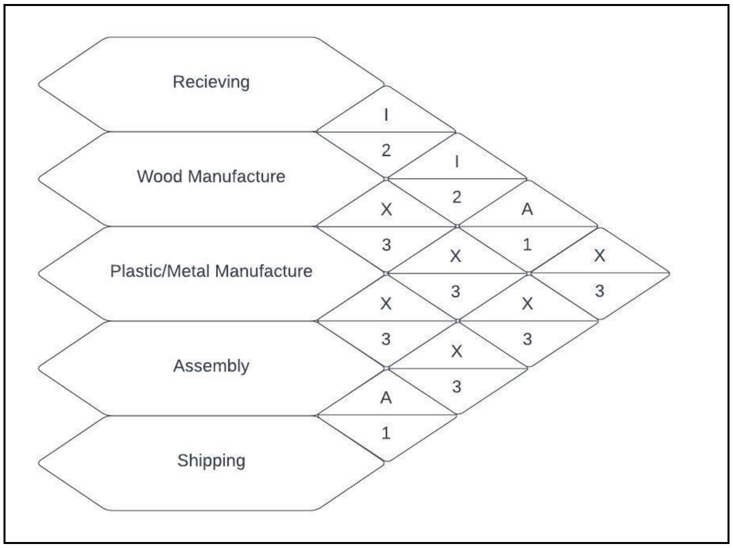

Figure 16: *Activity Relationship Chart*

To maximize the facility's overall efficiency, an activity relationship diagram was made to help organize the many departments in the most effective way possible. The diagram takes into account the relationships and interdependencies between each department and its operations. Using Tompkins' established parameters, the figure effectively distributes the appropriate resources among the various departments to increase production and decrease waste. (shown in tables 7 and 8). The block flow diagram in Figure 13, which depicts the end result, demonstrates exactly how each department should be positioned in relation to one another and depicts the interrelationships and importance of each one in the right way. The completed block flow diagram will be incorporated into the facility design to ensure that the departments are set up for optimal efficiency and output.

