3DPGS Project Report

Date:

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Introduction

Define

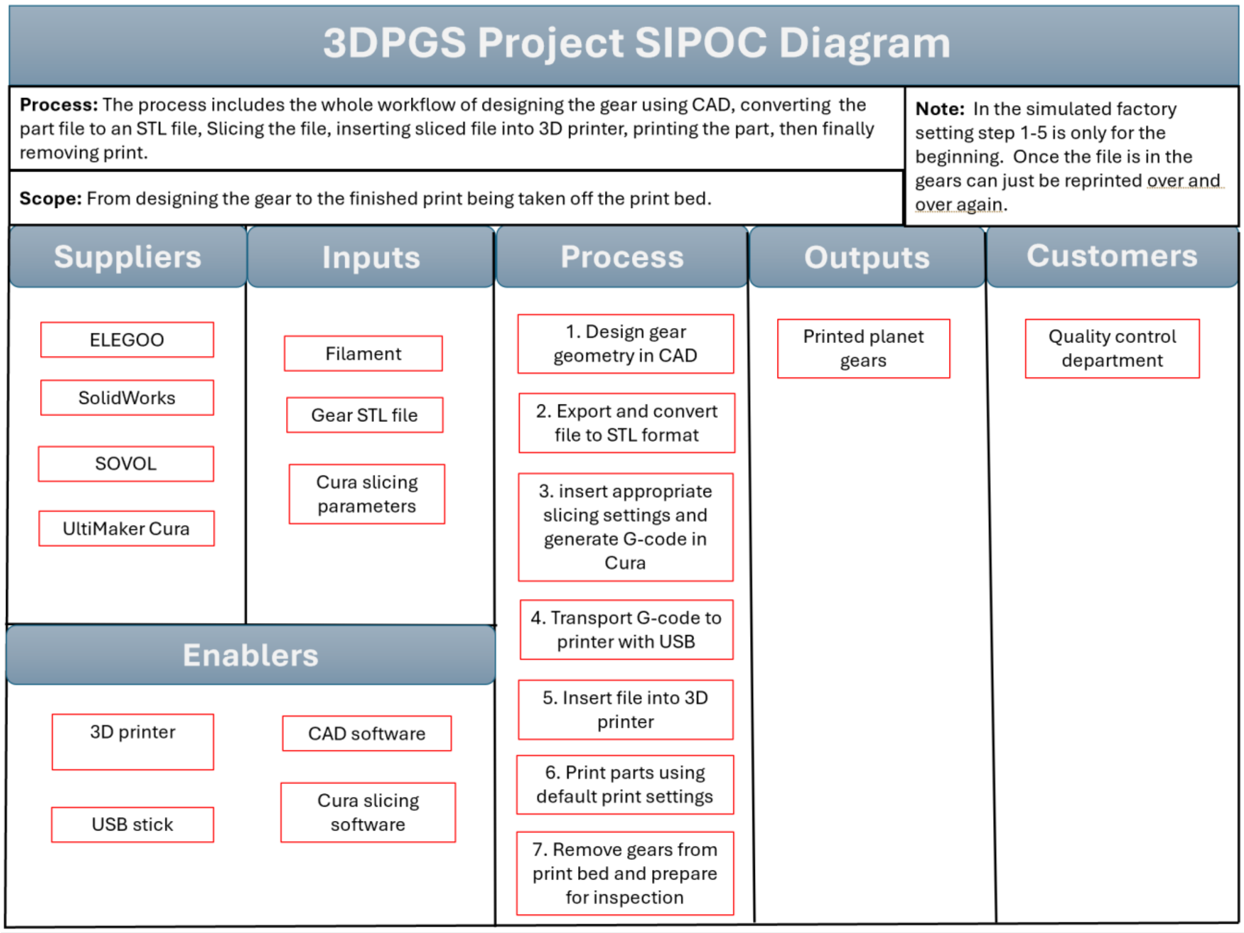


Figure 1: SIPOC Diagram

Problem Statement:

On November 4th to 5th, 2025 the 3d printer gear facility printed 35 planet gears. Of those 35 gears 45.71 % of them failed from either spaghetti or other defects and could not be used in the assembly of the planetary gearboxes. Overall, 94 % of printed parts showed at least 1 visible defect and the average visual check was 4.8/10, suggesting an unstable process with high variation. At an average print time of 81 minutes per part, these failed parts create significant Muda of rework where the defect frequency and failure rate reduce throughput and increase material and production costs, estimated at $0.17 per gear and $83.22 a month.

