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An Integrated Lean 3P and Modeling Approach for Service and Product Introduction

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Abstract

Production Preparation Process (3P) is an integral part of a lean design process. Lean tools, such as Kaizens and Standard Work are designed to make improvements in a given process, whereas 3P focuses on waste elimination through product and process design. 3P helps meet customer requirements by designing a waste-free product or service. In this research, an integrated 3P, simulation modeling framework is presented. Given the importance of 3P on rapid product design, simulation modeling provides the what-if analysis capability that helps the 3P teams make well informed decisions. The research also explores alternatives to address the complexity in building models in the absence of historical data. Another critical component of a successful 3P implementation is the role of teaming and team dynamics; and particularly the dynamics between Manufacturing and Design teams. Using cultural transformation tools, the 3P framework would also identify the impact the team's culture on the success of the new product or service implementation. Lastly, most existing approaches discuss the application of 3P in the product introduction domain, but rarely discusses the application in the service sector. In this paper, the application of the integrated 3P-Simulation Modeling to a (i) manufacturing product introduction, and (ii) new service introduction.

Keywords
Production Preparation Process (3P), cultural transformation, modeling and simulation

1. Introduction
Production Preparation Process (3P) is a key element of the lean design process for testing new process improvement ideas and incorporating Lean manufacturing concepts into product and/or process design [1]. The key benefits of the 3P includes; (i) employing a cross-functional team to address design changes and improvements to a new product or process, (ii) rapid testing of ideas, and (iii) embedding the lean manufacturing concepts into design itself. The 3P process differs from the traditional lean Kaizens – 3P focuses on eliminating the 'muda' through innovative process and product design, whereas the Kaizen approach seeks to make improvements to the existing process. While the solutions from lean Kaizen events are quick wins that have low-medium business impact, the 3P improvements would lead to medium-high impact solutions and are designed to be "quantum leaps" [2]. Teaming and the contributions from its team members is a critical success factor for a successful 3P initiative. These teams need to be extremely innovative and require thinking outside the box mentality to successfully achieve a transformation to the product or service. Constructive and highly adaptive team members are ideal for 3P project teams. There are documented research efforts and case studies that discuss Kaizen events, but only very few are available for 3P. In this research, a hybrid approach to the 3P and modeling methodology is presented. Typically, 3P approaches documented in the literature applies to product design and processes. This approach discusses the application in both product and service domains through illustrative case studies. The main focus of this paper is to highlight the benefits of the 3P methodology and framework that employs other lean, lean six sigma and transformational culture elements to be used in such a methodology.

2. The Traditional "3P" Approach
There are three main phases in the 3P methodology as defined by the Toyota Production System (TPS) [1-3]:

- Information Gathering Phase – During this phase, the 3P team identifies the demand profiles, part numbers, drawings, TAKT time and the baseline process. This phase will provide the teams with defining the scope and improvement targets.

- Creative Phase – In this critical second phase, the various alternative ideas for the product/service is identified. After considerable brainstorming, the 3P team identifies the solutions to be prototyped or simulated before selecting the final solution.
- Redefine Phase – During this phase, the 3P team selects the final solution for the product/service redesign and subsequently implements the process. In addition, the TAKT times are redefined, the process is standardized and measures are put in place for monitoring the impact of the solution. Figure 1 shows a high level view of the current 3P approach, along with the various lean tools and techniques employed within.

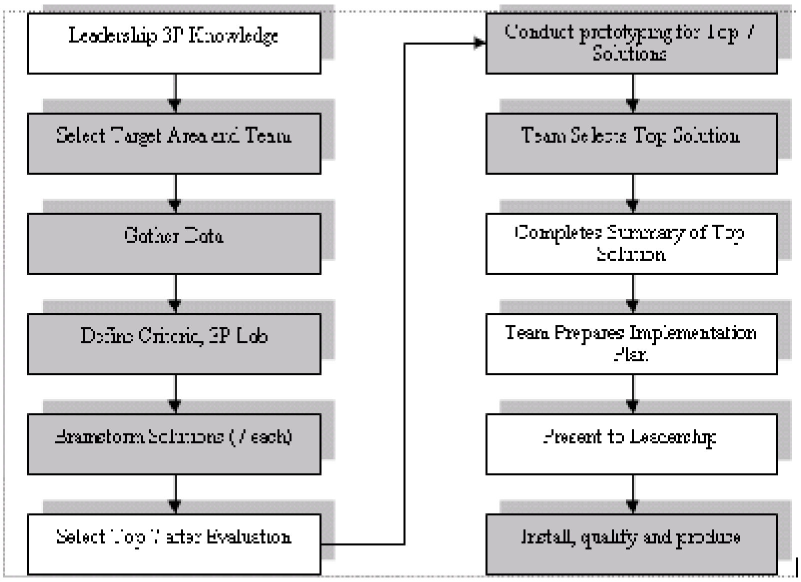

Figure 1. The Traditional 3P Approach (Grey Cells Highlight Opportunities)