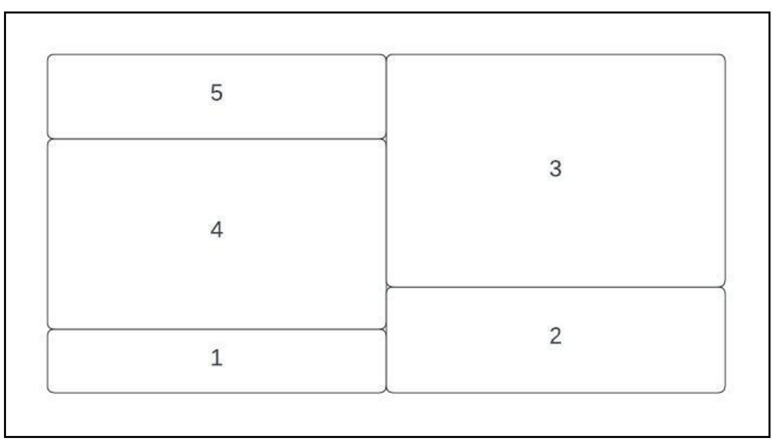

Figure 17: *Final Block Layout*

Warehouse Operations

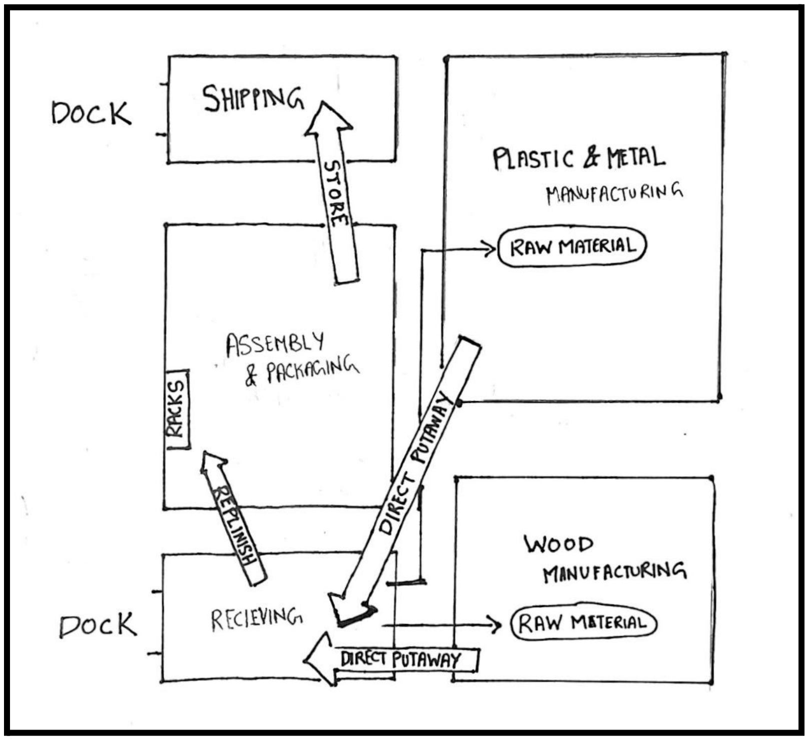

Figure 18: *Warehouse Flow Diagram*

The warehouse flow diagram substantially explains the flow of material across the plant or the warehouse operations of the facility. Warehouse operations are defined by receiving and storing of the material until it is used or shipped by the plant. The goal of this operation is to maintain optimal flow of material, utilize storage area, utilize material handling and store according to the scheduled plan. This plant functions in a very systematic manner. The screw parts are received according to the receiving schedule, it is stored in the receiving storage.The wood, plastic and metal parts after being manufactured are moved to the racing storage right away through direct pathway. Now, the assembly room storage is filled with manufactured and screw parts kept in the storage room to perform assembly tasks, as soon as these assembly racks are about to empty, they are replenished again by material handlers using the parts present in the receiving room. After the product has been assembled and packaged, it is palletized and stored in shipping storage until the shipping schedule takes place.

Racking and Pallets

As seen in the warehouse operations, the whole storing process is dependent on the racks, therefore it is vital to have correct length and sizes of racks present in the warehouse to utilize space and provide efficiency. Rack length and dimensions are dependent on the size of a filled skid and the size of a filled pallet is dependent on the size of a packaged carton box.

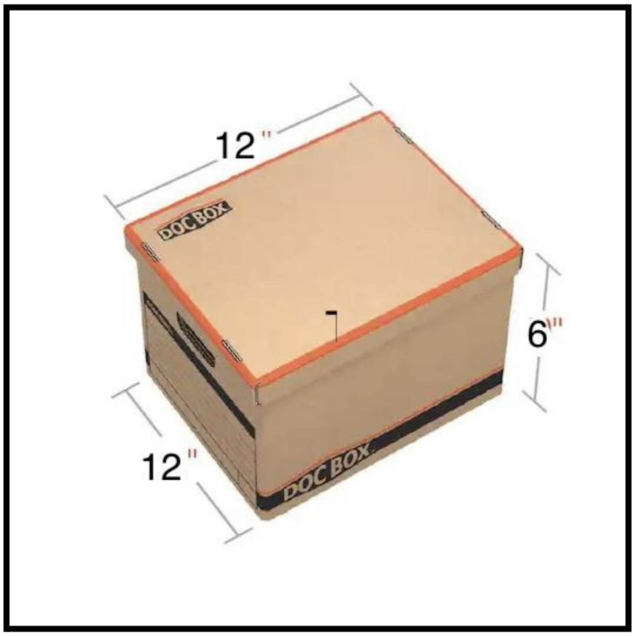

Figure 19: *1' x 1'x 0.5' Carton Box*

After the product has been packaged by the Blister machine, it is then put inside a 1'x1'x0.5' carton box and placed on a pallet.