Business Case

The current 3D printing process used for gear production suffers from high failure rates, high defect frequency, and unstable print quality. These issues directly reduce throughput, increase material waste, and limit the ability to meet production demand. Improving process stability will reduce Muda of rework, improve consistency, and enable predictable production scheduling. With a current material loss of $84/month, there is clear financial justification for improvement. This project aligns with organizational goals of reducing waste, increasing process capability, and enabling low cost, high quality printed components.

Goal Statement:

The goal of this project is to reduce failure rate, defect rate, and visual check to improve stability in the process. This can be done by optimizing 3D printing parameters to improve the consistency and quality of the prints. Minor changes in the print time or material usage are fine, as long as they result in a more stable higher yield process and save more money than lose money due to rework/defects.

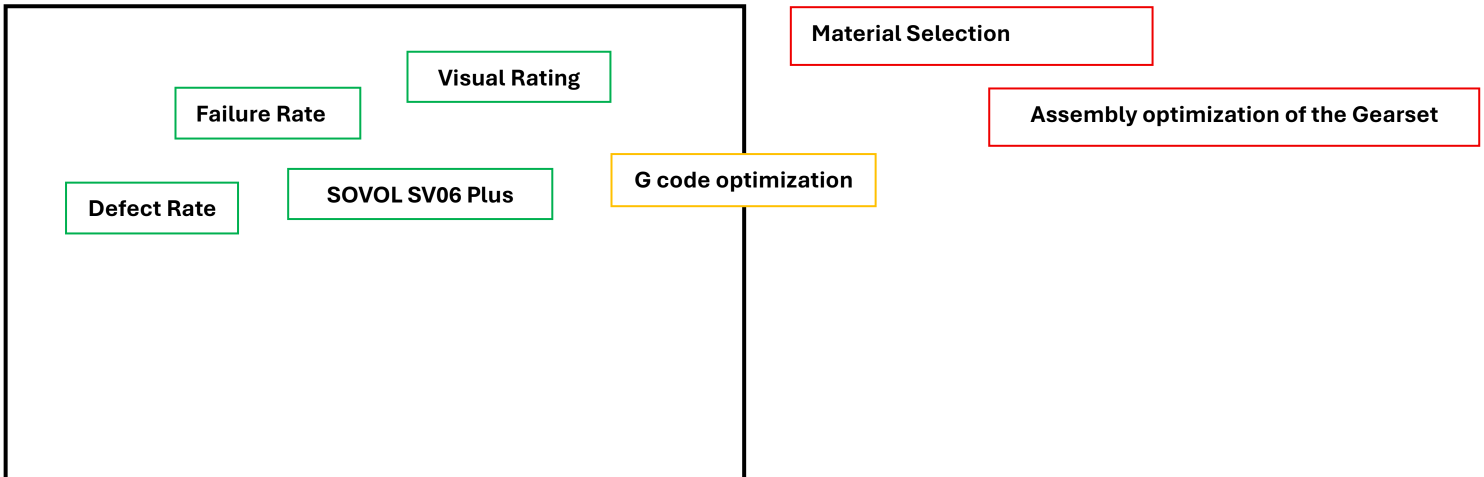
Failure rate now: 45.71 %
Goal failure rate: Below 10 %

Defect rate now: 94.29 %
Goal defect rate: Below 30 %

Average visual check now: 4.85/10
Goal average visual check: 7/10 or higher

Scope:

