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Application of lean principles to reduce break down cases in processes in automotive product development- A case study of Toyota company limited

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ABSTRACT

Production process in the manufacturing industries has proven wasteful of the resources in the production process over time. Integrating of lean principles in the manufacturing activities has brought notable success in a complex and slow production process in an industry. This study aims at integrating of lean principles to a product development process to eliminate break down cases as it makes the process easy as well as speeding up the product development in an automotive industry. Three major phases are applied in product development namely; the early concept phase, middle core design and the launch phase. An exceptional definition of products development of lean principles are applied to come up with an analysis framework. Through interviews, observations, documentation and experience barriers that causes large number of wastes can be established. Lean principles will then be applied to eliminate such causes in the product development and then derive conclusion that shows the industry the process of lean in product development in the entire process

Keywords: Lean, Quality Tools, Productivity, Lean Principles, Continuous Improvements, Lean Manufacturing, Lean Transformation

1. INTRODUCTION

The introduction of lean principles in many East African automobile industries have gained from the integrating lean process in manufacturing. This is evident in the industry high reduction of waste through decrease or elimination of batch size in order to achieve one-piece flow down the production line, reduction in the manufacturing cycle through application of error quality and POKA-YOKE methods. The sequence supplier shipment is achieved. Such method has enabled various industries attain great success in the plant floor. Lean process can also be applied on other industrial activities such as acquiring orders for the parts and services, deliveries and accounts received and paid making it generally acceptable that applying lean principles leads to high achievements. This study focuses on large global automobile manufacturer located in East Africa that has shown high achievement after practicing lean principles in its production activities though small success in product development. The company's strength is; well-known brand, global distribution network, strong union relation and worldwide segment leadership making the company the strong force in the auto-mobile industry. To attain financial target and expand the business as well as stimulate the customer base, the company must generally make improvements in all the process which is achieved through application of lean principles. The challenge is that lean doesn't give instant results especially in product development. It demands that all departments in the company practice it. In order to attain value, the mindset to flow, effectiveness and strive to perfection should be put in consideration. Change in culture and product development is also key toward attain product and or service value. Currently, there are several issues to culture and processes to company studied. These inhibitors must be identified by product development department and be rectified in order to propel the transformation to lean and extend lean process to the rest of the company.

2. RESEARCH DESIGN

The research method is based on the literature review that focuses on lean manufacturing methodology, performance and solution already applied in it. Then, interview of the employees at the Toyota company East Africa under research, assessment and analysis

of the data will be made prior to implementation of the approached project until its completion. At the end the results obtained are properly evaluated for a concise conclusion of the overall objective of practicing Lean manufacturing as opposed to not practicing Lean using the case study of Toyota Company research as the study base. Methodological procedure is literature review, analysis and discussion and conclusion.

3. LEAN PRINCIPLES

Lean process was developed by D. Jones, J. Womack and D. Ross in 1990 where global automobile industry in Manufacturing techniques was studied. It was used by Japanese automobile Manufacturer, Toyota Production System while researching on Auto-assembly plant. Since then, there has been continuous progress in the lean application owed to the success associated with it. Lean process uses five basic principles described as follows;

3.1 Value

Lean first principle specifies the “value” of a product. The level at which a product or service meets the customer need at a given time and price defines its value. Company with product and services that meets the minimum set standards to/by customers is successful in creating value. The important objective is to move the focus of management from the existing organization assets to product itself and technology hence, giving a company the ability to differentiate value from waste. By assessing all actions in terms of how value is affected, assessment by customers will help in focusing on product. Identifying the value is important at it help to eliminate waste from the system.

3.2 value stream

It's the second principle after specifying the value, where the value stream map identify activities that are end-to-end linked, process and actions that transform input into output and help to identify and eliminate waste. In developing the stream map, every action is sorted into three categories. First, activities that create real customer value, Secondly, activities that are needed by the system (product development, ordering, purchasing and other inter-departmental activities) though create no value are kept for evaluation and thirdly, activities that have no value to customers thus not required in the system which are eliminated immediately in order to clear way to assess the second category. Mapping lays out the current state of the process in that the required change are recognized easily and later it can be modified.

