COVER PAGE AND DECLARATION

	Master of Business Administration (M.B.A.)
Specialisation:	Entrepreneurship
Affiliated Center:	CEO Buisness School
Module Code & Module Title:	MGT550-Managing Operations
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Word Count:	3826
Date of Submission:	19 January 2022

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Introduction:

There are key ways manufacturers can grow their business and thrive (Ed Thompson 2017).

- Be Visible.
- Invest in Your Employees.
- Listen to Your Customers.
- Keep Current With Technology.
- Keep an Eye Out for Acquisition and Merger Opportunities.

This study has two main Scopes:

1. Help Big Green Tractors growth by maximizing the efficiency of their production and distribution processes
2. Make the production process more environmental friendly as part of the new vision of the company

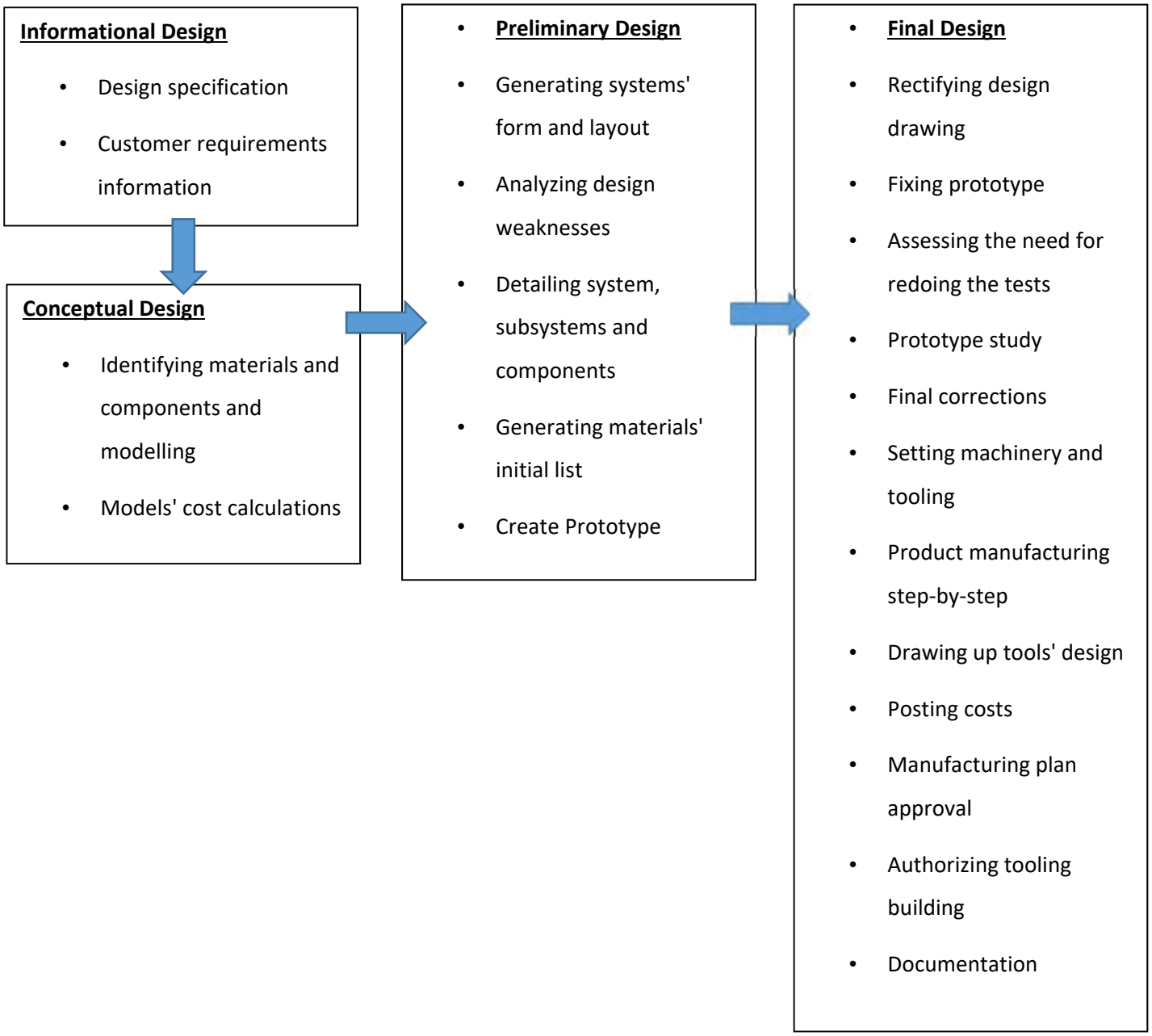
The inputs of this study will be the design and Production process of Big Green Tractors, the data of most common defects happening during production and after sales customers' complains.