In and Out of the Box Method



Printer Hardware Modifications

CAD design changes

Printer settings (Nozzle Temperature, Infill Pattern, Infill Density, Resolution, Print Speed, Shell Thickness Horizontal walls and Vertical walls, Fan Speed, Layer Height, Support, Adhesion)

Getting a brand-new printer

Filament Brand

Long term machine wear

Print Time per part

Amount of filament used per print

Environmental conditions

Print orientation

Bed leveling

Scope Summary:

Looking at the in and out of the box method above we can use this to grasp the scope for this DMAIC project. The scope of this project focuses on improving the quality and consistency of 3D printed planet gears produced on my Sovol SV06 Plus using PLA filament. The project will address controllable printing settings (nozzle temperature, print speed, Infill pattern, etc.), as well as measurable outputs like failure rate, defect rate, and visual quality. Print time and amount of filament used per part are needed as well for comparison to original process, and to calculate costs of the process. Elements such as Material selection, CAD design changes, printer hardware modifications, and environmental conditions, are considered out of scope. This makes sure the project remains focused on process optimization rather than equipment or design changes. Some of the elements were placed on the line of the box such as print orientation, filament brand, and G code optimization. These components could be included in the scope later on but are not the main details the project should focus on.

Voice of Customer (VoC)

In the case for this project, the customer is the quality control department who evaluates the printed gears. Therefore, the VoC is what the quality control department cares about to make sure the gears meet production requirements. The VoC data is the data recorded in the excel sheet for the simulated production of the 35 gears.

Voc Data:

The VoC Data is found from taking the quality controls departments excel sheet that has certain information about the given printed gear. The table is broken down into batch member and Print ID given below, as well as metrics that are measured for each planetary gear. The gear is then given either a fail or a pass, where a pass means it is ready for the assembly stage. Notes were taken by the quality control department as well which gives us a better understanding on what is important to the customer. Below in *Table 1*: Batch 1 of Quality Control Departments Quality Check*,* the first batch of the quality control departments quality check is displayed for that day. This table is to help give a visual on what kind of information this excel sheet contains. There are 6 other batches in the excel sheet (7 total) that are formatted just like this one.

Table 1: Batch 1 of Quality Control Departments Quality Check

Quality Control Department													
Print Batch Number	**Placement on print bed**	**Print ID**	**Print Time (actual min)**	**Mass (g)**	**Visual Check (1-10)**	**OD (mm)**	**ID (mm)**	**Width (mm)**	**Defect Yes/No?**	**Defect Type**	**Fail/Pass**	**Failure Type**	**Notes**
1	1	PLANET001	78	1.58	0	N/A	N/A	N/A	Yes	Spaghetti	Fail	Spaghetti	Fully Spaghetti, can't measure it
1	2	PLANET002	78	1.58	7.5	19	8	10	Yes	Minor stringing and over extrusion	Pass	N/A	Very decent print, surface is a bit rough on top and bottom of gear and a few minor holes on the teeth, but not enough to make it fail. Also has minor stringing in gear bore and minor overextrusion (not enough for failure)
1	3	PLANET003	78	1.58	7.5	19	8	10	Yes	Minor stringing and over extrusion	Pass	N/A	Very decent print, surface is a bit rough on top and bottom of gear and a few minor holes on the teeth, but not enough to make it fail. Also has minor stringing in gear bore and minor overextrusion (not enough for failure)
1	4	PLANET004	78	1.58	8	19	8	10	No	N/A	Pass	N/A	Good
1	5	PLANET005	78	1.58	8	19	8	10	No	N/A	Pass	N/A	Good

One of the most common failure types is the spaghetti (*Table 2*: Representation of 1st Placement Spaghetti*),* where the part instantly fails and turns into a unusable yarn of filament. This is very bad as it causes Muda of rework, increasing costs of production. During the simulation, it was noticed that the 1st placement on the print bed, ended up in a full spaghetti across all 7 batches. This is a repeated failure that needs to be assessed.