3.3 Value flow

The value creating steps flows comes after the value stream already identified and waste elimination. The value creating steps must move continuously without interruption in order to achieve flow which unveils more wastes thus optimizing the value stream. Batch and Queuing causes long waiting time between processing result to long lead time both in internal and external customers since batch and queue production have large equipment that favors large batch processing. One-piece flow focuses on “right sizing” the equipment and locating it such that it requires minimum space or no transfer space from one station to the next. This help reduce the in-station process time and over production as product flows. Henry Ford changed the assembly process to a continuous manufacturing line which resulted in 90% reduction in assembly effort. Toyota has shown that one piece flow with several product variant is attainable and reduces the overall cost.

3.4 Pull

This lean principle deals with not allowing product to proceed to the next level unless downstream customer needs it. As the product comes out, there must be a customer who needs it or there will be excess product in the market which eventually get pushed to the potential customers which are associated with discounted prices because of the diminished value of the product. Pull principle respond to the demand of the customer which is not easy as customer demand changed with time as economy keeps changing when the season pass.

3.5 Perfection

The last lean principle is perfection which continuous and never-ending cycle. Perfection principle makes the company not to stop improving in the lean principle as it always need to continues to improve value, flow, pull and eliminate wastes throughout the company. The modification in value specification will be required with re-identification of the value stream that must flow and pull properly as customer's requirement keeps changing. Perfection must sum the lean principle and challenge the company to create value, waste elimination in value stream, flow the process and parts faster as it responds to customer by putting the product rather than pushing on the market place. All these principles are meant to be applied to the entire company.

4. LEAN ADVANCEMENT

4.1 Lean background

Mass production system Idea established by Henry Ford lead to methods where manufacturing strategies that arrange tools, machines, people and product to achieve the flow as value is added to the production process. This was done through manufacturing philosophies such as Just In Time (JIT), Design for manufacturing, waste elimination, continuous flow for manufacturing, waste elimination, Standardization and Continuous Improvement. There were shortcomings in Ford's philosophy which caused the introduction of other dynamics such as multiple models away from model T, Multiple colors and advent of labor unions. The Japanese competitors improved Ford's philosophy to produce quality work by W.E. Deming and Joseph Juran were introduced. Eli

Toyota then combined the statistical and quality management technique to develop new invention in production now known as Toyota Production System which does combine the old and new lean concept methods. A summer of advancement of the lean production over a century is shown below.

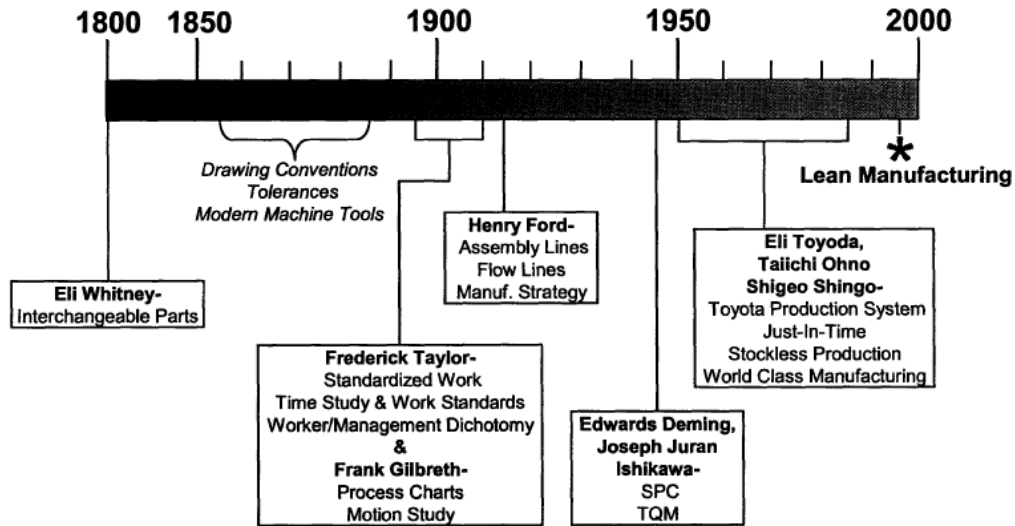


Figure 1. Timeline advancement of Lean production.