The report will include the analysis of the data and the output will be recommendations on how to improve the process by:

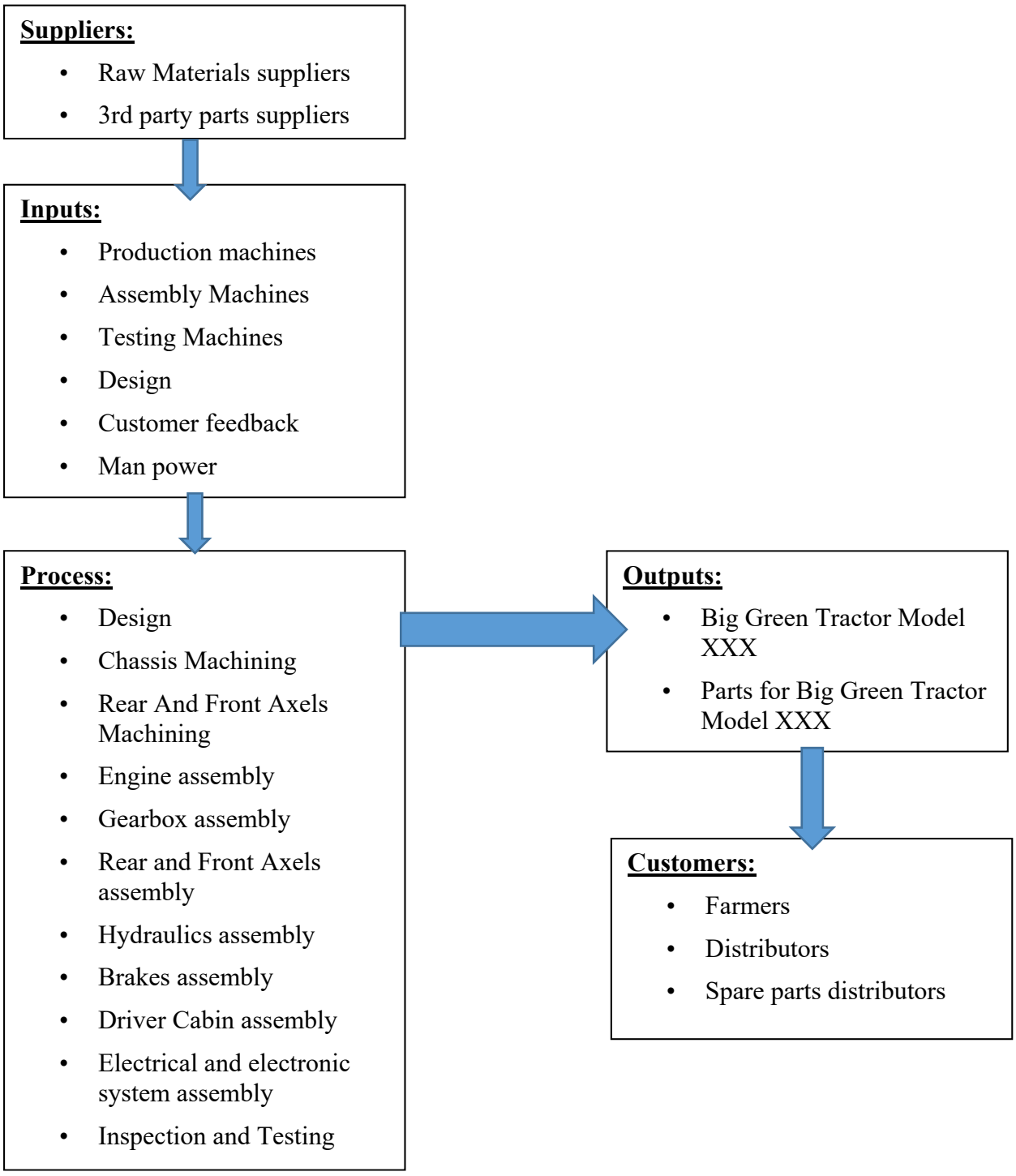
- Recommunicate the vision of the company with all stakeholders, and clearly deliver the message of the company will to grow and to become more environmental friendly.
- Increasing the process capability of detecting the defects before end of production, which will minimize the customer complains.
- Best utilization of various types of resources
- Minimizing the various operation wastes
- Use of 21st century production technologies and Lean Manufacturing Methodology
- Follow the global standards of environment friendly manufacturing process and waste management and disposal.

Below we will demonstrate the Design process into through all phases of design and manufacturing Process of Big Green Tractors in SIPOC format and will give efficiency improvement recommendations of each step if required.

Design Process:



Manufacturing Process:



Cost-efficiency Guide of Big Green Tractor Processes:

The guide will focus on two factors resources and wastes and on both Processes the Design and the Manufacturing

Best utilization of resources (8 M):

1. Management
2. Materials
3. Man Power
4. Money
5. Method
6. Measurement
7. Machinery
8. Mother Nature

Minimizing the Wastes (9 Wastes):

1. Defects
2. Overproduction
3. Over processing
4. Resistance to change
5. Waiting Time
6. Non utilized skills
7. Inventory
8. Unneeded motion
9. Transportation

Cost-efficiency Guide for Design Process:

Big Green Tractors Brain Storming:

At the Informational design stage, use efficient tools to collect customer feedback data, such as surveys and complains reports
Use brain storming between different departments to

- Formalizing customers' requirements
- Valuing customers' requirements
- Setting customers' requirements
- Prioritizing customers' requirements
- Identify issues of similar Designs

Documentation of Brain storming meetings results will prevent conflicts in the future design phases

At the Conceptual Design Phase, use the main elements of the Design concept to determine the best utilization of the resources

