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Project Title: Implementation of Lean Manufacturing In the Diamond Industry

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Date: 5/09/2025

2. Abstract

The initiative focused on the adoption of lean manufacturing by Jasani, making it the pioneer company within the diamond sector to adopt such practices, and monitoring the effects on increasing production effectiveness. Focus was laid on the rethinking of the traditional departmental flow by the infusion of the lean cellular layout, where the focus remained on the elimination of the unnecessary and the streamlining of the process around the right chokepoint.

Major methods included detailed time studies of all processes, including both setup and processing time. Also, Value Stream Mapping (VSM) was used to determine cycle times, lead times, and value-added ratios as well as to detect wastes across the entire system. Going beyond just time-based measures, VSM also studied physical distances diamonds moved during different processes. Due to the lean cell layout, the distance was significantly decreased, virtually eliminating transportation waste and overall increasing efficiency. Machine ratios of the cell were calculated by these measurements to provide balanced flow. Barcoding systems and cross-utilization of employees were also used to improve flexibility and simplify accounting.

The key outcomes showed remarkable improvement. Output improved by 33%, lead time decreased from 70 days to 27 days with a 15-day target in the future, and 4 hours of daily overtime were removed. Labor needed declined due to increased multitasking and 1-up, 1-down cross-training of the workforce. Space utilization declined with the use of compact cell layouts, and unnecessary accounting was also abolished by electronic tracking. Overall Value-Added Ratio attained 80%, on par with world-class lean leaders.

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4. Introduction

Background Information

The diamond production business is precise, craft-intensive, and time-driven. Even slight imperfections can result in enormous differences in diamond value. Historically, the movement of rough stones into polished stones required separate physical moves as well as separate departments, each having responsibility for different movement in the process. While this process has been effective enough, it can also create delays and inventory pile-ups. Lean manufacturing is an easy way to remove waste, simplify processes, and improve flow. Lean manufacturing was first developed in the automotive sector; using their ideas and integrating them into the production of diamonds, Jasani is the first diamond manufacturing company to use lean cellular manufacturing in the world.

Project Aim

This project looks into Jasani's use of lean manufacturing in diamond production. It focuses on designing lean cells around the 4P machine, which is the intended bottleneck. The project examines machine flow through Value Stream Mapping(VSM). It also evaluates how effective the process is at reducing waste and identifies the processes that benefit the most from lean changes. thereby determining how beneficial lean manufacturing is for the diamond industry.

Objectives

The project should achieve the following objectives:

• Identify the restricted bottleneck: Outline the entire production process using the process mapping (VSM) tool to verify the 4P machine as the planned bottleneck.

•Balance machine ratios: Determine the proper number of machines by stage such that stock accumulation does not happen and smooth flow continues both into and through the bottleneck machine.

•Lean cell layout optimization: Implement a compact, serial equipment layout to reduce the movement of people, save on floor space, reduce the travel of the diamonds through the plant, and permit ease in tallying.

•Increase workforce effectiveness: Utilize 1-up, 1-down cross-training of the workforce to decrease the number of people needed while boosting versatility and flexibility.

•Increase productivity and shorten lead time: Experience definitive gains, such as more produced in volume, less overtime spent, reduced lead times, and less redundant accounting.

Additional information

In diamond production, various technical procedures work together to develop rough diamonds into finished diamonds. A 4P machine is one single-purpose machine that puts four primary phases—fixing, running, smoothing, and bruting—into one system, keeping the range of different machinery to a minimum. Value Stream Mapping (VSM) is employed to examine and improve these procedures. VSM tracks setup time, cycle time, entire process time, and even the distance diamonds move between stations. Long-distance traveling and waiting times are Muda, Japanese for waste, which lean works to condense systematically. To do so, machines and operators are laid out in a Cellular or U-shaped format so that materials flow easily without traversing great distances. Back on the shop floor, actual performance is evaluated via Gemba observation so that data is factual and not assumption-based. The production speed is controlled by Takt Time, which matches production to the requirements of the next person down the supply chain, that being the eventual customer, while the Pull System produces just that which the next phase can take on, avoiding making too much and accumulating excess stock. Lastly, lean focuses on Kaizen, continuous improvement, which translates to many small adjustments that incrementally improve procedures. These methods together facilitate a lean diamond production change, eliminating waste and maintaining high efficiency.

Significance

The value of this project comes from the ground-breaking application of lean manufacturing to a luxury industry that relies heavily on traditional manufacturing methods that emphasize skill and artistry. Lean manufacturing definition is derived from automotive and electronics industries and focuses on reducing waste, optimizing flow, and improving productivity. The application of lean to the diamond manufacturing industry has never been attempted and Jasani has become the first diamond company in the world to utilize lean principles, creating a benchmark from which the industry can no longer ignore both as an industry and in terms of their practices.

A major principle of this system is the creation of the cell with the 4P machine being the controlled bottleneck. By utilizing this robust design, it allows Jasani to not wait for bottlenecks to happen, rather Jasani's 4P machine is at the centre of the lean cell. Therefore, production can be constant as the upstream and downstream processes are designed to operate at the controlled bottleneck or capacity of the 4P machine. In addition, the flow of production - flow - is constant and minimal queueing occurs whereby the system remains in balance. Value Stream Mapping plays a crucial function within the design process because it helps ensure that the correct number of machines are used in the design and the sequences are optimum for supporting the cell design.

This study offers clear direction concerning boundaries of lean. Specifically, the difficulty of attempting to integrate planning into the cell produced more variability and unnecessary inefficiencies, whilst polishing and all related finishing processes could not be included into the lean cell because of the organic variation associated with diamonds.

5. Literature Review

The Toyota Production System (TPS) was the first system to describe the concept of lean manufacturing, which emphasizes the elimination of waste, enhanced flow, and value creation to the customer (Ohno, 1988). Womack, Jones, and Roos (1990) popularised the concept within the book, The Machine That Changed the World. They identified five core lean principles of specify value, map the value stream, create flow, establish pull, and strive for perfection. These principles have become dominant within the scope of the manufacturing sector and have been expanding into the non-industrial sectors such as the service and healthcare sectors (Holweg, 2007).

A fundamental concept of lean is balancing bottlenecks. Goldratt's Theory of Constraints (1990) stipulates that every system will contain at least one constraining factor that dictates the overall system's workings. Efficient lean systems don't seek to eradicate the absence of bottlenecks altogether. Rather, they engineer the processes with the chosen restriction determining the production rate. This aligns very much with Jasani's practice of deliberately making the 4P machine the restriction of its diamond production cells.

Additional research indicates that cellular manufacturing can enhance efficiency as well. Black (2007) explains that it is possible to group processes into autonomous cells that result in smoother movement of materials, reduced waiting times, and lower stocks. Value Stream Mapping by Rother & Shook (1999) is also typically utilized here. It makes process flows understandable, determines wastes, and levels the workloads of the machines and operators. Researchers also point out that VSM is more than just timing analysis and also emphatically illuminates movement of materials and distance traveled, directly linking to the lean wastes of transportation and motion. These methods directly provide clear indications of how to apply lean to more complicated production situations.
Yet lean works differently within highly variable industries. Hines, Holweg, and Rich (2004) contend that lean does well with high-volume, certain conditions, but issues develop if the product is highly customized or if the raw materials change unpredictably. Luxury and artisan sectors have shown that lean can make the organization more efficient but needs modifications, particularly the leanness of which processes versus those that must remain adaptable (Shah & Ward, 2007).

There is good precedent-based literature on lean production more broadly, but very little on diamond production application of lean. Diamond production is distinct from typical commodities due to the range of size, shape, hardness, and inclusion within diamonds. This makes it challenging to apply lean practices, especially where flow and fixed cycle times are concerned. Focusing on Jasani's creative application of lean to diamond production, our project seeks to fill the void and shed new light on the application of lean to highly customized and variable production situations.

6. Preparation (200 words)

Planning

Resources and Training

The project began by having a concentrated learning phase in which I studied lean manufacturing. Since the concept of lean manufacturing had not been implemented in diamond making at all, it became necessary for me to research and learn the very basics fully before trying to introduce a cell. For two or three months, I read extensively on the concepts of lean production. I studied how to eliminate waste, how to design production flow, value stream mapping, and the effect of controlled production by bottlenecks.

On this groundwork having already been laid, I proceeded to plan how the concepts would be implemented in diamond production. It was my aim to establish a cell production system that put all the concerned activities together and had the 4P machine as the selected bottleneck. As I proceeded to plan, I came up with a conceptual model of the cell. As a prior-to-implementation simulation of the new flow, I had a U-shaped cellular layout created using cardboard and thermocol. This small model facilitated my visualization of machine locations, movement of materials, and operator interactions. The planning eased the conversion of departmental workloads to lean cells and minimized the chances of mistakes.