Toyota Production System is now known as “Lean Manufacturing” as it does more with less. Since then, many companies have emulated the process on their factory floor. Major development has been achieved on areas like Waste reduction and process variation though Japanese companies are still leading in advancing lean concepts. The company studies in this work developed production system similar to Toyota’s system and have gained by practicing Lean in its production process.

4.2 Lean Enterprise

It refers here in to correctly specifying the value for the customer avoiding the normal tendency for each firm along the value stream defining it differently to favor its rule in providing and identifying required actions that convert the concept to a launch by combining the five lean principles. The advantages gain from practicing lean in an organization extends its application beyond manufacturing to areas such as Order Processing and delivery. Lean enterprise is an integrated entity that efficiently create value to a company applying lean principle and practicing it. All the action are put into a system to optimize result and create value. The figure below illustrates the stakeholders in an integrated system

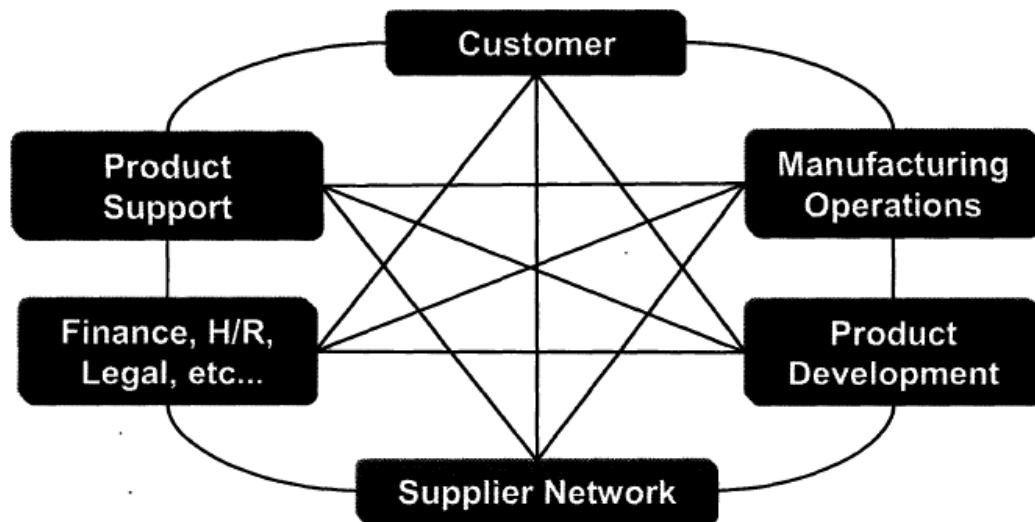


Figure 2. stake holders in an integrated enterprise

4.3 approach to product development (Japanese model)

Toyota objective is to achieve flow of new product continuously and many alternatives and designs possibilities are carried out although their interfaces are kept open to give room for flexibility. When new system proves unacceptable, different design is allowed by the interface and unsuccessful data is captured and store for reuse in future programs. This calls for system Engineers with strong technical background with good decision making to achieve a background with good decision making to achieve seamless product development flow. Toyota approach majorly consider set of possible solution then comes up with set of possibilities to derive solution known as “Set-base concurrent Engineering” (SBCE) identified with its three major principles as demonstrated below.

Table 1. Principle of Set-Based Concurrent Engineering

Principles of Set-Based Concurrent Engineering	1. <i>Map the design space</i>	<ul style="list-style-type: none"> • Define feasible regions • Explore trade-offs by designing multiple alternatives • Communicate sets of possibilities
	2. <i>Integrate by intersection</i>	<ul style="list-style-type: none"> • Look for intersections of feasible sets • Impose minimum constraints • Seek conceptual robustness
	3. <i>Establish feasibility before commitment</i>	<ul style="list-style-type: none"> • Narrow sets gradually while increasing detail • Stay within sets once committed • Control by managing uncertainty at process gates

Each group have checklist that have all the functional and attribute data that helps to come up with other alternatives that are possible.