3. The Integrated Lean 3P and Modeling Approach

The 3P philosophy is centered on developing a product or service for a customer in a form that has the amount of Lean waste involved. Using Lean techniques such as standard work, standard layout, cycle time management and cellular flow, the process is carefully redesigned and implemented across the organization. In this lean 3P-modeling approach, certain critical decision support systems and criteria around product and process redesign are integrated with the existing lean tools and techniques. They will impact the cells highlighted in grey in Figure 1 above. These criteria and decision support systems will help design teams to successfully implement a new product or service offering. The 3P framework presented in this research is depicted in Figure 2. Please note that the research is focused on using 3P for redesigning the process while introducing a new product or service.

- **Behaviors and Cultural Outcomes**: One of the key elements of a successful 3P initiative is the involvement of cross functional teams to achieve the task at hand. For example, while employing 3P during new product introduction (NPI), the cross functional team should consist of members from manufacturing, design, engineering, support functions, order management and from the field to understand the various view points from the stakeholders. Oftentimes, it has been observed that the NPI team formation aspect is overlooked and in some cases, despite the team consisting of all these stakeholders, the outcomes are sub-par. This can be attributed to the behavior styles of the various members of the team. Some members may have dominant passive or aggressive styles of behavior, rather than constructive styles of behavior. By virtue of this, teams can get less constructive and result in competitiveness and avoidance resulting in a poor outcome. There are numerous research efforts which prove that organizations (or teams) with dominant passive/aggressive styles of behavior have inferior business results compared to organizations (or teams) with dominant constructive cultures (see Figure 3) [4]. In this framework, an explicit focus is made on the behavior styles of the members of the 3P and the leadership team.

Figure 2. The Integrated Modeling - 3P Approach

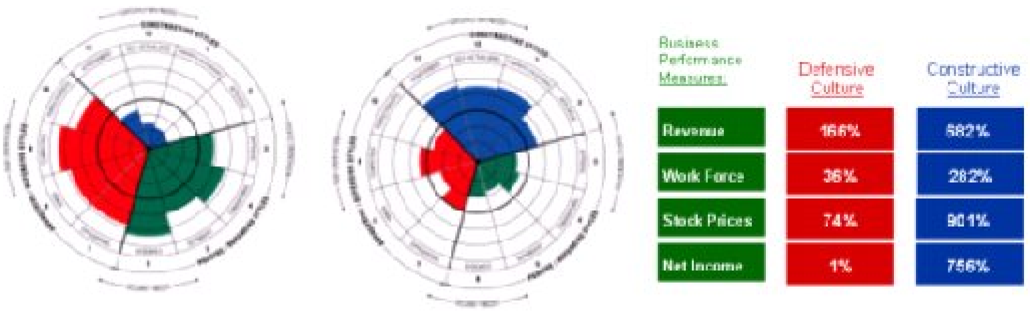

Figure 3. Comparison of Non-Adaptive/Defensive Cultures vs. Constructive/Adaptive Cultures [4]

- **Lean Decision Support Tools and Techniques**: Traditional 3P efforts focus on using the standard lean tools and techniques to redesign the product, process or service. Some of the key tools used include process mapping, standard work, standard layout, TAKT/Cycle time and cellular manufacturing. In this framework, additional decision support tools and techniques that supplement the lean techniques are presented. Two of the key decision support elements are discussed below:
    - FLOW Matrix: The Factory Layout Optimization Worksheet presents a novel approach to the facility layout problem. Most plant layout software's and tools focus primarily on distances and the frequency of transactions between two areas alone, which may often result in sub-optimal layouts. However, in this matrix, designed experiments were conducted to identify the various factors that impact the performance of a layout, such as (i) shared resources and shared tools, (ii) transport modes, (iii) distance between operations, (iv) frequencies between operations, and (v) ease of movement. Statistical methods were then used to develop a proximity index – an alphanumeric indicator that depicts the relationship between two operations. Opportunities for re-layout are identified based on specified criteria through the user-friendly interface. Subsequently, discrete event simulation models were used to perform "what-if" analysis on the opportunities identified from the FLOW. The details of the FLOW matrix are discussed in [5]. Figure 4 shows the functionality of the FLOW – it helps to identify areas for relocation based on the factors above.
    - Resource Deployment Matrix: The RDM is another novel method for measuring employee skills on two key factors (flexibility and performance), assigning an index to support future deployment of their skills, and identifying recommendations for improvement. Using established workload planning methods to translate historical product demand into skill requirements, the RDM meets this need by assigning employees to tasks based on their Resource Deployment Index (RDI), a

unique alpha-numeric indicator representing the employees' comparative skill flexibility and quality.