Timeline

The preparation period arrived on schedule:

•Months 1-2 (≈25 hours): I studied lean manufacturing foundations through mentoring by an IIM faculty and studied the practices and case studies by Toyota. This period proceeded just as scheduled.

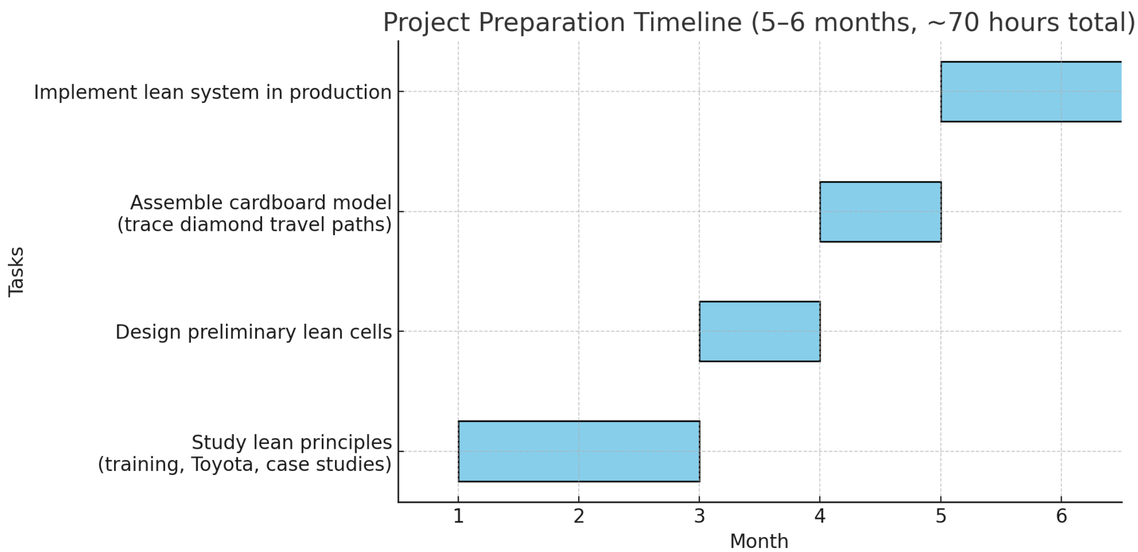
•Month 3 (≈10 hours): I defined the first lean cells. This was completed on schedule with no deviations.

• Month 4 (≈15 hours): I created a cardboard U-shaped model and drafted diamond travel routes to approximate distances. It took a bit longer than planned in this step because more tweaking was necessary to achieve realistic flow.

•Months 5–6 (≈20 hours): The lean system has already been validated in real production. Implementation continued through month 6 rather than concluding at month 5 since there was a greater amount of validating and balancing needed.

Gantt chart

7.



Methodology

Approach

The methodology started by calculating the time of every diamond production cell procedure. Operator movement and cycle times were accurately observed directly by Gemba walk on the shop floor, supported by stopwatch studies and cardboard simulation. The machine and operator times were accurately accumulated over many trials to be able to calculate the averages and reduce errors. We also quantified the movement of the diamonds inside the plant by the implementation of VSM in an effort to determine unnecessary movement. These unwanted movements of diamonds between different departments were revealed as Muda, depicting transportation and motion waste. These readings helped greatly in clearly showing the amount of time every procedure took in the entire production flow.

From these, the following that could be ascertained next were which of the processes were the ones which would become the bottlenecks. Calculating this took both the time that it took as well as where along the production chain that the process appeared into account. Processes that appeared later along the chain were afforded more chance of becoming the bottlenecks because late-occurring issues have lower probabilities of gathering great stockpiles of partially formed diamonds.

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Experimental design

The experimental layout focused on procedures that could be reliability studied within a lean environment. These processes were Galaxee scanning, planning, laser sawing, weighing and division, 4P fixing, 4P operation, table smoothing, final bruting, and polishing. Traveled distances between procedures were also recorded, since unnecessary travel is a type of Muda (waste).

For each process, stopwatch measurements were repeated continuously to capture setup time, machine time, and operator time. These were averaged to obtain reliable total times for intercomparison. Independent variable was the process under investigation while total time taken per piece was the dependent variable. Controlled conditions were maintained by using comparable production conditions, comparable class of rough stones, and comparable operating practices for operators.

The data thus obtained were then juxtaposed across several process lines to establish which phase will be the lean system's best bottleneck phase. It is such analysis that formed the basis on which a Value Stream Map (VSM) could be produced.

Materials and equipment

Considering these factors, Value Stream Mapping (VSM) was conducted to illustrate the flow and quantify the distinction between value-added and non-value-added activities. This comprehensive analysis of time data and process placement led to the identification and confirmation of the 4P machine as the most effective bottleneck within the lean system.

In order to pursue this task, a combination of elementary measuring instruments, digital tools, and simple prototypes was used to record, study, and visualise data. A stopwatch was utilised to record setup time, machine time, and operator time for every process, facilitating calculation of exact averages. Complementarily, production logs and worksheets were carefully laid out to record processed numbers of diamonds, rough weights of diamonds, and products of every process. Further, inventory counts were carefully tracked to quantify waiting times and work-in-progress (WIP) between different phases.

The barcode system of the company played a significant role in eliminating manual counting that was not necessary while ensuring that detailed traceability of diamonds at each stage was precise. In the phase of designing and analyzing, Microsoft Excel was used to bring together recorded times, calculate average values, and produce graphs, such as bar graphs. In addition, I applied Google Drawings to create visual renderings of lean cells and value stream maps. In order to support digital efforts, a cardboard model was made, physically bringing to reality the lean cell design proposed, helping to understand placement of machines, movement of operators, and flow of diamonds before implementation took place.

Procedure

The journey of this project commenced with the identification of the production stages that would constitute the lean cell. Processes such as laser sawing, weighing and splitting, 4P fixing, 4P operating, table smoothing, and final bruting emerged as the focal points of the study. Meanwhile, planning, Galaxee scanning, and polishing were set aside for this phase, allowing the analysis to move forward solely with those processes amenable to testing within a stable lean framework.

After establishing the scope, stopwatch measurements were made for every process. Several repetitions were obtained to cover setup times, machine times, and intervals of operator engagement. Data was recorded manually prior to being entered into Excel, where the removal of outliers gave calculated means to result in total time per process that formed a base of comparison. Waiting times were also approximated by looking at work-in-progress between stages and dividing it by daily demand to reflect delays in time units.

Once the data was processed, a preliminary review took place to identify which processes consumed the most time. Initially, it appeared that laser cutting might present a potential bottleneck; however, deeper analysis unveiled that the 4P machine was the most effectively designed bottleneck. Subsequently, a Value Stream Map (VSM) was crafted in

Google Drawings, with each process depicted alongside its respective times, while the flows of material and information were illustrated with connecting arrows. Work-in-progress was noted between processes, and a timeline was incorporated at the bottom to compute the total lead time and the value-added ratio.
In light of these results, the cell was crafted with the 4P machine identified as the bottleneck. Careful attention was paid to balancing machine counts to avert delays from other stages, and the prospect of a double-cell arrangement was contemplated for instances where multiple diamonds could be extracted from a single rough stone. To further aid in visualizing the arrangement, a cardboard model was constructed, allowing for an examination of operator movement and material flow prior to implementation. Workforce considerations were thoughtfully incorporated by designating multitasking roles in areas where machine time extended, while ensuring that workers were cross-trained one-up and one-down to sustain flow in the event of absenteeism. Ultimately, barcode scanning replaced manual counts, delivering traceability without disrupting production.

Safety and ethical considerations

Safety emerged as a paramount concern throughout the duration of this project, particularly due to the high-powered machinery involved and the substantial value of the materials at stake. Standard operating procedures were meticulously adhered to during each observation and measurement activity, aimed at minimizing risk for both operators and observers alike. When utilizing stopwatches to gather cycle time data, great care was exercised to maintain a safe distance from machines such as lasers and the 4P system, which could pose significant physical hazards if mishandled. Workers were specifically instructed not to disrupt their normal routines during observations, ensuring that safety practices remained unyielding in the pursuit of data collection. Furthermore, the cardboard model of the cell was crafted as a risk-free means to visualize flow and operator movement before any physical rearrangements took place.