5. THE PRODUCT DEVELOPMENT PROCESS

5.1 Product Development Overview

Automotive is largely a mature industry with dominant designs established over time. The processes that have proved disruptive in the industry have been efficiently eliminated through lean manufacturing. The new challenge is to integrate lean technique through the rest of the industry to achieve maximum efficiency. The enterprise includes all functions and processes from development, customer need, recycling plans, manufacturing in holistic nature. The company enterprise doesn't control a large portion of the enterprise though it should satisfy the stakeholders of the whole enterprise. The figure below shows the enterprise boundaries.

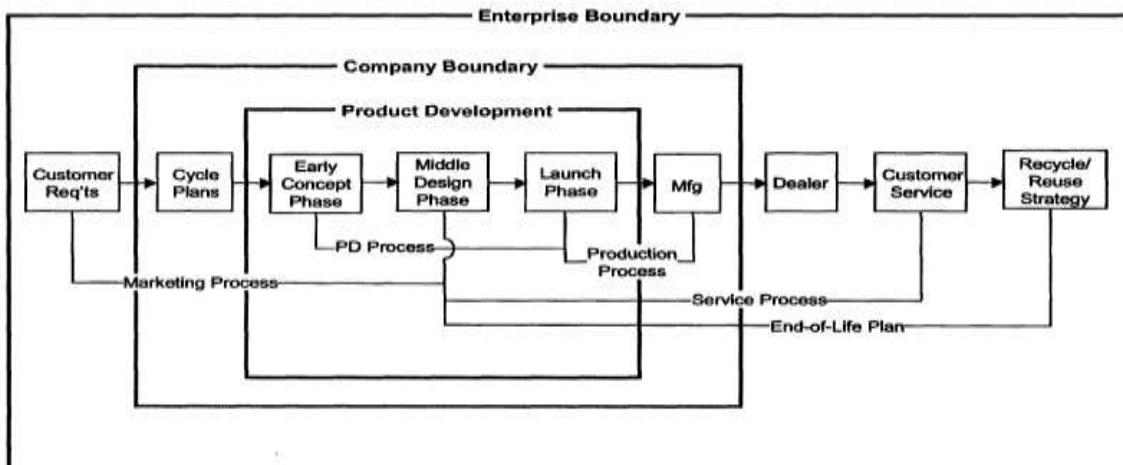


Figure 3. Enterprise boundaries.

5.2 The functional base organization.

A new program is launch to gain technical competence in the functional organization that weaken over time. The new program established a system that give a deep technical excellence rather job experience. Every engineer develops a technical maturity plan that identify training and skills that is required to meet the set objectives. An illustration on how the current functional group interact with the vehicle group or cluster is shown in the figure below.

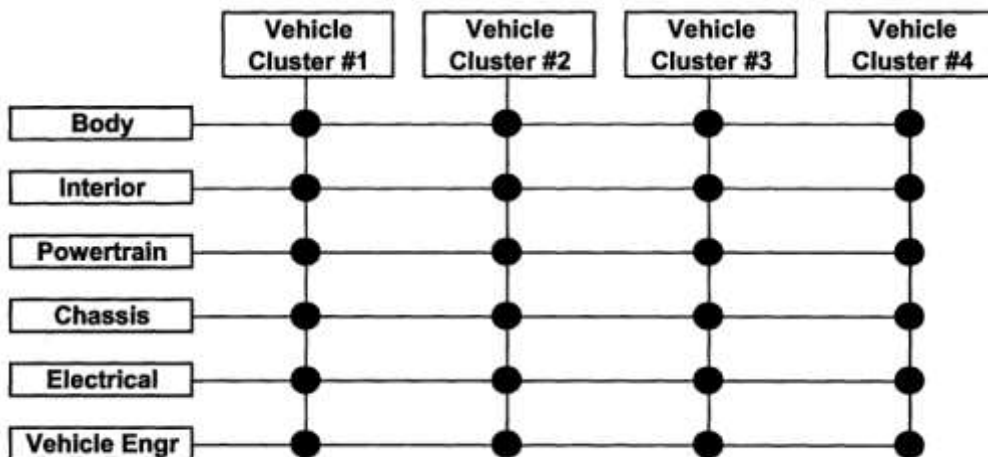


Figure 4. Functional-based organization.