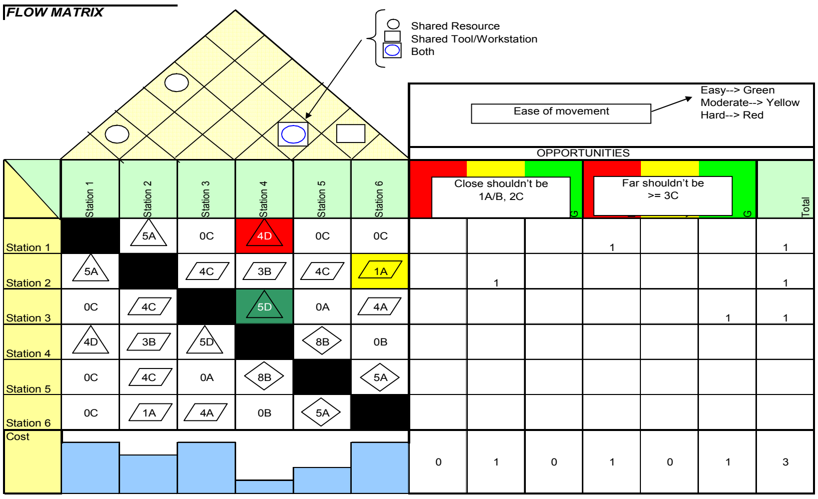

Figure 4. Factory Layout Optimization Worksheet Showing Opportunities for Improvement

Utilizing employees' skill certification records and performance (job quality), a statistical analysis creates a Skill Flexibility Index (SFI) based on the penetration of a resource into an enterprise's skill base and Job Quality Index (JQI) based on their history of non-conformance to standards. Skill needs are then met by deploying the least flexible employees first, leaving your highly flexible workers to fill the dynamic needs of the business. Each operation also is assigned a target JQI, ensuring a specified operator quality level accounting for critical operations. The details of the RDM are presented in detail in [6].

- **Modeling Framework**: In a traditional 3P event, the evaluation of the various alternative designs happens through a series of prototyping and simulation. While physical prototyping is extremely useful for product designs, modeling and simulation technique has proven to be effective for process designs. The discrete event modeling technique provides the design teams numerous advantages over the prototyping phase. Standridge and Marvel [7] provide an interesting discussion on "why lean needs simulation". The authors claim that for maintaining an efficient process and for producing defect-free products, lean and design for six sigma techniques may fall short in (i) accounting for variability and randomness in the process, (ii) interactions between the various sub-systems, (iii) studying alternatives and perform "what-if" analysis and (iv) quantifying the various performance metrics to make informed decisions prior to implementation [8].

  In the 3P framework, the simulations are done using a mock representation of the product flowing through the process in the facility. This still does not account for the variability inherent in the system. Ramakrishnan et al. [8] present a detailed summary of integrating lean tools and techniques with Design for Six Sigma philosophy. In summary, simulation is a powerful tool for analyzing and designing complex system, due to the following reasons – (i) conceptualize the project without implementation, (ii) cost effective comparison of alternatives, (iii) improve efficiency, work within minimum available resources and (iv) offers flexibility to analyze systems with high granularity. The two distinct advantages of using a discrete event simulation in a 3P framework are listed below:

  - Accounting for randomness: Variability from the expected performance is a significant factor that impacts the successful launch of new products or services. Through discrete event simulation, the 3P team can gather frequency distributions for process steps required to build the product or deliver the service, thereby making the model reflect the real-life situation.
  - Time-effectiveness: Most discrete event simulation software's available in the marketplace have the ability to perform what-if analysis by changing parameters, process steps and the flow. This feature is extremely helpful for the 3P team to brainstorm numerous ideas and evaluate them instantly through the models, rather than building prototypes for each solution.