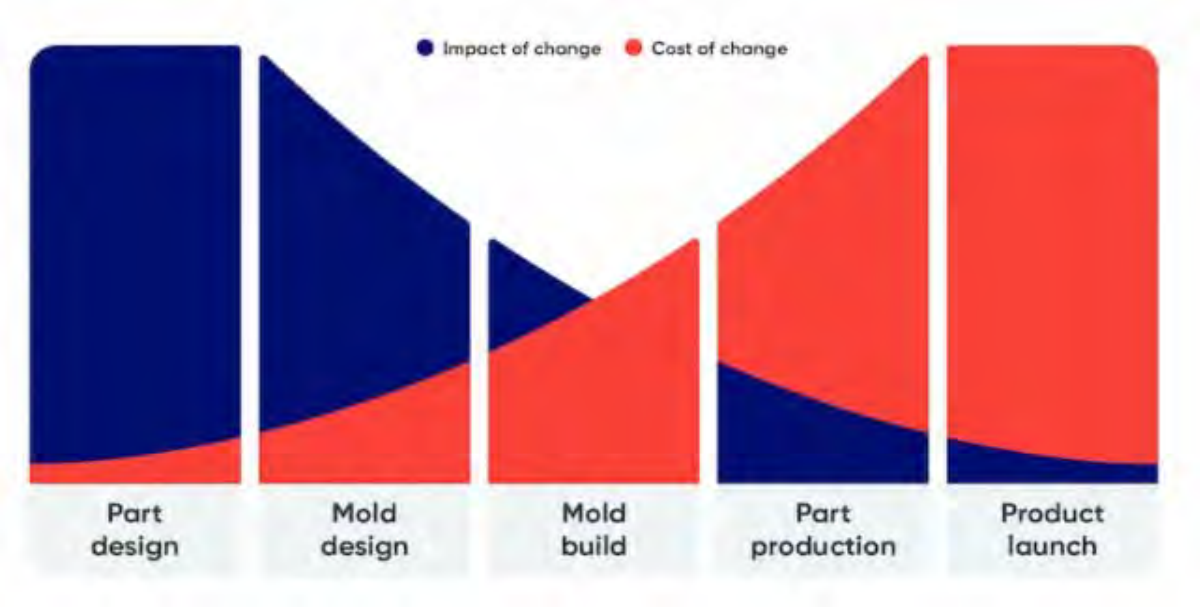
Big Green Tractor Model XXX (The Farmer's Best Friend)

1. Powerful Tractor
2. Light weight
3. Manufactured from environment friendly materials
4. Provide high safety for the operator
5. Affordable price

Big Green Tractor need to create a DFM (Design for Manufacturing):

Design for Manufacturability is a product design ideology that focuses on creating a better design at a lower cost by optimizing the selection of materials and manufacturing processes (Siim Sild 2021).

Early implementation of DFM makes design progress changes fast and with low cost



(Picture retrieved from: https://fractory.com/design-for-manufacturing-dfm/)

Selecting Raw materials:

- Use trained and experienced Manufacturing engineers to select the raw materials used in the production considering the right metal, machining process, heat treatment, surface finishing , and rigidity
- Use of Software which help to identify the weight and form of raw materials
- Engineers must consider the effect of environment (rain , humidity, corrosion, etc..) on the Tractor during operation to develop a reliable and cost effective design
- The selection of form and shape of raw materials is very important to reduce the cost of inventory as the cost of storage of raw materials depend on its shape and how it can be protected against environment factors during storage
- The Engineers must consider the availability of raw materials in required form to avoid delays from suppliers and delays in production and sales

Design simulation and testing:

It is possible to efficiently optimize vehicle durability with virtual methods and high-end test methods (StijnDonders 2020).

- Transform the design drawings to a digital design Model (Digital Prototype)
- Perform digital simulation for the operation of different sub-systems of the tractor
- Perform simulations using the digital prototype in different operation scenarios to analyze the weakness of the design using advanced software; this will reduce the cost of building a real prototype.
- If a real prototype still needed it will be much closer to the final product to test other aspect of the design including operator experience, which cannot be evaluated by the software.
- Testing compliance with standards must be done during design stage to prevent costly changes during the production or very high cost of rejection due to non-conformance to standards.

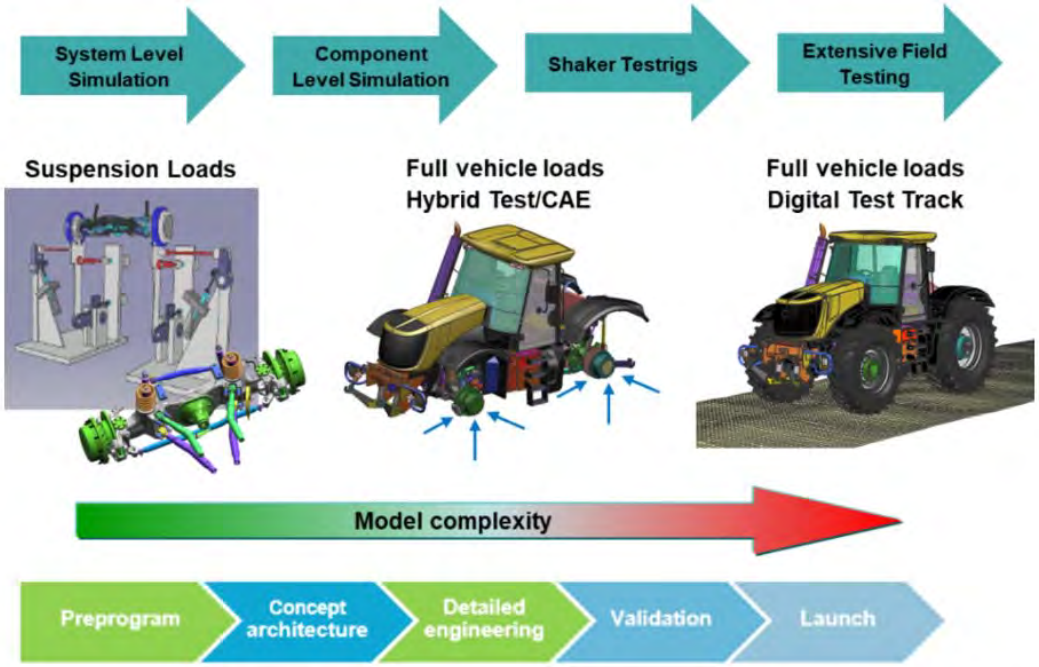


Figure 2 – Time Waveform Replication (TWR): Capabilities and Process workflow in Simcenter 3D Motion TWR, enabling to efficiently optimize vehicle durability