From the figure above, each vehicle cluster houses approximately six models that a support group supports. The vehicle programs within each cluster communicate through a dedicated functional program management team that interact on daily basis to communicate to specific requirements and associated timing.

5.3 Scope analysis

This research focuses on three major phases that include; 1st phase, Early conception definition phase, 2nd phase is Core design and 3rd phase is Transfer design to manufacturing.

5.3.1 The conception definition phase- It in cooperate technological trends, competitors’ analysis and company’s cash flow where marketing, planning and engineering plays a key role. Customer needs and specification, government requirement and cooperate need are carried out in parallel to help optimize the results. Specific deliverables in this phase include, quality discipline plan, resource identification and planned marketing strategies, variable cost, investment status and plan to meet the targets agreed upon. The program specific work begins until solid program assumptions are taken forward for approval to proceed.

5.3.2 Core design phase- Engineering leads this part of the second phase in carrying out the plans to reach the targets. It’s a failure test or if it doesn’t meet the target or if the iteration may affect the subsystem which risks the ultimate optimal design. The deliverables at this stage include prototype plans, complete bill of materials and released, design failure mode effects analysis (DFMEA), manufacturing and assembly readiness and packaged with its compatibility confirmed. A big challenge in core design phase is the overlapping of tasks including design, prototype built, data collection and new customer data. The main objective is to manage the interaction and allow proper decisions to be made before going to the next phase.

5.3.3 Launch phase, transfer design to manufacturing. It’s a critical stage as it meets the end users’ needs, quality is key at every step. The requirements in this phase are the prototype confirmation test analysis, assessment of production build readiness, release of final component, validation of supplier manufacturing process and emission of certificate approval. It involves transfer of leadership from engineering to manufacturing.

5.4 Application of the analysis

The scope was limited to the product development process and culture within that process to find out the main barriers in implementing lean in the organization. Lean principle maybe modified to suit the area studied as methods can be utilized by groups such as planning, marketing, manufacturing, purchasing, finance service and dealers. When the barriers have been broken down, there is no end to improvement in the industry.

6. METHODS TO APPLYING LEAN PRINCIPLES

Integrating Lean production into a company results to increase its success. Company have grown lean manufacturing to a successful functional area. This study majors on the actions required to speed up lean transportation in production development.

6.1 Lean transitional characteristic in the product development.

For transition characteristic in product development, mental model begins with organization realization that people are not trained in practice thus training of employee is key. The figure below demonstrates the mental model structure.

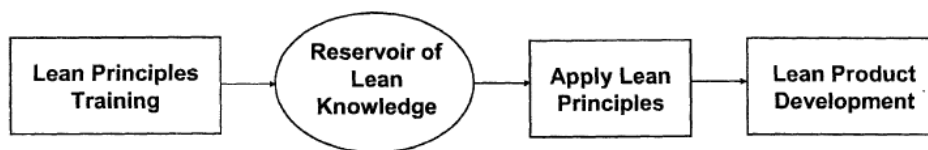


Figure 5. Linear mental model of lean transition.

For the company to benefit from lasting lean product development successes, it must understand all of the ground rules for lean integration. The disadvantage with linear mental model the inability to endure nor practice continuous improvement (KAIZEN). Once they had large-gain, short term projects are depleted, the smaller successes get overlooked which considerably stifles the energy. In order to break down the process barriers to gain form lean results, product development organization have to interpret the five key lean principles as demonstrated below

6.1.1 Specifying Value- to specify value correctly, stake holders have to be considered because the value varies from program to another as the user customer has different value based on marketing segment. Technology and government regulation as constantly changing targets makes the program to vary. Specifying value means realizing program’s technical challenges and expectation while holding time as sacred through understanding technological innovations and committing to time accurately.

6.1.2 Identifying the value stream- implies that the specific actions required for production are well understood as the whole process in optimized by eliminating the waste. Cross functional communications are required to achieve seamless to knowledge and data throughout the entire process. All the organizational sectors and stakeholders should be treated equally to avoid ultimate confusion. Also, it’s important to understand avoidable wastes as there are unavoidable wastes in the product development value stream., it’s

essential to differentiate between real value and perceived value. In the process to enable minimize the avoidable wastes. Working together by all stakeholders in this phase is important to the success of executing this lean principle.