- **Factors to Select Top Recommendations**: 3P methodology employs the notion that for every major contributor to the cost in a product, designers need to assess the pros and cons of seven alternative processes. This is a paradigm shift from the traditional design process, where a few processes and repeated over and over again for building the product or providing the service [9]. While the "seven-alternative" process uses costs as the deciding factor, there are other critical aspects to consider before the solution is selected. The framework presented in this research employs the philosophy of the balanced scorecard and its corresponding metrics during the solution selection process. The include, (i) Impact to the Customer/Client Satisfaction, (ii) Impact to the Financial Metrics (costs), (iii) Impact to the process (limited variability) and (iv) Impact to the employees (people delivering the product/service). These four elements are used to generate a business impact rating. Subsequently, the solutions are also rated based on the ease of implementing the solution. Once the two ratings are obtained for each of the proposed solution, they are plotted to a 2 by 2 matrix. The 3P team then selects the recommendation for the new design.
- **Lean Waste Elimination**: 3P focuses on eliminating the lean wastes by redesigning the process. The 8 forms of waste – Defects, Overproduction, Waiting, Non-value add process, Transport, Inventory, Motion and Unused employee talent – are identified in the process and solutions are designed to eliminate them. In this framework, the 3P teams analyze the process steps in detail and identify the forms of waste that exists. During the brainstorming session, the team members use this information as reference to identify solutions that overcome these wastes. A Value Stream Map (VSM) is also constructed to identify the lean wastes.
- **Team-based problem solving**: One of the critical success factors for any change to sustain is the "buy-in" of the employees and personnel directly impacted by the process. Although the 3P team is responsible for providing recommendations for the process re-design, it is critical to have the input from the rest of the organization for a successful implementation. In this framework, the team-based problem solving methodology is employed to gather the feedback from the employees through focus groups. Members from the 3P provide an update of the progress made on the process design and solicit their inputs and other alternatives. This has proven to be a critical success factor in the organization's buy-in to the suggested change and driving innovation. The role of team-based problem solving and decision making in a lean transformation is discussed in detail in Orth et al. [10].

4. Applications of the Proposed Approach

4.1 Application in a Complex Manufacturing Environment

In this section, the application of the 3P framework in a complex, high-end server assembly and test environment, during the midst of a new product introduction cycle is presented. This domain is characterized by high complexity products with an equally complex manufacturing and testing process. These products are expected to perform at 100% reliability and hence, the product design and the processes to support them are very rigorous with little to no room for error. 3P provides the NPI teams a reliable methodology to test the new product and define an efficient process to launch a product and support it through its life cycle.

Typically, during NPI, the manufacturing team is faced with a dual challenge – (i) prepare the facility for the new product (layout, process etc.) and (ii) support the existing product base to meet the peak demands. For such domains, facility layout changes are significant between product generations due to the advancements in the product technology. For example, chilled water maybe required to cool the testing stations. This implies significant changes to the facility layout and design.

- **Formation of the Team** – As the first step in the 3P process, a cross functional team was assembled from the various stakeholders involved. The leadership team was also involved in the formation of this team to show their commitment and support behind the 3P initiative. The team then is taken through a quick review of lean concepts and team based problem solving and decision making techniques. In addition, they are asked to work in certain simulations as a team and a Group Styles Inventory (GSI) ® is taken. A GSI is a product of Human Synergistics International, designed to understand the team behavior and dynamics during a problem solving exercise. The GSI is used to assess the styles and processes of teams as they work to solve "real-life" problems. They also help to improve the team dynamics to enhance the quality of decisions made (Human Synergistics, 2007). The GSI classifies the team dynamics into three primary clusters: Constructive, Aggressive/Defensive and Passive/Defensive [11]. Action plans for overcoming dominant passive/aggressive behaviors will also be developed and closely monitored through the 3P event.
- **Information Gathering** – Most 3P/NPI approaches start off the standard layout design without considering the existing design. This is not feasible in the domain being discussed due to the design complexity of the

products and the need to meet critical demands. Hence, a Re-layout Prioritizer called FLOW is used to determine areas where the layout has to be re-designed so that the lean wastes from the design are eliminated. Other information gathered include the drawings of the product, volumes, ramp schedules, process steps and the operating costs targeted for the product. Another key aspect captured here is the employee skill required for each process step. This would help minimizing the employee talent waste.