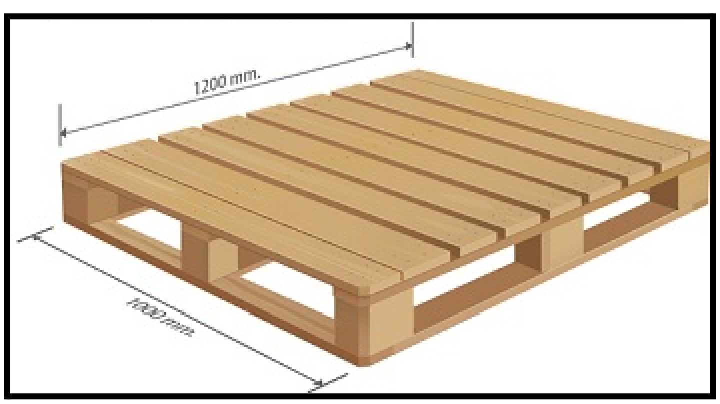

Figure 20 : *4' x 4' Pallet*

The size of the pallet is the standard size of 4’ x 4’ and a 1’ height. Therefore, one box occupies 1 ft^2 of space on a pallet. One layer of a pallet will contain 16 boxes and a filled pallet will have 6 boxes worth of height totalling 96 boxes in one pallet. The total outside dimension of a filled pallet is 4’ x 4’ x 4’ (height included six 0.5’ boxes plus pallet height).

According to ‘Freight Run Company’, a 53 ft trailer can contain 12 of 48”x48” pallets, therefore the shipping racking storage must have racks that are able to hold 12 pallets worth of material for each shipping routine (FreightRun.com, n.d.).