Table 2: Representation of 1st Placement Spaghetti

Print Batch Number	Placement on print bed	Print ID	Print Time (actual min)	Mass (g)	Visual Check (1-10)	OD (mm)	ID (mm)	Width (mm)	Defect Yes/No?	Defect Type	Fail/Pass	Failure Type	Notes
2	1	PLANET006	82	Mass (g)	0	N/A	N/A	N/A	Yes	Spaghetti	Fail	Spaghetti	Fully Spaghetti, can't measure it

Some other common errors include minor stringing, minor over/ under extrusion, and mild surface roughness causing the part to not look as good as it could. These are more "minor issues" that don't affect the working gear in the assembly too much but still would be convenient to remove or improve. Also, these "minor issues" would help us improve the visual rating and removing defect rate of the printed gear, satisfying our goal statement. Some of the gears on the print bed also resulted in localized spaghetti failure, resulting in an unusable gear for assembly.

The quality control department or our customer in this case, essentially stated that the parts need to be visibly pleasing, reliable, and consistent where no or low number of defects are present. The the next step is to use this Voc data in a CTQ tree to help narrow work scope and understand how to enact change in this process.

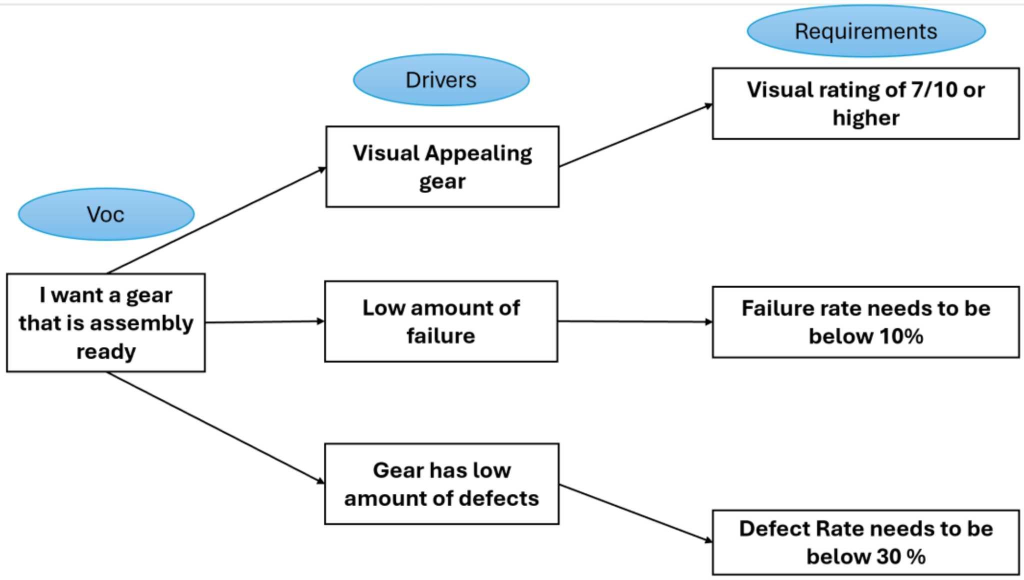


Figure 2: CTQ Tree

Above in *Figure 2*: CTQ Tree is the CTQ tree for this project. It starts with the customer expectation or what the customer ultimately cares about (needs an assembly ready gear). Then once the expectation is stated, drivers are generated on whether the gear is ready for assembly or not. This includes visual appearing gear, low failure rate, and gear has low number of defects. After the drivers are made, specific measurable requirements are created, these are metrics or success criteria's that help me understand if the process is performing well. The requirements are visual rating higher than 7/10, failure rate below 10% and defect rate below 30%. The Critical to customer tree coincides with our problem statement showing that failure rate and defect rate need to be decreased and visual rating needs to be increased. Since it wasn't really stated how visual quality is assed here is some sub requirements below that helps us visualize better on what a good visual quality looks like.