- **Elimination of Lean Wastes**– Based on the input from the process baseline assessment above, the 3P team then shifts its attention to the various forms of lean waste in the defined process. The FLOW helps the team identify the motion and transport wastes very effectively. The defects, overproduction and employee talent wastes are identified by the RDM. By conducting the qualitative process analysis, non value added processing steps are also identified. Inventory wastes are monitored through the TAKT and Cycle Time Management systems. Based on all this information, the 3P team now moves into the creative phase, where they define alternatives. Additionally, the various risk factors which can impact the process design are also identified here. Teams use Failure Mode Effects and Analysis (FMEA) to evaluate these risk factors.
- **Brainstorming Countermeasures/Alternatives** – With all the data gathered from the previous stages and the lean wastes identified, the 3P team now focuses on building alternatives to the process design to support the product or service being offered. The traditional 3P calls for identifying seven alternative process designs. Every member of the team comes up with their list of potential solutions and subsequently, the solutions are evaluated based on the selected criteria.
- **Using Modeling and Simulation to Evaluate Solutions** – One of the novel elements of the proposed 3P approach is the use of discrete event modeling to aid the 3P decision making process. Traditional 3P uses prototyping by conducting a dry-run of the various choices in the process and then selecting the one which successfully meets the goals set out by the team. However, it is very time consuming and expensive to prototype layout changes and equipment changes. In addition, the prototyping may fail to see the interaction of this new process with any other existing process supporting the legacy product or service. The 3P team builds the discrete event simulation model using the data gathered. Arena® 11.0 was used for modeling the process flow. The team first agrees upon a baseline model and then, the various solutions from the individual team members are then replicated as alternative/what-if scenarios. One of the key challenges of developing the baseline model is implementing the complex logic to accurately represent the process. As in any simulation study, it is critical to ensure the model has the appropriate level of granularity and modularization. Another key consideration during model development was the definition of the rework or repair actions. During the early life of the product, the yields are lower and hence, it is important to define the repair/rework process. The model was verified using the animation feature of the Arena simulation model. Statistical tests, including hypothesis testing and t-tests were conducted to validate the model accuracy. Historical data, based on legacy products, were used for the analysis. The key performance measures studied include the total number of orders processed, yields, operator and machine efficiency and cycle time.
- **Factors to Select Top Recommendations**: Once the various solutions are simulated, the various performance measures are noted. The solutions which are not within the target are not considered for further evaluation. From the top solutions, the teams rate them based on two factors – business impact and ease of implementation. The business impact was calculated based on the four elements of the balanced scorecard. The top solution was then presented to the organization for feedback and then, to the leadership team. The 3P team makes any necessary adjustments before implementation. Upon implementation, the performance measures are monitored continuously, and any out-of-control situations addressed. The simulation model serves as an excellent test-bed to evaluate solutions during these situations also.
- **Summary**: The 3P methodology presented in this research was successfully used for numerous new product introductions. In this specific example, the organization was challenged with determining a location to house the book-build operation for the new high-end server. The top two options after brainstorming were: Scenario 1 – Book Build room in the server assembly area and Scenario 2 - Use an existing controlled environment area in Building B for the Node Build operation. The obvious choice based on cost criteria would be Scenario 2. However, after applying this 3P methodology, Scenario 1 was chosen. Figure 5 shows the before and after layout. The business case was developed by including costs associated with each scenario. The cost factors considered included the inventory carrying costs, the capital cost of construction, and the space occupancy costs for both the scenarios. It was observed that the costs associated with scenario 1 were approximately 28% of the costs incurred by scenario 2, although scenario 2 had no capital cost of investment required.

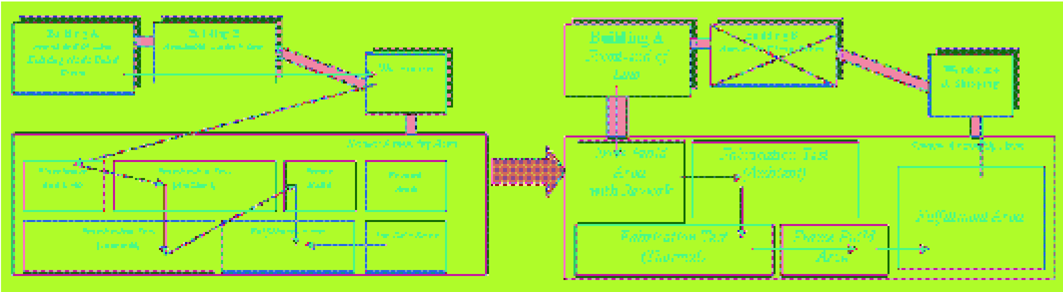

Figure 5. Before and After Layout Design for the New Process Layout

4.2 Application in a Service Introduction

The 3P methodology presented in this research can also be applied to service introductions. The same tools and techniques discussed in Section 4.1 can be used, with a few variations. For example, the FLOW matrix will capture the information distance between the operations instead of the physical distance. Additionally, handoffs will be considered to calculate the frequency of interaction. Here, the 3P methodology is applied to the design and implementation of accessible learning materials for an organization. Developing accessible learning seems to be a straightforward task. However, due to the variability in the design and development makes it an excellent candidate for applying 3P while the process is designed. The following summarizes the application of the 3P framework for developing accessible learning.