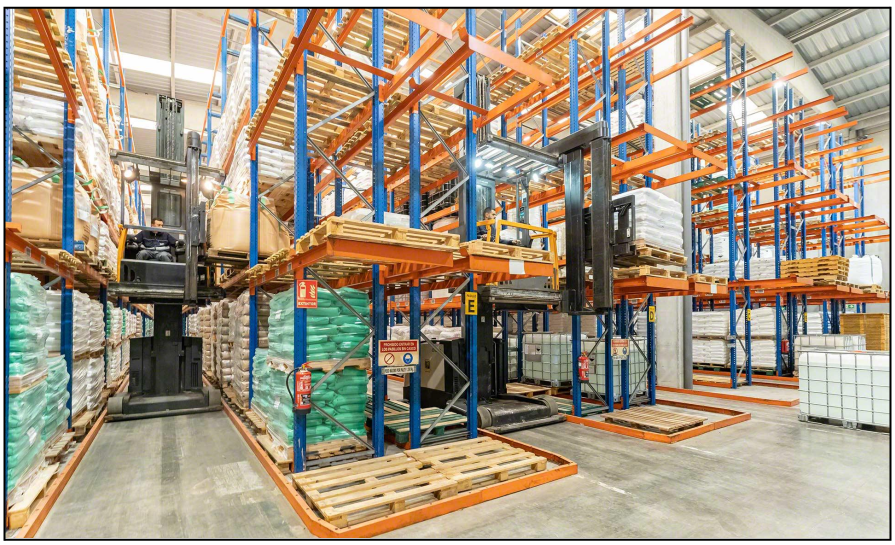

Figure 21: *Receiving and Shipping Area Racking [8]*

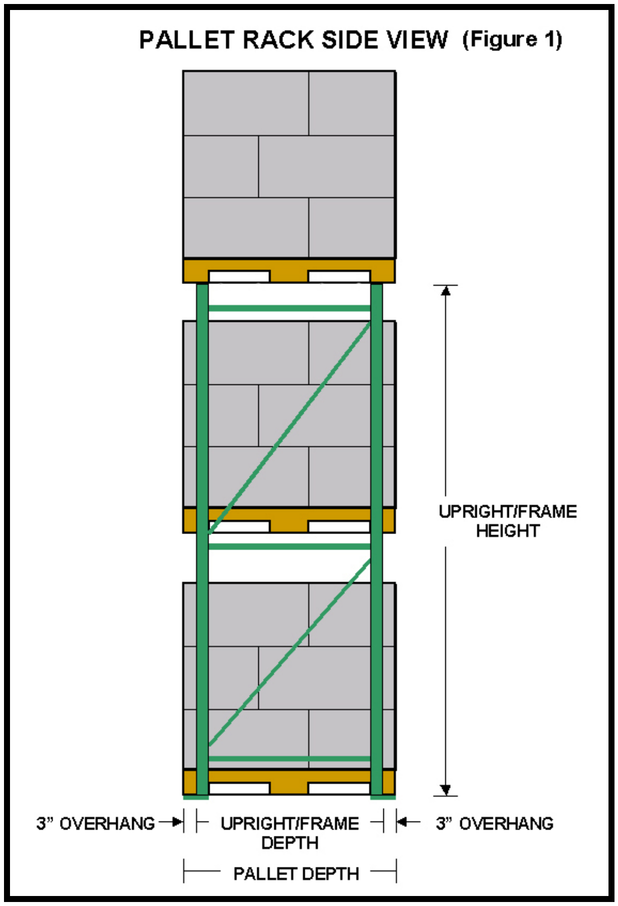

Figure 22: *Racking Height Side View [9]*

The Single frame height of a rack with right unloading and loading space for the filled pallets should be 5 ft, totaling the total height of a rack to be 15ft. The safe width of a rack to store filled skids should be 5ft as well. The depth of the rack can be 4ft allowing 12" of overhanging. For 12 skids to be stored the rack must be of 4 x 3 type totalling the width to be 20ft. The floor occupancy of the shipping rack is 80ft^2 with an outside volume of 1200 ft^3.

Shipping and Receiving Docks and Schedule

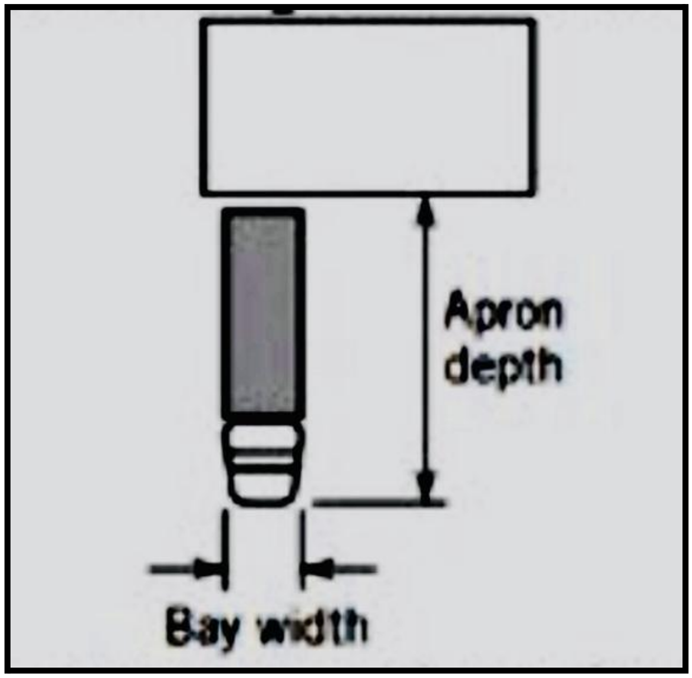

***Figure 23**: 90 degree docks*

1. Receiving:

   Frequency - Once a week

   Product - Screws, 4 big, 1 small

   With 3% scrap rate

   412,000 small screws required to meet yearly demand

   103,000 big screws required to meet yearly demand

2. Shipping:

   Frequency - Twice a week

   Product - Finished item in carton box stored in pallets.