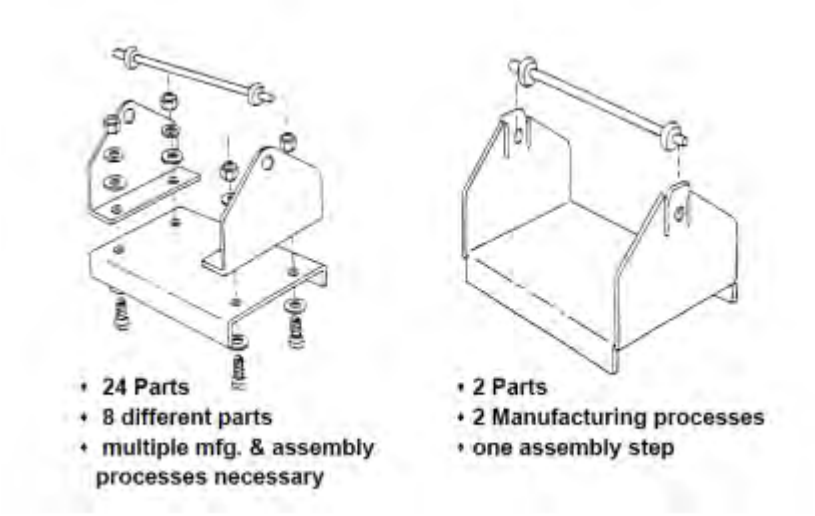
(Picture retrieved from https://blogs.sw.siemens.com/simcenter/efficiently-optimize-vehicle-durability-with-virtual-testing/)

DFM techniques can optimize dimensions and weight, tooling costs, scrap reduction, labor costs, and overheads.

Big Green Tractor need to create a DFA (Design for Assembly):

Design for Assembly (DFA), simplifies the product's structure by reducing the number of components and minimizing the number of assembly operations required. The aim is to make the manufacturing process easier, faster and more consistent, therefore more productive (Andreas Velling 2021).

- DFA will identify the number of production steps, the machinery used during each step, the method of performance either automated or manual.
- Good DFA will prevent the waste due to unnecessary motion of parts during production , the layout of production line and the facility departments will be organized to insure the most easy and time efficient process
- Many factors affect the selection between Automated and manual assembly for each step in the production line, such as sensitivity required, weight of components, complexity and safety. Good DFA will allow Big Green Tractors to select which step in the assembly line will be automated and which will be manual, and further more will be the selection of type automation and robotics used.
- Consider good training for the labors if Manual assembly is selected to be more cost effective for a particular assembly step to ensure good quality.
- Avoid human mistakes especially in manual assembly by making the design Mistake-Proof (Poka-Yoke), the components are designed in a way that they cannot be fitted together in a wrong way.
- Consider good training for maintenance engineers, and good warranty and support package for the Automation systems.
- Minimizing number of parts is much cost efficient to minimize waste of time and extra steps in the process, also it minimize the inventory.
- Design with fewer parts is usually more durable and easier to repair and avoid confusion and problems during assembly and operation, which leads to cost efficient production and more customer satisfaction.



(Picture retrieved from https://fractory.com/design-for-assembly-dfa/)

- Speed up the assembly and reduce the cost by using standard parts , this will reduce the customized machined parts and will increase the availability of the parts from many suppliers , also will reduce the cost of inventory , as Standard parts already in the suppliers inventory so no need to store big quantity of these parts.
- Avoid very large and very small parts to improve the handling process, also avoid parts that can jam or tangle together to avoid loss of time while workers are untangling and separating parts, it has potential to delay the production and waste of money.

Cost-efficiency Guide for Manufacturing Process:

- **Suppliers selection and negotiation:**

  Researching in the purchase market and selecting the most appropriate provider is one of the most important activities in today organizations.

  Ranking and selecting of suppliers in order to cooperate in providing the parts must be accomplished respecting to several criteria and indicators. (Soleyman Iranzadeh and Farzam Chakherlouy 2011).

1. Quality	**2.** Participation in Quality Improvement
3. Set Price (Pricing)	**4.** Cooperation in transport
5. Price flexibility (discount conditions)	**6.** Packaging conditions
7. reliability in delivery required amounts	**8.** Easy ordering
9. Reliability in timely delivery	**10.** Easily returned
11. Flexibility in delivery	**12.** Communication and Information
13. Promotion activities and incentives	14. Sales Support
15. Securing Policies	

After constructing a scientific method of selecting the suppliers depending on their Rank according to the above criteria, the purchase department can have more bargaining power in the negotiations with the suppliers to lower the cost and improve the purchasing conditions.