6.1.3 Allowing value to flow- this is the complex among lean principles to implement in product development as there are many tasks need to make it a complete process. With the help of various applications, tracking has improved greatly over a period of time even though the seps required to perform the tasks can be vary in quality and completeness. With this objectiveness, the productivity can highly improve and attempt to identify the obstacles that hinders the progress and will strengthen it.

6.1.4 Pull the knowledge and behaviors through the process. Simply implies that allowing customers tell you what they want other than pushing the product on to them. Knowledge and behaviors are required to pull through the process. Thus, the ability to provide timely and accurate responses to the needs of the program is required to achieve pull in product development and the needs should be laid out in advance as part of the program plan. The key organizational sectors need to be considered in assessing and improving the roles and responsibilities, cross-functional terms as management reviews and program timing.

6.1.5 Pursuing perfections- it's the final and ultimate goal of the five principles of lean production. It described as systematically continuing in improving the value, flow, pull and waste elimination in production. In this research, key aspects of process and behaviors that limits the achievement of the product development are discussed.

6.1.6 Summary of lean principles definitions and their application. The approaches to assessing and implementing lean principles are lean production, lean behaviors and lean product development as demonstrated in the tables below. The unique definition of each lean production is compared. It's important to come up with unique lean principles for an enterprise to help reduce confusion during integration process.

Table 2. Lean principles applications

Lean Principles	Lean Production ⁴⁶	Lean Behaviors ⁴⁷	Lean Product Development
Value	Value is defined by the end-use customer.	Understand the wants and expectations of the people that we interact with.	Realize the program's expectations and technical challenges while holding timing as sacred.
Value Stream	Understand all the specific actions required to produce a product, and eliminate the waste.	Understanding what people do and why they do it.	Understand the cross-functional communication required to achieve seamless access to knowledge and data throughout the entire process.
Flow	Get the value-creating steps to move continuously without interruption.	Behave in a manner that minimizes or eliminates delays or stoppages in the work performed by others.	Ensure that knowledge and inputs are attained at the proper timing and commit to them with minimal change.
Pull	Respond to the demand of the customer.	Recognize that people operate under many different mental models which require us to adjust our styles or approach often.	Ability to provide timely and accurate response to the needs of the program.
Perfection	Systematically continue to improve value, flow, pull and waste elimination in production.	Systematically identify and eliminate behavioral waste.	Systematically identify and eliminate waste in developing products.

6.2 Identifying wastes

When the lean principles discussed above are applied, the wastes begin to be identified in the product development process. In this research, waste is reviewed in three major stages of product development. The wastes have been described as defects in the product, overproduction of product not needed, excess inventory of raw materials, unnecessary movement of workers and gods and excessive waiting time to process the product.

6.3 System Dynamic of Products development lean principles

The difficulty in quantifying the effects of procedural and cultural inhibitors in product development and system dynamic can help realize hoe inhibitors affects the system. In this research, the objective is to utilize the existing model to help discover the important barriers in becoming a lean in product development. Through this system dynamic models, the analysis can be enhanced to explain how the process and cultural inhibitors affect the lean transition process. This model help to explain ho waste increases when there is lack of awareness of the reinforcement processes and behaviors.

6.4 Benefits of lean transformation in product development

Committing long term transformation plan throughout the product development and growing it to the entire enterprise to guarantee that there will be great improvement everywhere in the enterprise. Fewer design iteration, eliminating firefighting with permanent solution in recurring programs issues, coordinated and motivated teams, less supervision with more empowerment, improved response time, stronger competitive advantage, higher reliability and delighted stakeholders are the benefits of lean production system. There is absolutely no reason not to strive to be a lean enterprise.