The team has chosen to use 90 degree docks to accompany the facility's short width. A 45 degree dock would have been considered if the width of the facility was greater than how it is designed in the section below. Therefore, utilizing the 90 degree docks ultimately maximizes the space availability inside the facility by taking more space from outside the facility in the docking area. This would also save some time for the trucking company operators to easily manage reversing close to the docking area. In addition, this selection would help the feasibility of the frequency and shipping or receiving schedules explained further.

Receiving screws will take place every Monday morning. 8000 of small screws and 2000 of big screws will be received,

Shipping of the final product will take place twice a week. Since each trailer will be able to carry 12 pallets, this results in (96 x 12 =) 1152 carton boxes or final products to be shipped. The minimum weekly demand is 2000 trains, thus two shipping routines will take place. Shipping is scheduled for every wednesday and friday morning.

Final Plant Layout

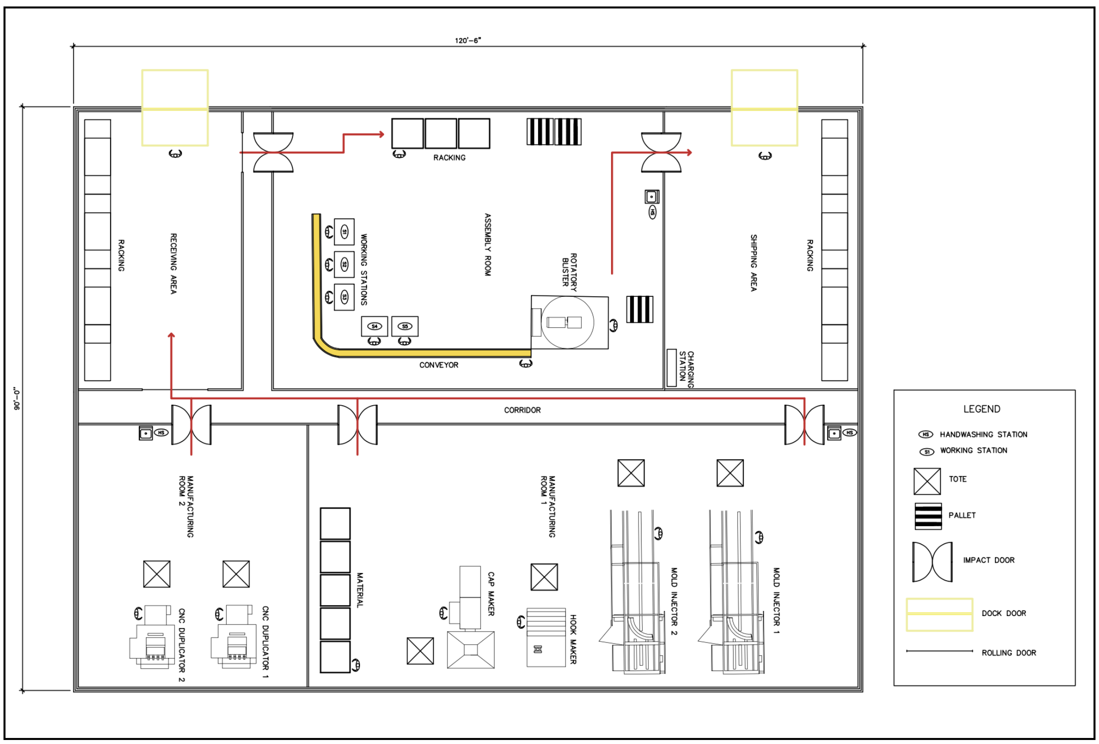

Figure 24 : *Final Plant Layout*

• Impact Doors: Impact doors would be used in the manufacturing rooms to prevent material from other rooms from entering and contaminating manufacturing machineries or parts.