Ethically, confidentiality and transparence were scrupulously respected throughout the procedure. No operator personal identifiers were recorded, and the collection of data focused entirely on process performance and not on personal outputs. The use of barcode scanning made it possible to track traceability of the diamonds without creating a superfluous administrative burden or taking a risk of loss. Ethical accountability also involved presenting findings accurately with no manipulation of the data and ensuring recommendations respected workers' wellbeing, as well as respect for company assets. In such a way, the project stayed committed to safety standards, as well as to ethical standards.

8. Results

Data presentation and Observations

To understand the results, some additional variables need to be defined in order to find the VSM these variables are listed below, as well as the formulae used to find them.

- Cycle Time (CT): Actual processing time it will take for one individual unit.
- Setup Time (ST): Time required for setup before processing.
- Total Time (TT): Setup time plus the time of one unit's cycle.
- Lead Time (LT): Overall time the unit has in the system, including waiting caused by the WIP.
- Value-Added Time (VAT): That portion of the time that adds value to the product directly (CT equivalent).
- Non-Value-Added Time (NVAT): Additional time not adding value, for example, waiting or idle time.
- Value-Added Ratio (VAR): Indicates the performance by demonstrating the proportion of value-adding time with respect to the total lead time.
- Travel Distance (TD): The actual distance traveled by a diamond between successive operations, a vital parameter of finding motional and transportation wastes.

I calculated the VSM using these formulas.

- **Cycle Time (CT)** = Processing time per unit
- **Setup Time (ST)** = Preparation time
- **Total Time (TT)** = ST + CT
- **Lead Time (LT)** = TT + WIP/Daily Demand
- **Value-Added Time (VAT)** = CT
- **Non-Value-Added Time (NVAT) =** LT − VAT
- **Value-Added Ratio (VAR)** = VAT/LT x 100

1) **Avg. Setup Time (AST)** for 4P Fixing (setup Values: 33, 32, 23, 24, 17, 24, 57 s

Calculation: AST=(33+32+23+24+17+24+57)/7=210/7=30.00

2) **Average Processing Time (APT)** for Weighing and Division

Values: 15, 16, 12, 17, 15, 14 s

Calculation:APT=(15+16+12+17+15+14)/6=89/6=14.83

3) **Average Total Time (ATT)** for Laser Sawing

As Given: Avg Setup = 125.40 s, Avg Processing = 1145.20 s

Calculation: ATT=AST+APT=125.40+1145.20=1270.60 s

4) **Value-Added Time (VAT)** for Table Smoothing

Values: 125, 102, 119, 182, 118, 195, 145, 60 s

Calculation (processing only): VATAPT=(125+102+119+182+118+195+145+60)/8=1046/8=130.75 s

5)**Non-Value-Added Time (NVAT)** for Planning

Average Setup Time = 1018.60 s

Average Processing Time = 277.80 s

Calculation: NVAT = Setup Time = 1018.60 s

6) **Value-Added Time (VAT)** for Planning

Value-Added Time (VAT) = Processing Time = 277.80 s

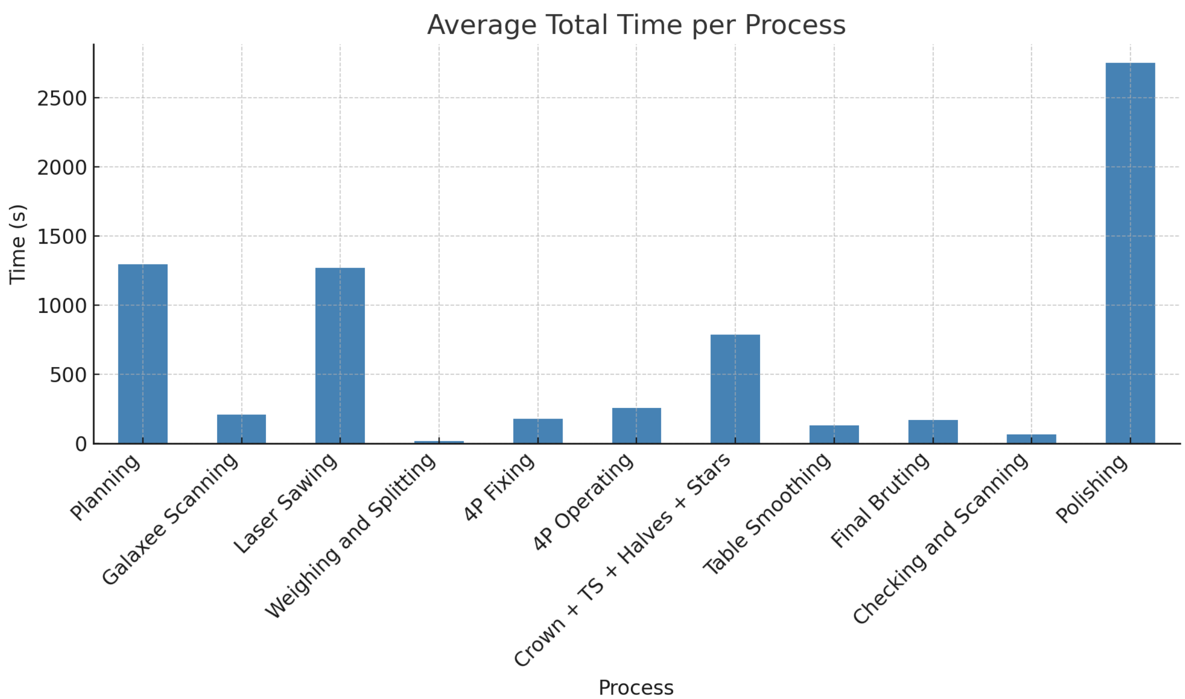
Total Time = Setup + Processing = 1018.60 + 277.80 = 1296.40 s

Process	Avg Setup Time (s)	Avg Processing Time (s)	Avg Total Time (s)	Value-Added Time (s)	Non-Value-Added Time (s)	Value-Added Ratio (%)
Planning	1018.6	277.8	1296.4	277.8	1018.6	21.43
Galaxee Scanning	0.0	209.5	209.5	209.5	0.0	100.0
Laser Sawing	125.4	1145.2	1270.6	1145.2	125.4	90.13
Weighing and Splitting	0.0	14.83	14.83	14.83	0.0	100.0
4P Fixing	30.0	147.29	177.29	147.29	30.0	83.08
4P Operating	45.38	209.63	255.01	209.63	45.38	82.2
Crown + TS + Halves + Stars	0.0	787.8	787.8	787.8	0.0	100.0
Table Smoothing	0.0	130.75	130.75	130.75	0.0	100.0
Final Bruting	0.0	167.625	167.625	167.625	0.0	100.0
Checking and Scanning	0.0	63.625	63.625	63.625	0.0	100.0
Polishing	0.0	2752.5	2752.5	2752.5	0.0	100.0