- The 3P team was formed after identifying the stakeholders and inputs from the leadership team. It was comprised of members from learning development, delivery, students requiring accessible learning, instructors and instruction/content creators. A SIPOC diagram is used for identifying stakeholders.
- Once the team was formed, the data gathering was initiated. Since there is no physical product/artifact in this scenario, the challenge for teams is to 'picture' the 'product' flow. To that end, a SIPOC, Functional Deployment Map and a Value Stream Map were constructed. The accessibility requirements and guidelines, which are not physical artifacts, were transformed to an information process for ease of understanding. The FLOW was constructed to understand process inter-relationships, frequency of hand-offs and any use of shared capacity or resource. RDM captured the resource skills required and their current quality levels to identify any training opportunities.
- After data gathering was completed, the team defined the desired process flow and metrics to measure the processes (e.g. turnaround time of learning development, % accessibility compliant, course satisfaction ratings). The team then brainstormed individually and then, as a group various process designs. This was then simulated in IBM® Websphere Business Modeler™ (v 6) to evaluate the solutions and monitor the performance measures.
- The top solutions were identified based on the rating scale of ease of implementation and impact to the business. After the top solution was selected, it was presented to all the stakeholder teams and the organization for feedback.
- The top solution was implemented in early 2010 and the process is being monitored for the performance measures. The 3P process took only 4-6 weeks from team formation to solution implementation – a testament to the modeling platform to evaluate solutions.

5. Conclusions and Next Steps

In this paper, a novel approach to the 3P methodology is presented. 3P is typically used by organizations that have reached a mature state in the fundamental lean tools and techniques. It is one of the most powerful advanced manufacturing tools. The benefits include cross functional team approach, quick testing of ideas and including lean concepts in process and product design. The framework presented in this paper has been implemented across different parts of the organization – both manufacturing and services and have resulted in significant process designs for new products and services. The new product introduction in the high-end server process alone has enabled over six seamless new product introductions with over $20M savings in operating costs, and untold increases in revenue gains. In addition, the organization's culture has also improved as a result of employee participation in the process design and their buy-in to the solutions. This 3P methodology has helped the organization move from a tool driven to a system-driven lean organization. In conclusion, the 3P methodology presented in this research is implemented in the framework of the 8 Step structured problem solving methodology. Table 1 shows the linkage of this 3P methodology with the 8-step, along with a mapping to the lean tools and techniques.

Table 1: 3P Event in an 8-Step/8D Framework, with Corresponding Lean Tools/Techniques

8-Step	This 3P framework	Lean Tool/Technique to be Applied
Step 1: Defining the Problem	Team Formulation, Define Goals, Information Gathering through lean tools	• Conduct GSI for team forming • Flowchart, TAKT, Cycle Time, Yield • Total Quality Management Tools • Workflow Diagram, Transportation Diagram, VOC
Step 2: Containment Action	Conduct FLOW Analysis, RDM and identify key wastes Identify Risk Factors	• Plant Layout – FLOW • Resource Deployment Matrix – RDM • Standard Work/5S/FMEA
Step 3: Root Cause Analysis	Lean Waste Analysis (5-why)	• 5-why analysis • Fishbone Diagram
Step 4-5: Countermeasures	Brainstorm Solutions, Build Simulation Models, Evaluate Solutions	• Modeling and Simulation • Balanced Scorecard Criteria, 2*2 Matrix • Risk Analysis, Poka-yoke, Jidoka • Involve all employees • Leadership driven
Step 6: Measure Results	Select Top Recommendations; Build Business Cases; Implement Solution	• Total Quality Management Tools • Business Case Development • FMEA
Step 7: Standardize	Obtain Employee Buy-in Standard Operating Procedures Control Plan, Update Baseline Simulation Model	• Measurement with balance scorecard measures • SOP's, Standard Work • GEMBA for addressing issues
Step 8: Celebrate	Recognize Team	• Conduct GSI to see progress • Involve all employees • Leadership driven

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