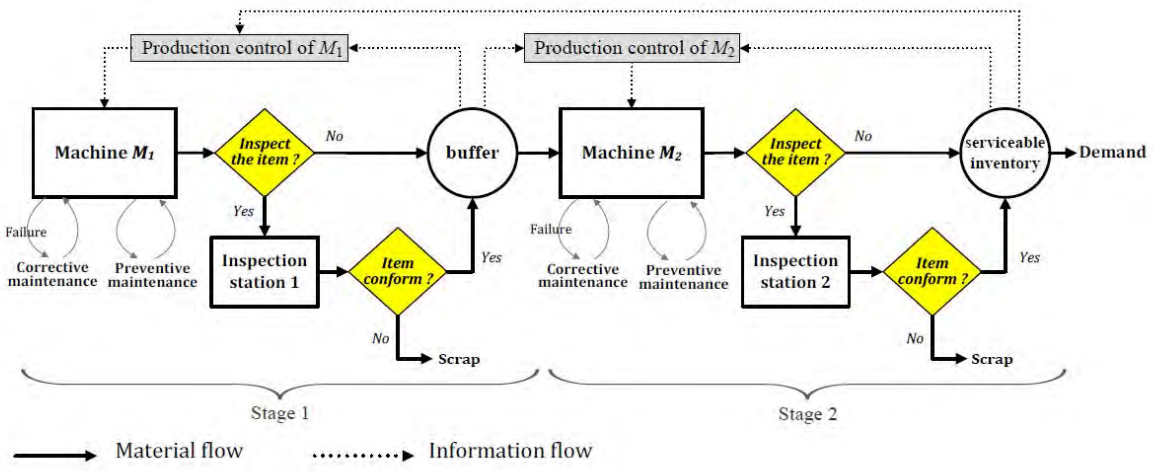
- **Machinery quality and maintenance:**

In the literature of operations management, the reliability of multistage manufacturing systems has been always modeled with uncorrelated failure processes where the reliability of each machine is assumed to be independent of any failure in the other machines. However, in real-life, machines may be subject to complex correlated failures such as increased degradation and tool wear caused by defective parts produced in preceding machines (B. Bouslah , A. Gharbi ,R. Pellerin . 2018)

Big Green Tractors need to implement a quality control management system for each step in the production line to prevent defected parts from causing damage to the machine in the following step.

A preventive maintenance schedule properly implemented and performed by trained technicians and engineers will keep the production line machines in good operating condition.

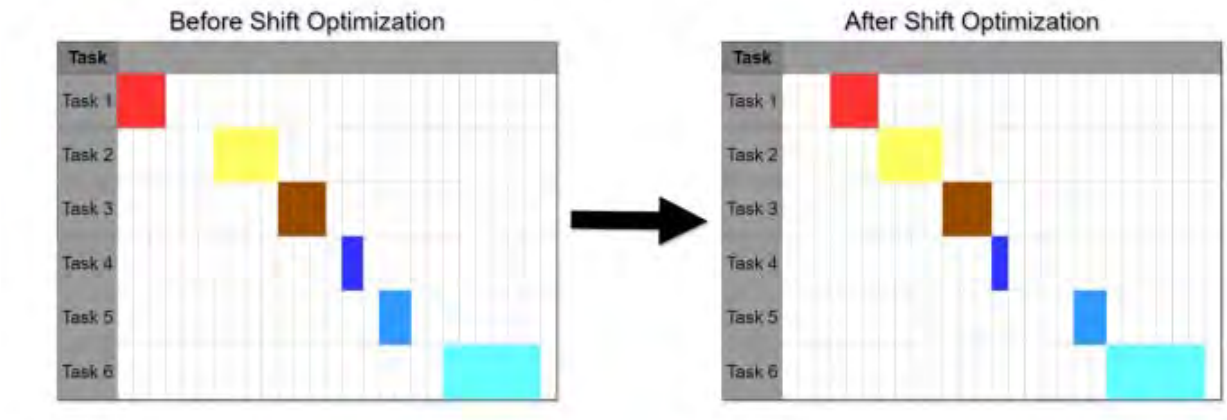
Corrective maintenance of a faulty machine in the production line must be done immediately when the fault happen to prevent degradation of other machines due to defected parts passed from the faulty machine.



Two-machine production line subject to quality and reliability degradation.

- **Reduction of energy consumption:**
  Apply automatic smart energy balancing and distribution system to make energy efficient distribution of power between machines of the production line.
  Use renewable energy and machinery driven with high power factor drives like Variable frequency drives.
  Consider installation of power factor correction solutions that has a big effect on lowering the cost of electricity bill in manufacturing facilities.
  Shift optimization is made by sliding tasks in time to reduce the time between them (Bruno Mota , Luis Gomes , Pedro Faria , Carlos Ramos, Zita Vale ,and Regina Correia 2021)

The electricity bill (cost) for production facilities reach higher levels when many machines are working in the same time because the consumption at this time will be much higher. This shift optimization will allow lowering the cost of energy consumption and providing time for other machines in the product line to operate while some machines are off, and the overall level of consumption will be reduced.



- **Workers and engineers training :**

  Good Training for the workers and engineers will help to reduce the defects not only because of the high performance of the work force but also it will increase the system capability of detecting the faults and defects in the production and assembly.

  Training is part of the cost of quality that will be compensated by customer satisfaction and better sales.