• Rolling Doors: Rolling doors are used in the receiving room to improve security as almost all raw parts and manufactured parts will be stored in this, it provides privacy of operation and is easy to operate.

• Plastic Totes: Different coloured plastic totes will be used inside the manufacturing room to collect finished manufactured parts which will then be moved to the receiving storage area.

• Pallets: After the packaging of each train inside a carton box is completed, it will be palletized and taped to be moved to the shipping storage racks.

• Hand Wash Stations: All employees will have access to the hand was and eye wash stations in every room of the facility for safety purposes mentioned above.

• Corridors: Both of the material handling equipment like tugger and forklifts will carry 4’ wide pallets, therefore the corridor has been designed a 5’ of width to accommodate safe movements and ensure collison free movement.

Conclusion

As a result of the facilities planning and design methodologies that have been carried out throughout this report, it can be concluded that the project team was successful in terms of finding an optimal plant layout for manufacturing and assembling the identified product. The designed systems and plant layout work very efficiently and effectively in order to meet the specified demands. The team was able to capture two different processes and compared them to assess feasibility and effectiveness of each system. It has been concluded that having five departments, and nineteen employees is an optimal solution to the given project. The indicated safety, quality, throughput, and maintenance items and contingency plans are also aiding factors to achieve a high level of production and quality in the manufactured products. Therefore, the team was successful in implementing all requirements and exceeding the expectations for the given case study project. All project requirements are met, and the facility is designed within a cost-effective way which is capable of producing high quality products meeting the specified demands and requirements.

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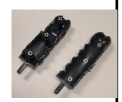
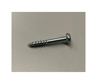
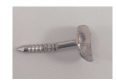
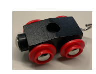
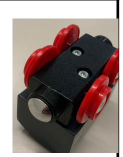
Appendix

Bill of Materials

Table 9: Bill of Materials for Brio World Speedy Bullet Train

Part No.	Quantity	Part Name	Material	Finished Size	Unit Received	Remarks	Figure
Main Train							
000	2	Front (Engine)	Plastic	10cm x 1cm ***(L x W)***			
001	1	Front Compartment holder	Plastic	12.5 cm x 3 cm ***(L x W)***			
002	1	Train Operator Cabin	Wood	3.6 cm x 3 cm ***(L x W)***			
000	4	Long Screw	Steel	2.5 cm x 0.25 cm ***(L x W)***			
001	1	Short Screw	Steel	2 cm x 0.25cm ***(L x W)***		Goes underneath the wood cabin	
003	1 2	Wheels	Plastic	*D*= 2 cm *T*=0.5 cm			
004	1 2	Wheel rims	Steel	*D*= 1 cm			

005	6	Metal Rod	Steel	L = 2.5 cm			
006	1	Small Magnetic Cap	Steel	D = 0.25 cm		At the front of the train	
007	3	Big Magnetic Cap	Steel	2 cm x 0.25cm ***(L x W)***			
008	2	Hooks	Steel	2 cm x 0.25cm ***(L x W)***			
009	1	Front Wood Block	Wood	4 cm x 1.5cm ***(L x W)***			
010	1	Middle Wood Block	Wood	4 cm x 1.5cm ***(L x W)***			
011	1	Coal Cabin	Wood	4.2 cm x 3cm ***(L x W)***			
012	1	Back Wood Block	Wood	4 cm x 1.5cm ***(L x W)***			
013		Stopper					