Calculation: VAR = 277.80/1296.40 x 100 = 21.43%

1. Data Table – Final VSM Metrics for All Processes

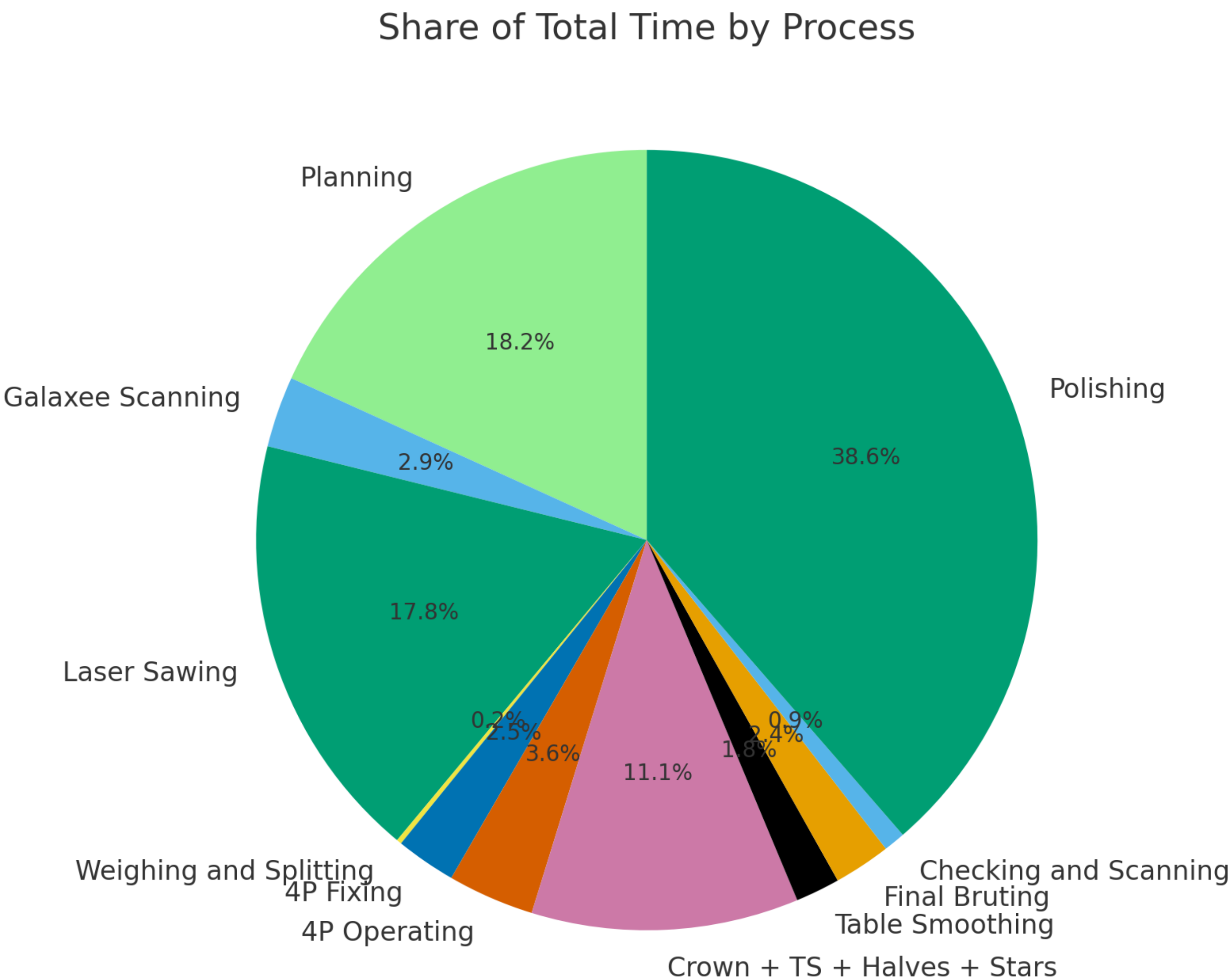
The table of VSM metrics elegantly details the average setup time, processing time, and total time for each process, alongside the value-added time, non-value-added time, and the calculated value-added ratio. It vividly illustrates the relative scale of each process, revealing that operations like polishing (2,752.5 seconds) and planning (1,296.4 seconds) have significantly larger total times in contrast to smaller processes such as weighing and splitting (14.8 seconds). In summary, the overall value-added ratio across all processes stands at approximately 80%.



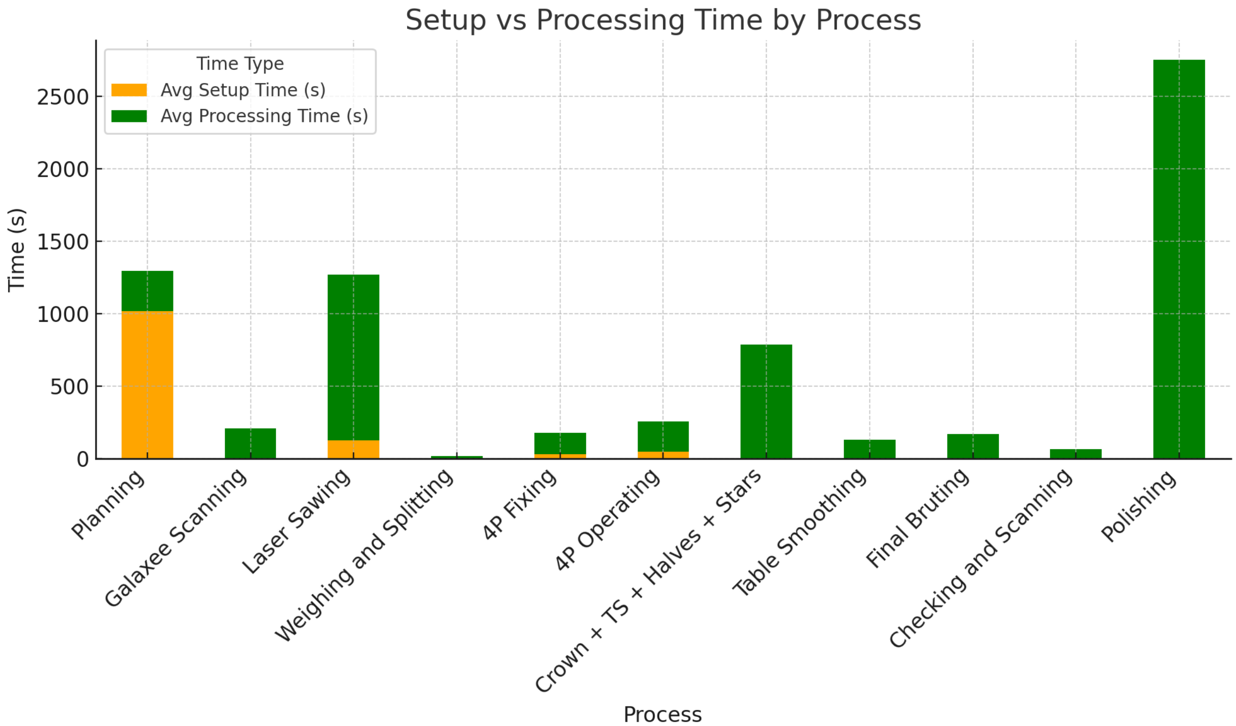
2. Average Total Time per Process Bar Chart (All Processes)

The bar chart represents average total time for each process for the total value stream. The highest bar is for polishing (2,752.5 s), followed by planning (1,296.4 s) and laser sawing (1,270.6 s). Short processes such as splitting and weigh- ing (14.8 s) are shown with extremely thin bars, meaning their total times are many times smaller than those of major processes.

3. Pie Chart – Percent of Total Time by Process (All Processes)

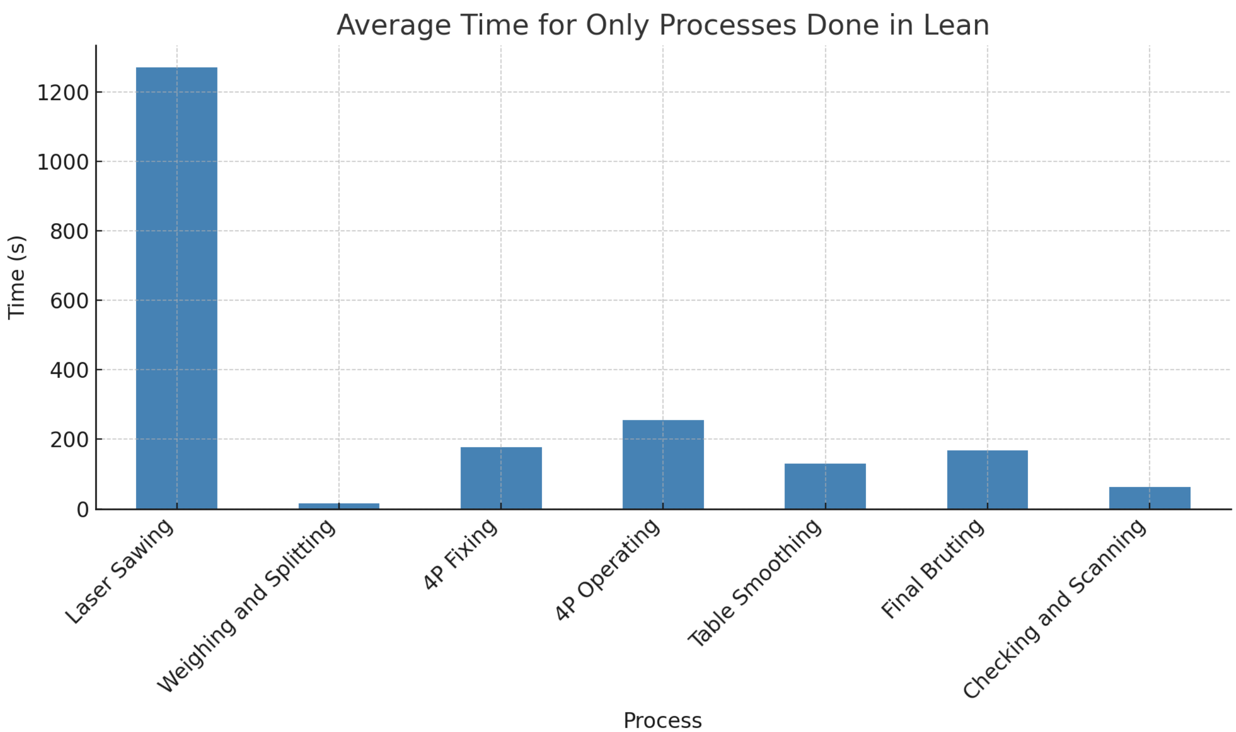


The pie chart shows the fractional amount of total time devoted to each process. Polishing occupies roughly 39% of it all, with planning (18%) and laser sawing (18%) being other large shares. Less than 1% of the chart represents the weighing and splitting. The planning wedge of the chart is shown in light green to draw attention to it.