- **Inspection and testing :**

  The quality control management system always include review , testing and inspection for each part in the product assembly process , as we previously mentioned the defected part will not only be wasted as scrap but also it can affect the quality and reliability of the assembling machines.

- **Standards conformance review:**
  ISO 25119 (all parts) sets out an approach to the assessment, design and verification, for all safety life cycle activities, of safety-related parts comprising electrical and/or electronic and/or programmable electronic systems (E/E/PES) on tractors used in agriculture and forestry, and on self-propelled ride-on machines and mounted, semi-mounted and trailed machines used in agriculture (ISO , 2018).
  Quality control department in Big Green Tractor need to review the conformance to the international and local standards at all the stages of the design and production processes, as a product that does not comply with the standards and legislations cannot be sold, and the cost of no-conformance will be huge.

- **Waste management and recycling scrap:**
  Using DFM method for designing at Big Green Tractors can minimize the wasted raw materials and scraped parts but will not eliminate it, considering recycling or selling back the scrap to suppliers can be very cost effective.
- **Safety precautions guide to avoid injuries during production:**
  Big Green Tractors need to have health and safety regulations within the production facility. HSE training must be provided to the workers to avoid injuries and lost time incidents (LTI) .The cost of injury or fatality caused by lack of safety procedures, precautions , and visual alerts such as warning signs and safety guides , MSDS (material safety data sheet) can be great.
  It is very important to avoid safety incidents that can affect the company reputation and growth by implementing Health and safety culture.
- **Marketing and negotiation with distributors:**
  Big Green Tractors need to be visible on the digital market and have website and presence on the social media platforms.
  Make it easy for normal farmer to have access to the company online catalogue and he can place order
  Select the distributors who add value to the product and have direct contact with the end user.

Select distributors who can make the product reach the overseas market.

- **Have a retiring management system for old Tractors Models:**
  Create End Of Life Plan for the old models with manufacturing defects that cost the company a lot of customer complains.
  Launch tractors replacement program for old models which passed in operation several years or number of running hours depending on the engineering department recommendation, to be replaced by new model and consider the value of the old one as down payment.
  Such programs will help the company to focus on the production of new models only that have improved cost effective production process.

- **Safety precautions guide to avoid injuries during operation:**
  Big Green Tractors must equip all their tractors with a safety instruction guide that clearly describe the Safe operating procedures of using the machine.
  The Tractors are not designed for Road usage, the safety guide must clearly mention the suitable operation conditions of the machine, and the tractor itself must be equipped with all safety signs and stickers to make it clear for the owners and the operators the safe usage
  Implement mistake-proof solutions on the safety systems.
  Check for defects that can cause injuries and accidents during operation and eliminate them.
  Install safety belts and rollover bars (Rollover protection system) in the operator cabin.
  Safety warning and procedures are very important to ensure the safety of the operator and to protect the company from legal action against it in case of accident proven to be caused by a manufacturing defect. this legal actions can cause great damage to the company reputation as well as costly compensations and may cause stopping production of defected models until proven safe , that very high cost should be eliminated in the design phase.

Defects Detection and improvement Plan:

Farm tractors due to the nature of their work are exposed to a substantial risk of failures. The issues of their reliability are unusually significant in the aspect of the time limit of realization of agricultural works in agrotechnical seasons (Jerzy Napiórkowskia, Jarosław Gonerab ,2020) .

Below analysis based on Data from "Analysis of Failures and Reliability Model of Farm Tractors" by Jerzy Napiórkowski and Jarosław Gonera , and assumed as Failure data of Big green Tractor Model XXX.