Packaging							
002	1	Cardboard Box	Cardboard				
003	1	Plastic Shell	Plastic				

Table 10: Flow Process Chart

Step	**FMSI**	**Description**
3D Wood Carving Machine Steps		
1	○	Start 3D wood carving machine process
2	D	Wear protective gloves and glasses
3	○	Clamp Existing wooden piece
4	○	Clamp duplicate pre-painted wooden piece
5	○	Align both pieces of wood with the machine
6	○	Turn on machine and start shaping duplicate wooden piece using the shape of the existing piece
7	○	Turn off machine when blocks of wood are shaped and sanded to the satisfactory standard
8	○	End 3D wood carving machine process
Metal Rod Manufacturing		
9	○	Start metal rod manufacturing process
10	○	Place metal rod in machine input compartment
11	○	Turn on machine
12	○	Machine pulls in metal rod
13	○	Machine cuts metal rod into smaller pieces using heat
14	○	Metal rods travel down to container for use

15	○	End metal rod manufacturing process
Hooks Manufacturing		
16	○	Start hook manufacturing process
17	○	Place metal rod in machine input compartment
18	○	Turn on machine
19	○	Machine pulls in metal rod
20	○	Machine cuts metal rod into smaller pieces using heat
21	○	Machine curves metal rod to form a hook
22	○	Hook travels down to container for use
Metal Cap Manufacturing Machine		
23	○	Prepare the raw material and necessary lubricants or coatings
24	○	Load Aluminium or Steel metal sheet into machine
25	○	Machine Preparation
26	□	Assure machine lubrication
27	○	Adjust settings with control panel(number of caps to produce, shape, size, speed)
28	○	Run the machine
29	○	Machine cutting mechanism cuts the loaded sheets in desired setting with variety of methods (ex: laser cutting, shearing, punching)
30	○	The cutting sheets are fed into machine forming dies into cap shape
31	○	The shaped caps are polished for smooth and uniform shape
32	○	The polished caps are cleaned for debris and residue removal

33	□	Monitor the machine during operation
34	⚪	Stop the machine after process completion
Plastic Mold Injector Machine		
35	⚪	Preparation of the mold
36	⚪	Cleaning it thoroughly
37	□	Assuring it is not defective
38	⚪	Securing the mold tightly in the injection machine's clamping unit
39	⚪	Preparation of the PVC resin
40	□	Assuring it is properly dried and mixed with necessary additives
41	⚪	Setting the machine parameters such as temperature, pressure and injection time using machine's PLC control and touchscreen interface
42	⚪	Loading the PVC resin into machine's hopper
43	⚪	Running and monitoring the machine
44	⚪	Machine's clamping unit closes the mold and hold it under pressure
45	⚪	Machine conveys PVC resin pellets to Machine's screw barrel
46	⚪	Screw barrel melts the resin by applying heat and pressure
47	⚪	Screw barrel injects the molten PVC resin into mold cavity
48	⚪	The mold cools down to solidify and take the shape of the

		mold
49	⚪	Machine clamping unit opens the mold
50	⚪	The ejector plate pushes the solidified part out of the mold
51	⚪	Stop the machine
52	⚪	Removing the finished part from machine's ejector system
53	⚪	Cleaning the mold and make it ready for the next cycle
Assembly		
54	⚪	Attach metal rod into the wooden block
55	⚪	Attach wheels onto the sides of the metal rod
56	⚪	Attach hooks into the wooden block
57	⚪	Attach magnetic caps to the wooden blocks
58	◻	Align top of wooden train block to bottom of wooden train block
59	⚪	Screw top and bottom parts together
60	◻	Align holes of plastic parts together
61	⚪	Screw top plastic part with middle and bottle plastic part
62	◻	Align assembled plastic portion with wooden blocks
63	⚪	Screw wooden blocks to the plastic portion
64	⚪	Hook train blocks together
65	⚪	Attach train blocks together with the magnetic caps
66	⚪	Place fully assembled train in the plastic casing
67	⚪	Place plastic casing in cardboard box
Packaging Machine		
68	⚪	Preparation of Machine
69	⚪	Connect the cable to power supply