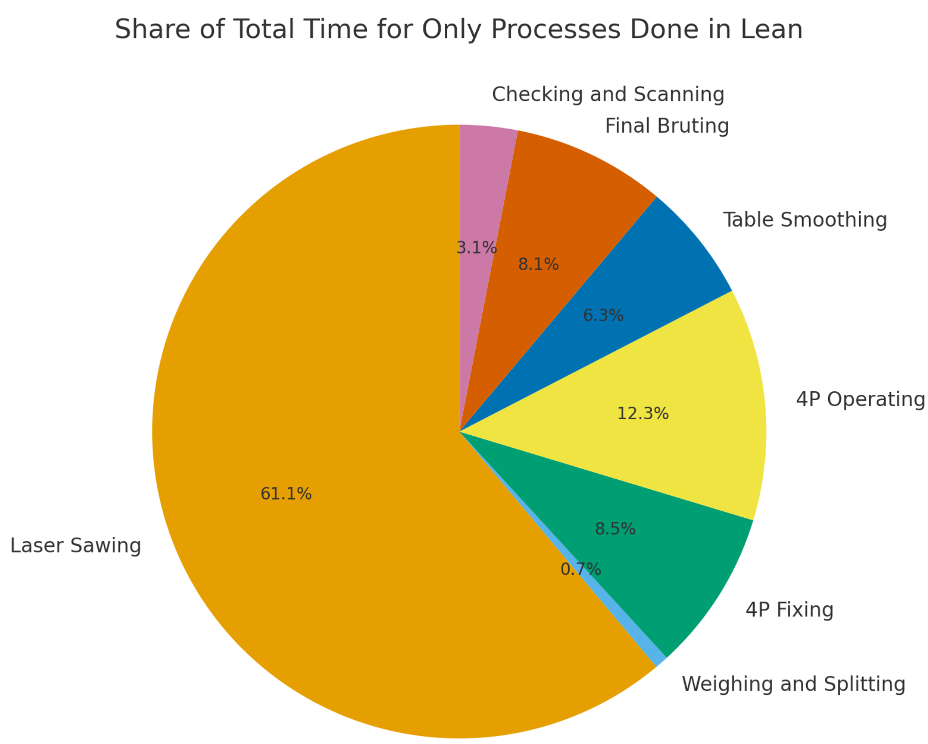
4. Stacked Bar Chart – Setup vs Processing Time by Process (All Processes)

The stacked bar chart disaggregates every process into setup time and contribution to processing time. Processes such as polishing, splitting and weighing, and Galaxee scanning present bars composed wholly of processing time. Conversely, planning has a large setup time of 1,018.6 s with 277.8 s of processing, while laser sawing is characterized by strong processing at 1,145.2 s with a setup of 125.4 s.



5. Bar Chart – Only Average Time for Processes Carried out in Lean

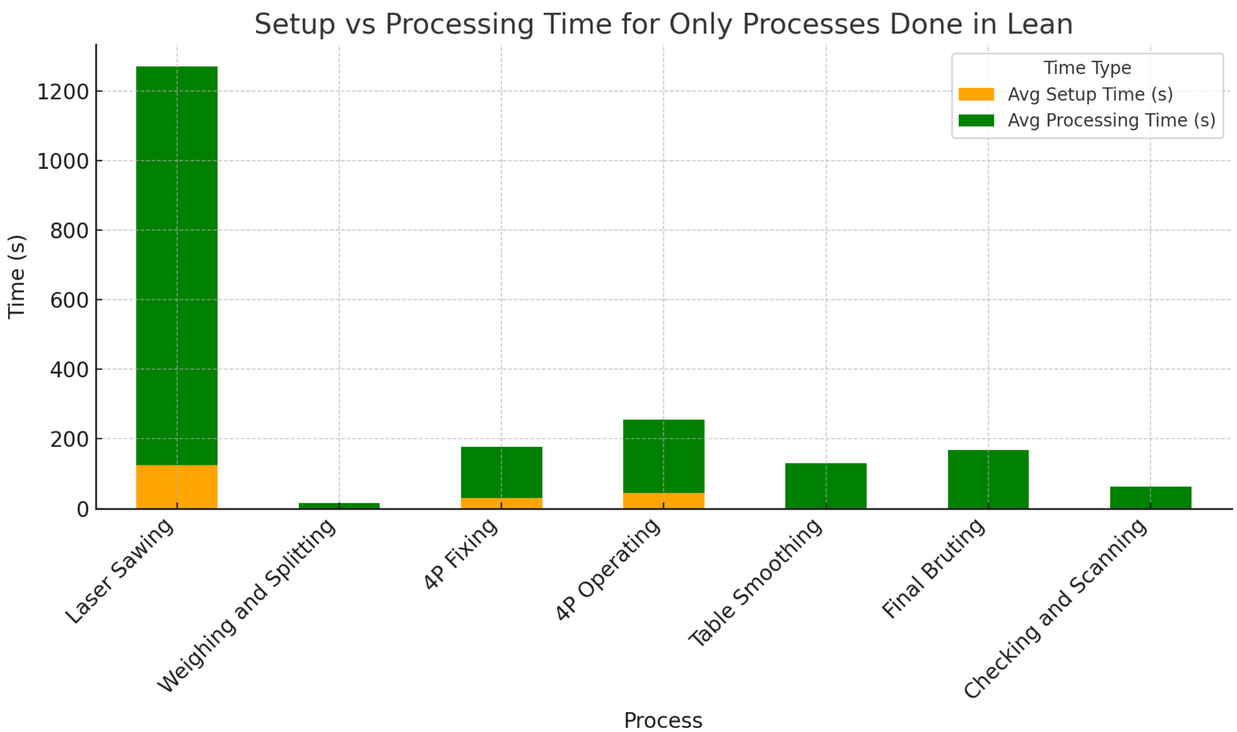
It shows average total time for processes contained in lean cell. These processes with maximum average times are laser sawing (1,270.6 s) and final bruting (362.0 s), while minimum average time is for processes of weighing and splitting (14.8 s). Between these two extremes, there are 4P fixing and 4P operating.



6. Pie Chart – Percent of Total

Time for Only Processes Performed in Lean

The lean process pie chart shows how much of overall time is contributed by each of these processes. Laser sawing takes a huge lead with around 61%, followed by final bruting (17%) and 4P operating (12%). Weighting and splitting takes up below 1% of lean percentage.



7. Stacked Bar Chart – Setup vs Processing Time for Only Processes with Lean

The stacked bar chart for lean processes breaks down total times into setup and processing components. Weighing and splitting (14.8 s) shows only processing time. Final bruting displays a larger setup component (194.4 s) compared to its processing (167.6 s), while 4P operating shows the reverse with 209.6 s processing and 45.4 s setup.