Visual Rating:

- Minimal stringing
- Smooth surface
- Sharp edges
- Proper layer alignment
- Looks very similar to CAD

Form Team

In a real-world DMAIC project, the team would be cross-functional and made up of several different roles, such as a process operator, quality inspector, design engineer, maintenance technician, and a Six Sigma project lead. This ensures diverse perspectives, reduces bias, and leverages the specialized expertise of each member during problem solving.

However, since this is a simulated DMAIC project, the entire team is only one single member: **Aaron Pedden (Me)**.

For the purposes of this project, I will be acting in multiple roles, including:

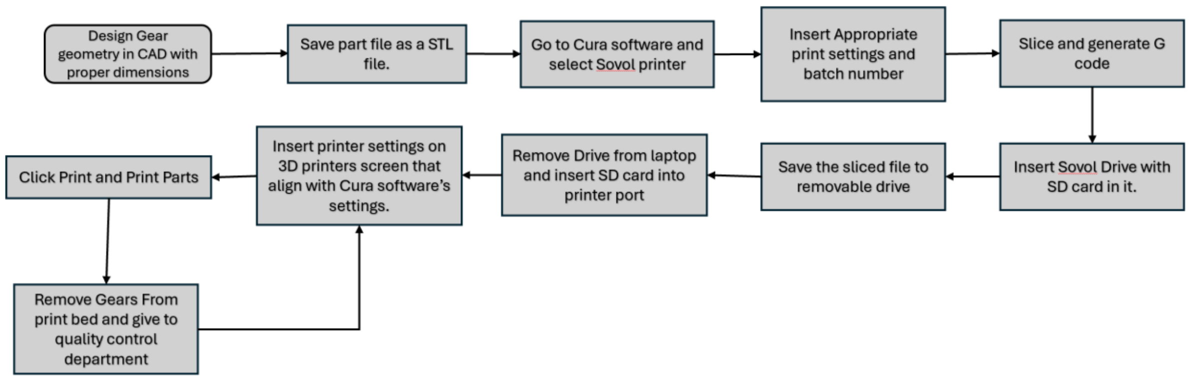
- Process Owner
- Quality Control Department
- Six Sigma Project Leader (Green Belt)
- Subject Matter Expert (SME) for the printing process
- Data Collector / Analyst
- Sponsor / Champion

Although these roles are typically distributed across multiple individuals, they are listed here to complete the project scope in this project environment.

Process Flow Diagram

Below is a medium to high level of the gear 3D printing process. It has a repeated loop which shows that the process repeats once the SD card of the STL file is inserted into the printer. This is because once that happens the file is selectable straight from the printer, so the user doesn't have to start from remaking the CAD file.

DEFINE Process Flow Diagram



Expected Financial Benefits

Avg Time (min)	Avg Visual Check (1-10)	Failure Rate (%)	Defect Rate (%)	Cost per Gear ($)	Money Lost per 35 Gears ($)	Monthly Loss ($)
81.29	4.85	45.71	94.29	0.17	2.77	84.38

Based on the current process performance, each gear costs $0.17 in material and the failure rate of 45.71% leads to approximately $84.38 in monthly material loss. The project's target is to reduce the failure rate to 10%. If this improvement is achieved, the monthly loss would decrease to approximately $18.46, resulting in an estimated monthly savings of $65.92.

Goal Faiure Rate (%)	Money Lost per 35 Gears ($)	Monthly Loss ($)	Predicted Savings per Month ($)
10.00	0.61	18.46	65.92

In addition to material savings, reducing these failures also eliminates wasted print time, which improves overall throughput, and reduces visual inspection effort. Lower amount of defects leads to a more stable process with higher predictability, encouraging a more consistent production schedule. These secondary benefits also increase the overall financial impact beyond the calculated material savings.

Stakeholder Analysis

Milestones

Gantt chart

Define
Weeks: 3

Measure
Weeks: 5

Analyze
Weeks: 6

Improve
Weeks: 6

Control
Weeks: 3

Total: 16 weeks

Gantt Chart

Project Charter

Measure

Analyze

Improve

Control

Conclusion