70	○	Adjust the settings using control panel (temperature, speed, pressure)
71	○	Load the blister packaging material onto machine’s feeder
72	○	Start the machine
73	○	Machine automatically advances packaging material to forming station
74	○	Forming Station creates blister cavities using heated mold and pressure
75	○	Load the product onto machine feeder to be packaged
76	○	Machine automatically places the product into correct blister cavity
77	○	The blister packaging is sealed at sealing station to a paperboard/foil backing
78	○	The packaging is trimmed and cut to desired shape at cutting station
79	○	Machine discharges finished product onto conveyor belt or bin
80	□	Inspect the finished product
81	○	Turn off the machine
82	○	Clean the machine

Table 11: MOST Analysis calculation table

Task	MOST Analysis with broken down steps Task Description	GET	PUT	Put aside	Frequency	TMU	Notes
1	Get front engine	A1B0G1	A0B0P1		x1	30	
2	Press the front engine parts together	A0B0G1	A1B0P1	A1B0G0	x1	40	
3	get magnetic caps	A1B0G1	A0B0P1	A1B0G0	x1	40	
4	screw the magnetic cap	A1B0G1	A0B0P6	A1B0G0	x1	90	
5	Get main train parts	A1B0G1	A1B0P1		x1	40	
6	Press them together	A0B0G1	A1B0P1	A1B0G0	x1	40	
7	Get screw driver and position 1 screw	A1B0G1	A1B0P1	A1B0G0	x1	50	
8	screw the holder to the wooden block	A1B0G1	A1B0P6T24	A1B0P3A1	x1	380	
9	put screw driver to the side			A1B0G0	x1	10	
10	get hooks	A1B0G1	A0B0P1		x1	30	
11	screw the hooks into the wooden base	A1B0G1	A1B0P6T24		x2	760	
12	Get rods from bin	A1B0G1	A0B0P1	A1B0G0	x1	40	
13	get wood wheel blocks from bins	A1B0G1	A0B0P1	A1B0G0	x1	40	
14	put rods through block	A1B0G1	A0B0P6		x2	160	
15	get wheel from bin	A1B0G1	A0B0P1		x4	120	
16	put wheel on rod	A1B0G1	A0B0P6	A1B0G0	x4	360	
17	get rim from bin	A1B0G1	A0B0P1		x4	120	
18	put rim on wheel	A1B0G1	A0B0P6	A1B0G0	x4	360	
19	Get assembled front engine	A1B0G1	A0B0P1		x1	30	
20	Get assembled wheel block	A1B0G1	A0B0P1		x1	30	
21	Get screw driver and position screws	A1B0G1	A1B0P1	A1B0G0	x1	50	
22	screw the wheel block to assembled front engine	A1B0G1	A1B0P6T24	A1B0P3A1	x2	760	
23	put screw driver to the side			A1B0G0	x1	10	
24	put assembled front to the side	A1B0G1		A1B0G0	x1	30	
25	get coal blocks	A1B0G1	A0B0P1	A1B0G0	x1	40	
26	Get screw driver and position screws	A1B0G1	A1B0P1	A1B0G0	x1	50	
27	screw the wheel block to coal block	A1B0G1	A1B0P6T24	A1B0P3A1	x2	760	
28	get magnetic caps	A1B0G1	A0B0P1	A1B0G0	x1	40	
29	screw the magnetic cap	A1B0G1	A0B0P6	A1B0G0	x2	180	
30	Get rods from bin	A1B0G1	A0B0P1	A1B0G0	x1	40	
31	get wood wheel blocks from bins	A1B0G1	A0B0P1	A1B0G0	x1	40	
32	put rods through block	A1B0G1	A0B0P6		x2	160	
33	get wheel from bin	A1B0G1	A0B0P1		x4	120	
34	put wheel on rod	A1B0G1	A0B0P6	A1B0G0	x4	360	
35	get rim from bin	A1B0G1	A0B0P1		x4	120	
36	put rim on wheel	A1B0G1	A0B0P6	A1B0G0	x4	360	
					TOTAL	5890	
					S.t Time	212.04	