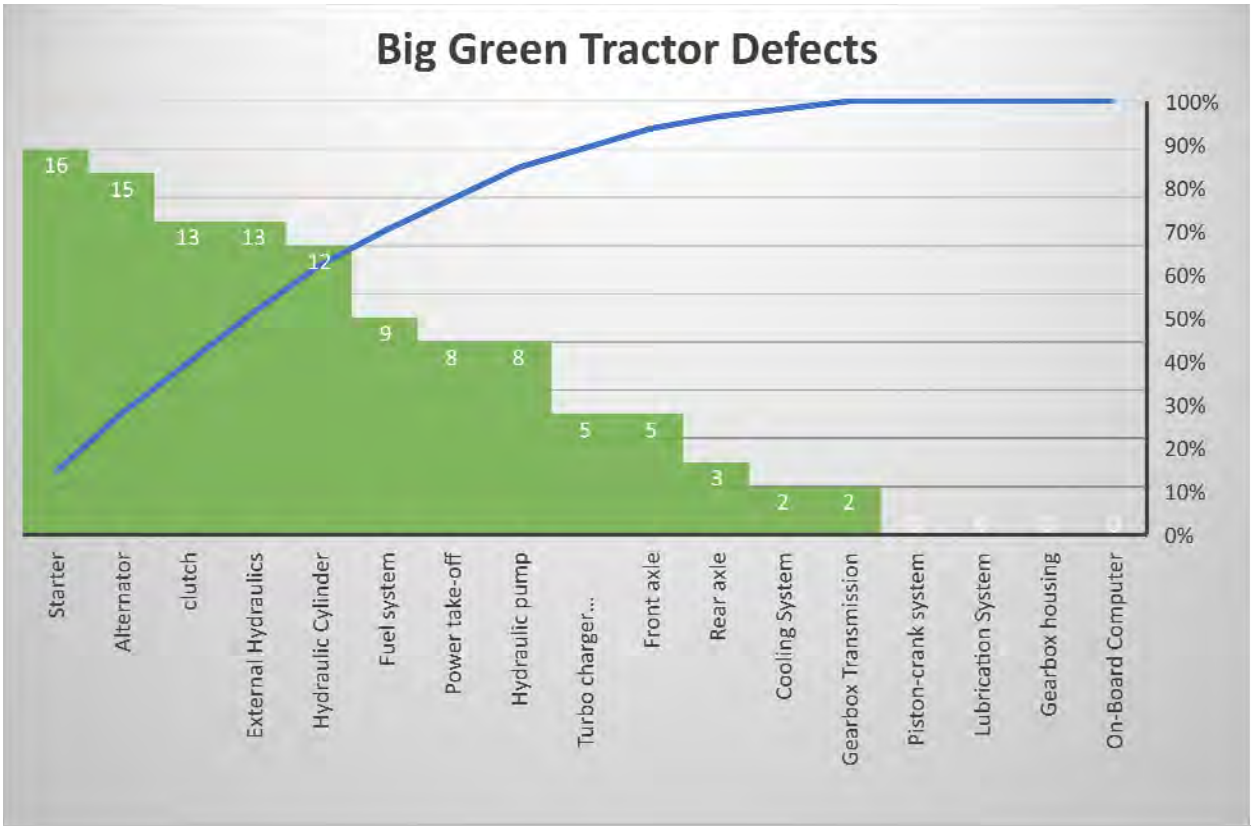
Big Green Tractor Model XXX Running hours 9000 Sample : 30 Tractors	
Faulty system/Part	Number of Defects
Engine	
Piston-crank system	0
Fuel system	9
Cooling System	2
Lubrication System	0
Turbo charger compressor	5
Gearbox	
clutch	13
Gearbox housing	0
Gearbox Transmission	2
Drive transmission system	
Front axle	5
Rear axle	3
Power take-off	8
Hydraulic system	
Hydraulic pump	8
External Hydraulics	13
Hydraulic Cylinder	12
Electric system	
On-Board Computer	0
Alternator	15
Starter	16
Total number of Defects	**111**
Average of defects per tractor	**3.7**
Average Electrical and hydraulic defects per tractor	**2.13**

We will use DMAIC methodology to develop improvement plan to solve this defects problem. Number of failures is calculated from the year of production until 9000 running hours for all tractors

Defining and measuring the Problem:

Project Charter	
Scope IN	Defects in electrical and hydraulic systems
Scope Out	Defects caused by misusage from the operator.
Primary Metric	Improve the Electrical and the Hydraulic components in the tractor production to avoid defects
Secondary metric	Make sure that the components improvement doesn't increase the cost of production and affect the profit margin Modification in the supplied parts can cause change in design and assembly procedures.
Business Case	It is very important to eliminate the defects created by those sub-systems to improve the quality and reliability of the tractor and allow better opportunity for sales.
Problem Statement	Each tractor experience more than two defects in the electrical and hydraulic systems before it reach 9000 hours of its operation age.
Goal statement	Decrease the number of defects in hydraulic and electrical system per tractor from 2.13 to zero in the first 10000 running hours.
Benefit	Reduce the cost of parts replacement under warranty. Better reliability of the tractors will be positively reflected on the company reputation and the overall sales.
Team	Purchase and quality control departments will be responsible of the improvement Engineering will be involved if the new improvement parts are not exact fit and changes in design and assembly are required

Problem Analysis:



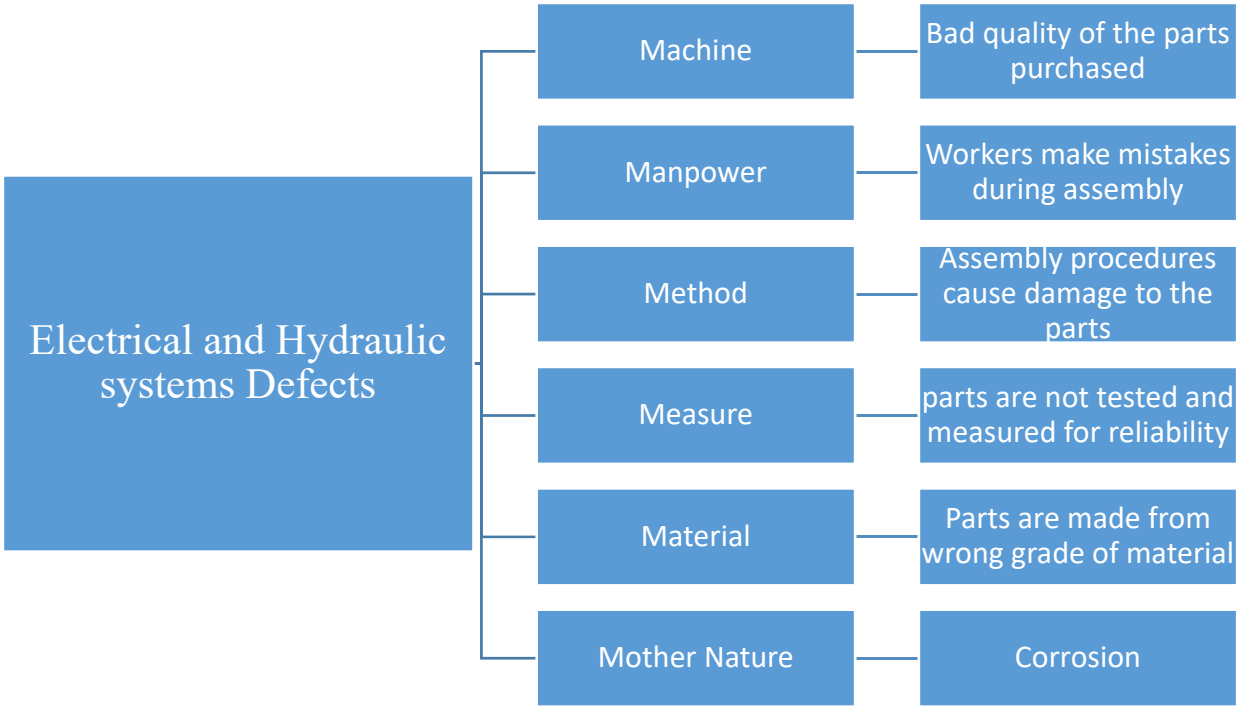
Hydraulic system (including the hydraulic pump) causes 29.7% of total defects