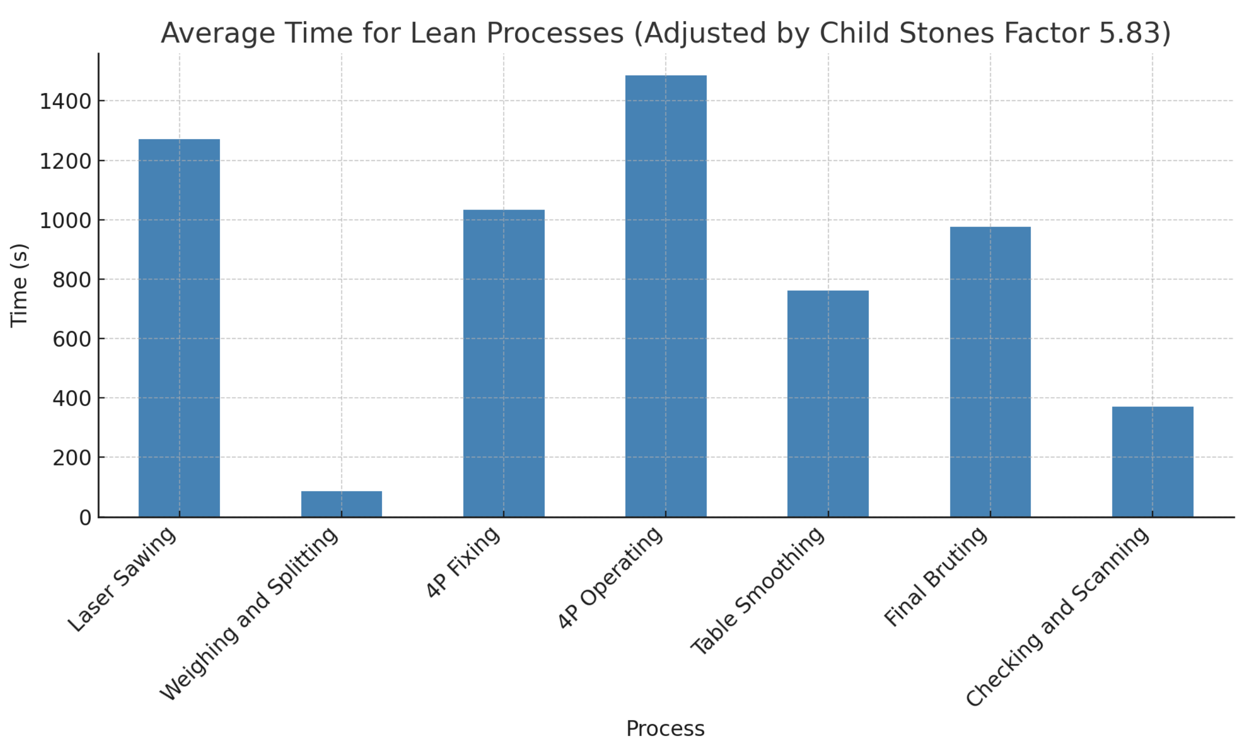
9. Discussion

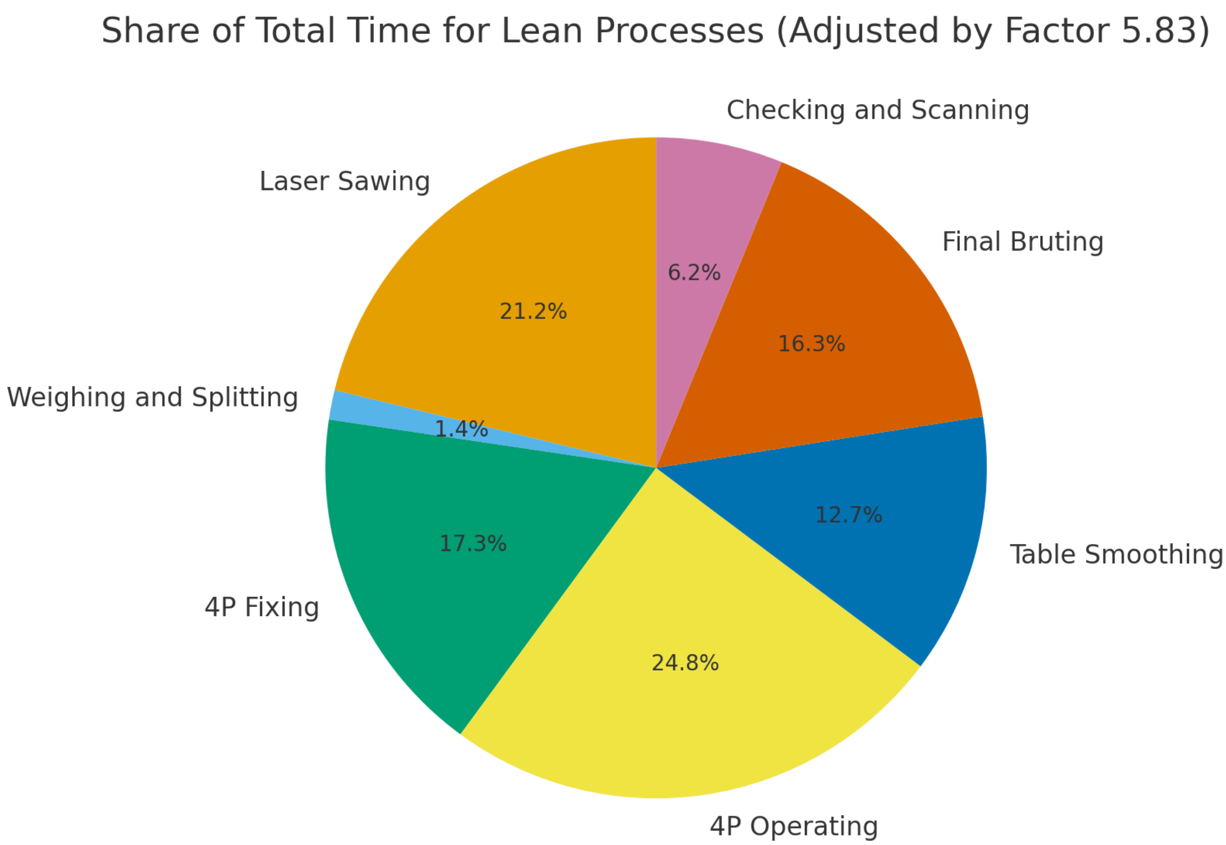
Interpretation

While it would seem that sawing with lasers consumed the largest average total time of 1,270.6 seconds to do so, it never really was the system's limitation. Instead, it was the 4P machine that constituted its actual constraint. It is that sawing with lasers operates with one rough stone to generate multiple child stones and essentially adds inputs to other subsequent processes downstream. In average terms, a single rough diamond has approximately six child stones that would translate into a required adjustment of the perceived time consumed by sawing with lasers to account for downstream flow. Multiplying the time consumed by subsequent stages by their number of outputs by which it is generated in sawing makes their resultant workload augment by a great deal. Hence, whilst individually sawing with lasers has the longest cycle time, it ends up being the 4P machine—to account for several critical steps for every child stone—that is the system's actual limitation by overall throughput, thus the 4P being the limitation.

A corresponding improvement led to the decrease of distance traveled. Before, diamonds were transferred between distinct departments, which involved long routes. With the cell layout of lean, the distance fell considerably, reducing transportation waste, handling, and lead time significantly. It indicates the elimination of both movement and time inefficiencies by lean. The next area of focus is on productivity improvement, which revealed that production grew by 33%, lead time fell from 70 to 27 days, and four hours of daily overtime were eradicated. These outcomes were reinforced by a companywide Value-Added Ratio of 80%, on par with world-class lean standards. Flexibility of the workforce enhanced by multitasking and cross-training also resulted, and utilization of spaces declined with the result of compact cell layout.

if we adjust the data by multiplying each process after the lazar we attain this graph and pi chart this is much easier understood





In the bar chart, 4P Operating exceeds 1,487 s, far surpassing Laser Sawing at 1,270.6 s. The pie chart confirms this, showing 4P Operating dominating lean time share, clearly showing that the bottleneck process is 4P

The value-added ratio (VAR) also explains the concept of efficiency. Take Weighing and Splitting, for instance, with an incredible VAR of just approximately 100%, or Laser Sawing with just shy of 90% VAR; these activities present exemplary efficiency, spending the greater percentage of time actually adding directly to the product's production. In stark contrast, Planning is very setup-intensive, taking 1,018.6 seconds to setup but only 277.8 seconds to process, thus securing a comparatively very low VAR of just 21.4%. It accounts for the reason that planning remained excluded from the lean cell, as it has much non-value-added time and generates variability to the process. Otherwise, the 4P machine handled the production rate excellently, generating a Pull System that harmonized upstream and downstream operations with its capabilities.