Electrical system causes 27.9% of total defects

Electrical and hydraulic systems marts are mostly supplied by 3rd party and assembled to the Tractor during production

Clutch causes 11.7% of total defects, those defects can happen because of misusage by the operators or bad quality of materials.

Root Cause analysis



Improvement:

- Purchase department needs to re-negotiate the terms and conditions with the suppliers concerning the quality of the parts supplied for electrical and hydraulic systems to be from suitable grade of material that is corrosion resistance and has to pass the reliability test of Big Green Tractors quality control.
- Purchase department need to make warranty agreement with the suppliers for those for more than 10000 running hours.
- Quality control department need to review the reliability tests on those specific parts and use methods as concentration sheet to avoid missing any points during the tests.
- Quality Control department need to review the assembly steps of those systems and make sure that the workers are trained on proper assembly procedures
- If the change of components by other more efficient parts causes changes in the DFM and DFA, the full process and training must be reviewed to ensure quality.

Control:

1. After implementing the change in components and the change in the process, the new improved tractors must be monitored closely during the first 10000 running hours and customer feedbacks must be reported.
2. After 10000 running hours of a sample of 30 improved tractors, another analysis of the number of defects reported must be done to verify the effect of the improvement.
3. If the goal of zero electrical and hydraulic defects per tractor is achieved, the improvement should be standardized in the production process.
4. Initiate another project to eliminate the defects in other tractor sub-systems.

Modernization of Big Green Tractor:

After implementation of the new guide lines in this study Big Green Tractor will be using a set of very strong 21st century tools that make it greener and more cost efficient successful company:

1. Using DFM and DFA methodologies in design will minimize the production of waste and recycling steps will be automatically implemented into the production process.
2. Using automated energy efficient production and assembly line.
3. Using renewable energy in the production facility and to power other administration functions offices
4. Using advanced modeling and testing software to simulate and test the design
5. Following ISO 25119 concerning the Tractors design ,production and safety systems included.
6. Following ISO 14001 for environmental management system.

Waste management Process:

There is many wastes are produced during the production:

1. Solid metal wastes during the machining and metal works
2. Chemical during painting and applying protective coating for the parts
3. Oil and fuel during testing operations
4. Plastics and other wrapping materials during packing

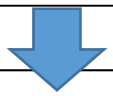
The Process of waste management will be on Four levels

1. **Eliminate** the source of waste from the origin
2. **Substitute** the waste material by another recyclable one
3. **Minimize** the quantity of non-recyclable waste produced
4. **Safe Disposal** of waste according to environmental standards

Reduction and recycling of wastes are inevitably site/plant specific (Chapter 6 , INDUSTRIAL SOLID WASTE) .

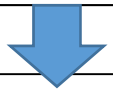
Elimination:

1. Make the DFM environmental friendly as well as required production material
2. Purchase non-toxic and recyclable production materials according to the DFM
3. Provide training for handling hazardous materials including knowledge about MSDS (Material Safety Data Sheet)



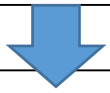
Substitution:

1. Modify production line to produce less wastes and introduce new recycling and reuse steps into the production process
2. Replace unnecessary non-recyclable material from production process



Minimize:

1. Implement strict preventive maintenance program to minimize leakages and wastes
2. Segregation of hazardous and non-hazardous wastes



Safe Disposal:

1. use certified waste recycling companies for recycling the wastes that needs complex process and cannot be recycled internally
2. Use certified waste disposal companies for safe disposing by incinerating or burial in special land fields for this purpose.

By applying this process guide Big Green Tractor will carry its social responsibility for raising the environmental awareness and minimizing the pollution during the production, but this role will not stop at that level, last step in the process must be implemented:

Operators and customers Training:

Big Green Tractor can give awareness training for the customers and tractors operators to help them to apply safe and environment friendly practice while they are working with the tractors.

This training can include basic maintenance as inspection for oil and fuel leaks , also hazardous material safety awareness as part of the farmers work with the tractors is moving fertilizers and other chemicals.

Conclusion:

To Maintain the Big Green Tractor Growth in the local and international Market , advanced operation methodologies needed to be implemented starting from design to production, assembly and waste management. Following and applying standards recommendation is very important to help the company to sustain that growth and to make it recognized internationally.

Example of those standards:

- ISO 25119 (Tractors and machinery for agriculture and forestry)
- ISO 9001 (quality management)
- ISO 45000 (Occupational Health and Safety)
- ISO 14001(Environmental management system)

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