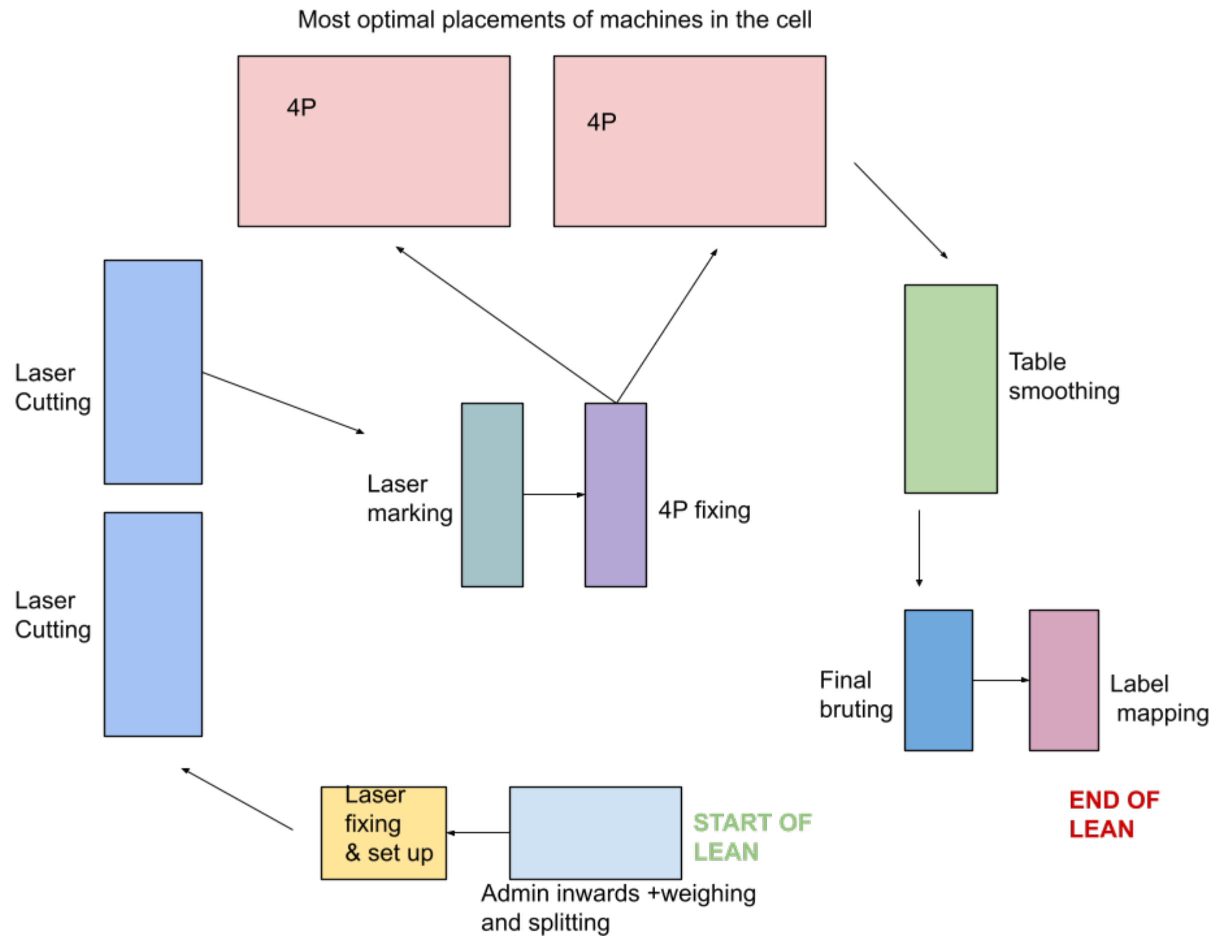
The other significant interpretation emerges when one contrasts non-lean processes with their lean counterparts. Collectively, the lean processes amount to roughly 2,080 seconds, while the excluded stages, such as Polishing, taking up 2,752.5 seconds, and Planning, consuming 1,296.4 seconds, extend the duration by several times. This juxtaposition underscores the necessity of selecting processes that benefit from integration with the lean methodologies, keeping any variables or uncertain phases outside the cell. Ultimately, the total system time exceeds 7,800 seconds, with around 80% of the jobs adding value. By designing the lean cell around the 4P machine, which acts as the bottleneck, the workflow adheres to lean principles, focusing on waste elimination and ensuring a seamless flow through essential stages.

These productivity improvements and cross-training of the operators constitute the Kaizen, or continuous improvement, that forms the backbone of lean transformation sustainability.

In order to be sure that the 4P machine would be the lean cell's constraint, the number of machines on every phase of the production line was chosen by calculating the average time per piece. We used the 4P Operating stage as the reference point, with the average cycle time = 255 sec./child stone. Upstream process times were normalized to the per-child basis. Laser Cutting, e.g., has 1,270.6 sec./raw, on average, however, every raw diamond will produce 5.83 child stones, so the effective per-piece time becomes 1,270.6 ÷ 5.83 = 218 sec./child, which is ever so slightly lower than the reference point 4P Operating. Others showed much lower times per-piece: Weighing and Splitting = 14.8 sec., 4P Fixing = 177 sec., Table Smoothing = 131 sec., Final Bruting = 172 sec., Checking and Scanning = 64 sec. With the ratio formula machines needed = ceiling(process time ÷ 255), Laser Cutting will need 1 (218 ÷ 255 = 0.86), 4P Fixing also will need 1 (177 ÷ 255 = 0.70), Table Smoothing 1 (131 ÷ 255 = 0.51), Final Bruting also 1 (172 ÷ 255 = 0.67), Checking and Scanning 1 (64 ÷ 255 = 0.25). Still, since Laser Cutting feeds directly into the bottleneck, but also due to the philosophies of not daring to produce inventory ahead of a slow stage when an upstream stage could benefit by accelerating, an additional Laser machine is assumed, taking the number to 2 Lasers, in an effort to smooth flow and not over-build the WIP. Similarly, 2 machines are assumed for 4P Operating to add robustness but also be sure of the throughput, losing the focus that it is still the true constraint of the system. The above procedures, e.g., Admin inwards and Laser fix/setup, just require 1 station respectively to supply Laser steadily.

The final configuration is therefore determined thus: Admin 1, Laser 2, Weighing 1, 4P Fixing 1, 4P Operating 2, Table Smoothing 1, Final Bruting 1, and Checking and Scanning 1—so that no stage aside from 4P is a bottleneck. Having determined the number of all the machines required per cell, the next thing that we need to work out is the optimum location of every machine within the cell.

implication



The placement of machines within the lean production cell is crafted with meticulous attention to detail, ensuring a seamless and continuous flow that eliminates unnecessary movement while avoiding the entanglement of lines or zig-zags. Each process is arranged in a sequential manner, allowing the output from one machine to directly feed into the input of the next, without requiring workers to abandon their stations or traverse the cell. The adoption of a U-shaped cellular layout further minimizes floor space usage and shortens the distance diamonds need to travel, thus enhancing both efficiency and compactness of design. This thoughtful arrangement significantly reduces wasted time associated with transportation and handling. To optimize space, smaller machines—such as weighing, splitting, fixing, and checking—are strategically positioned toward the center of the cell, while larger machines like lasers and the 4P units encircle them, creating a compact yet functional layout. This central configuration effectively utilizes floor space, maintaining a circular workflow that keeps the beginning and ending points of production in close proximity to one another. Such a design simplifies the tallying of goods, enabling diamonds to be scanned, barcoded, and accounted for without the necessity of covering extensive distances. Furthermore, an ergonomic layout allows operators to multitask as required, providing immediate feedback should any errors arise. By carefully balancing flow, space, and accessibility, the cell design not only minimizes waste but also enhances worker efficiency, safety, and accountability.

Comparison with Literature

The results of this project are in alignment with the ground-level principles discussed in lean manufacturing texts, yet also emphasize the distinctive modifications required for the diamond sector. Ohno (1988) emphasized recognizing bottlenecks and flowing through the slowest process as keys to lean success. This project substantiated that rule by demonstrating how, even though Laser Sawing had appeared most time-intensive at the outset, the actual bottleneck was the 4P machine, on which the whole cell focused its flow. Similarly, Womack and Jones (2003) argued that lean systems seek the elimination of waste and minimization of lead time through the synchronization of processes; the lead-time reduction from 70 to 27 days in this study illustrates that synchronization.

Yet previous studies largely focus on stable input industries, for example, the automotive and electronic sectors. Diamond production, on the other hand, has raw materials whose quality, size, and hardness are not uniform. This intrinsic variability made activities such as planning and polishing not fit for inclusion in the lean cell. This development supports Liker's (2004) argument that the principles of lean need to be contextuated rather than uniformly applied. Jasani's distinction as the initial diamond company implementing lean manufacturing illustrates the successful transfer of theory to practice with the potential to expand the application scope of lean in the field of producing luxury goods.

10. Success of the Algorithm

Performance Measures

To measure the efficacy of the algorithm and the lean rollout, performance was monitored against both technical and operational dimensions. Traditional lean indicators such as throughput time, lead time, Value-Added Ratio (VAR), and Non-Value-Added Time (NVAT) were calculated based on Value Stream Mapping (VSM) data. Machine usage percentages and worker usage were monitored to maintain the 4P machine as the true bottleneck and have the rest of the processes have sufficient capacity. Inventory buildup reduction was validated by verifying the Work-in-Progress (WIP) stock quantities before and after the bottleneck.

Performance indicators also comprised:

- The production volume increased by 33%.
- The overtime hours were decreased from 4 hours to zero since the new workflow evenly distributed the load.
- The lead time diminished by 70 days per diamond set to 27 days, and 15 days will become the target in the very near future.
- Interdepartmental diamond counting and intermediate accounting were eliminated by barcoding, which decreased unnecessary administrative activity.
- The man-vehicle hour required diminished since the operators could manage procedures one step up and one step down due to cross-training and multitasking.
- Space utilization decreased considerably by the use of the tight cell layout, again verifying the effectiveness of the lean methodology
- Distance traveled by diamonds within the plant was reduced to the minimum, verifying elimination of transport and movement wastes.

Results

The Lean implementation driven by algorithm resulted in quantified gains in the performance of production. Total output improved by 33%, and the time spent on completing one complete set of diamonds reduced from 70 days to 27 days, with an aim to reduce this further to 15 days. Overtime, which used to average 4 hours daily, was eradicated totally. Departmental accounting elimination and intermediate counts of the diamonds through the use of the barcoding system reduced avoidable administrative activities and enhanced traceability. The cell structure also lowered the total number of employees required, as most became multi-skilled and trained to work on machines one step previous or following their major process. This not only reduced the size of the workforce but also enhanced skills. Another thing the cells did was to compress space demand, further buttressing the lean improvements in efficiency.

Comparison

Jasani's algorithm-based lean implementation adheres to sound principles of lean but adds distinctive innovation. It focused on identifying bottlenecks, eliminating waste, and flowing continuously, in line with the Toyota Production System (Ohno, 1988). The algorithm determined the 4P machine as the primary bottleneck, similar to the slowest stage identified by lean. Parallel machines, such as doubling laser and 4P, avoided WIP accumulation and kept the balance, similar to best practices described in the lean literature (Womack & Jones, 2003) of smooth flow with the avoidance of secret bottlenecks.

Jasani's implementation shows measurable business outcomes in a variable industry. Unlike automotive parts, diamonds vary in hardness and cutting plans, complicating lean adaptation. The algorithm excluded unpredictable processes like planning and polishing from the lean cell. Real-world results were transformative: production rose by 33%, lead time fell from 70 to 27 days, and overtime was eliminated. Compact cell layouts saved space, and barcoding reduced administrative work. Cross-training improved worker flexibility, skill levels, and labor efficiency. State-of-the-art lean implementations register 75–85% value-added ratios. Jasani's lean cell hit 80% VAR. In contrast to most other industries, gains resulted in quantifiable business advantages: reduced throughput times, lower man-hours required, and improved profitability with its competitors in the highly competitive diamond market. Having been the initial diamond facility implementing lean manufacturing, Jasani met industry standards and demonstrated the flexibility to apply the principles of lean to the making of luxury goods with quantifiable market effects.

Challenges

Algorithm development and testing also encountered some challenges. One challenge involved the long learning curve for the principles for lean production, where months of training were needed before the team could efficiently implement the principles in the production of diamonds. Another challenge was the integration of planning, Galaxee scanning, and polishing in the lean cell, where the integration created variability and inefficiencies, hence the elimination. Another crucial challenge was the gathering of correct time data for all the processes where the errors would misestimate the bottleneck. Setting the adjustment factor for the child stones was also imperative where misestimating laser sawing outputs would misalign the bottleneck. Another challenge was the training of the workers where the employees needed to be cross-trained for the different machine operations and initial resistance to the new role was observed. Finally, cell layout design for optimal flow with minimal wasted space needed several iterations. Overcoming these challenges ultimately enhanced the performance of the algorithm.

11. Conclusions

Summary of Findings

This project revealed that the principles of lean manufacturing could be adeptly applied to the realm of diamond production, with the 4P machine recognized as the essential bottleneck around which the cell must be organized. By analyzing setup, processing, and total times via Value Stream Mapping, processes like planning and polishing were pinpointed as unsuitable for lean integration. The final design of the lean cell improved the flow, eliminated unnecessary inventory, and balanced machine counts to avert WIP buildup. Among the additional advantages were reduced space usage, streamlined accounting through barcoding, cross-trained workers, and an increase in overall efficiency. These findings affirm that lean concepts, when thoughtfully tailored, can significantly enhance performance in industries characterized by high variability, such as diamond manufacturing.

Project Success

The project attained its key objectives. Volumes of production increased by 33%, overtime came down from 4 hours to zero, and lead time came down from 70 days to 27 days with the target of reaching 15 days. Inventory buildup was prevented, and the plant became more productive, shown by an 80% Value-Added Ratio, the world-class lean standard. Employee competence was expanded by the acquisition of more skills by cross-training and by doing multiple jobs, so with fewer employees, the plant became more productive. Space requirements also came down by virtue of the space-efficient cell layout. Lean manufacturing also has instant feedback between stages: if something isn't working right on a machine, the problem is highlighted instantly by the next stage. This enables quick identification of issues and correction prior to the production of a large lot of diamonds, thus minimizing rework and scrap. Overall, the design incorporating the algorithm succeeded in balancing the system such that the 4P machine remained the controlled bottleneck and also minimized waste and achieved quantifiable operational improvements and business benefits.

Future Work

Additional research could include investigating the possibility of further lead-time reduction to the hoped-for 15 days by streamlining cycle times in the latter stages of production. Additional avenues for future research would include investigating the possibility of partially standardizing or semi-mechanizing the polishing procedures, moving in the direction of greater accordance with the lean ideals. Furthermore, the algorithm itself has the possibility of streamlining by the use of real-time data collection, allowing for the dynamic adjustment of the chokepoints as conditions change. Future research can include the quantification of the exact distance reduction (in meters) by the use of RFID tags or by real-time sensors, providing one more dimension to the VSM analysis. Scalability to multiple production lines or plants would serve to test its robustness. Finally, comparative studies between Jasani's lean diamond cell and other high-end items industries may prove enlightening, stretching the applicability of the lean methodologies to situations where variability and precision come secondary to thought of consideration.

12. Personal reflection

Roles and Tasks

My key responsibility for this project was to apply and interpret Lean Manufacturing principles to the working of Supreme Gems. I undertook time studies, value-stream mapped the processes using Value Stream Mapping (VSM), and established key points of waste, including wasteful movement and delays.

My job involved:

- Acquisition and examination of process data from stopwatch studies.
- Measuring lead times, cycle times, and the lengths diamonds travel throughout departments.
- Developing and evaluating a mockup of cardboard to resemble a lean cell layout.
- Identification of the bottleneck process (4P machine) and construction of improved production flow for the same.
- Comparing performance measures prior to and subsequent to the implementation, such as productivity, lead time, and layout efficiency.

Learning

It taught me the principles of lean manufacturing applied to highly variable diamond manufacturing. I was taught how to compute and analyze cycle times, lead times, and value-added ratios using Value Stream Mapping, and how these statistics are used to accurately identify the 4P machine as the bottleneck. I also came to see how layout of the machines, the use of barcode tracking, and the cross-training of employees reduce waste directly, make the operation faster, and help improve the flow.

Challenges and Improvements

One issue was validating the process time data, for even miniscule mistakes would distort the identification points for bottlenecks. This would hold promise for future projects by including real-time sensors and dashboards to collect data with greater specificity. Potentially other improvements could involve the use of simulation software to virtually test cell designs prior to implementing them, as well as expanding worker education to not only multitask but also problem-solve and quality-check. In addition, benchmarking with other high-end goods businesses would provide additional insights as well as help narrow down the lean techniques further.

13. Acknowledgments

Advisors and Mentors

I would like to sincerely thank my mentor and advisors for the unlimited support, direction, and helpful comments they offered throughout the project. Their expertise in Lean Manufacturing and practical experience truly helped make the study successful.

Institutional Support

I am truly indebted to Supreme Gems and Jasani for giving me access to working with them, enabling me to execute this study in real-world conditions. I would also like to express my gratitude to my institution and faculty members for granting me constant encouragement and academic support throughout the lifetime of this project.

Additional Thanks

I would also like to express my gratitude to my friends, colleagues, and family for their ever-going encouragement, discussions, and moral support, which kept driving me to finish this wor

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15. Appendices

- **Appendix A:** Raw timing data for each process (Laser Sawing, 4P Operating, Table Smoothing, Final Bruting, Checking and Scanning, etc.).
- **Appendix B:** Full Value Stream Mapping (VSM) calculations, including setup times, processing times, and Value-Added Ratios.

- **Appendix C:** Graphs and charts (bar charts, pie charts, stacked bars, adjusted charts with child-stone factor).
- **Appendix D:** Photos of the lean cell layout and cardboard model used during planning.
- **Appendix E:** Comparison table of Before vs After Lean implementation.
- **Appendix F:** Sample worker training plan (multitasking, 1-up and 1-down cross-training).