7. ANALYSIS OF PRODUCT DEVELOPMENT

7.1 Product development lean principles

Principles discussed above will support the research of identifying barriers and obstacles in process and culture in product development in the company studied. The methods used to carry out this research includes, interviews, secondary process data and cultural evidence. The analysis will find barriers throughout the product development. Fifty-three (53) interviews were conducted both formally and informally from various levels of company ranging from executive to working engineers. The current product development process for new product can take eighteen (18) to twenty-four months (24) depending on the scale of program. The scale is defined by the level of complexity involved while taking into account the long lead times aspect off changes. this analysis will take into account process and cultural inhibitors that are specific to a phase being executed. The analysis compares the process and cultural lean barriers for in barriers for significant difference and impact on the principles. the results can be applied to models such as Human Performance System and Capability Trap representation. Also help the system view of how the results affects the enterprise clarifying the steps that need to be taken in adopting lean principles and eliminating wastes.

7.2 Parallels in Process

In the analysis involved first, is the identification of the issues in the product development enterprise. Those are issues which were collected during the interviews, observation and evidences form the previous programs and experience within the system. This section focuses on the process issues that are common throughout the product development phases. After the assessment of the process data by its effects on lean principles, a pie chart shown in the figure below showed the impact of the process inhibitors. The value stream and flow have a slightly higher effect, 27% versus 21% for value, pull 16%, flow 19% and perfection 17%. The process is heavily engaged in the value stream and flow of new product development hence seeing higher percentages in these areas.

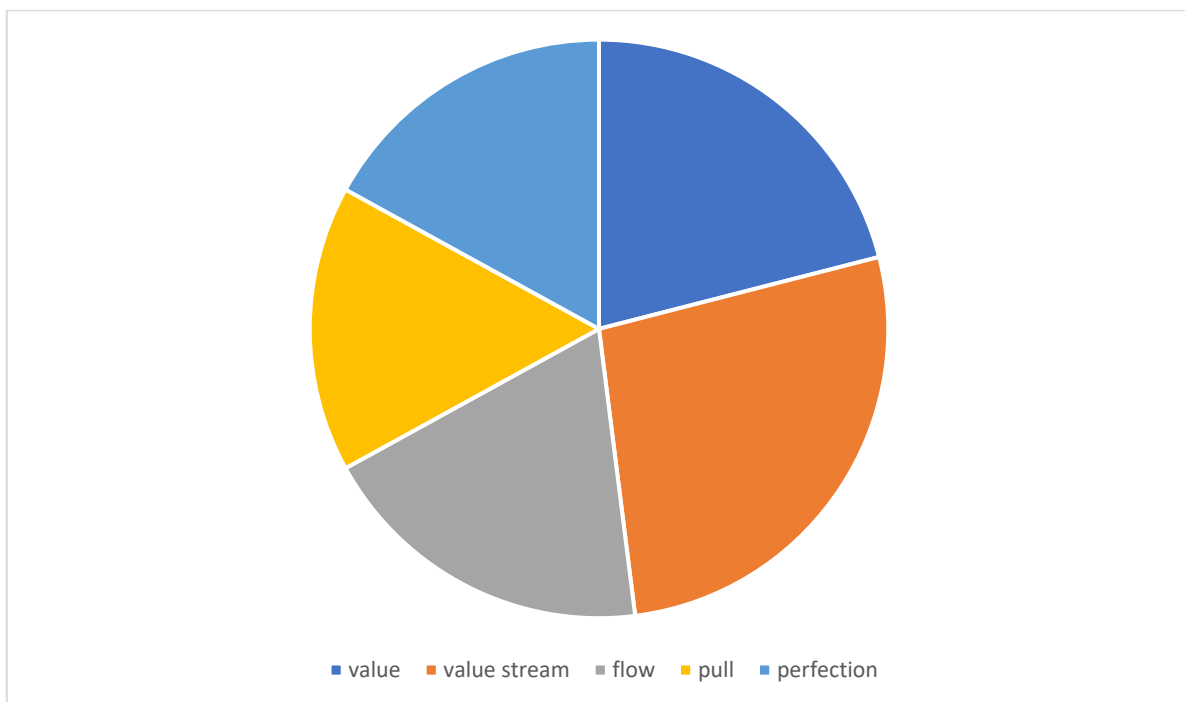


Figure 6. process lean inhibitors impact breakdown

7.3 culture norms

Cultural lean inhibitors that were considered for evaluation were items that are common throughout the interviews, observation and experiences in the process. From the study, its noted that product development doesn't vary so much from the overall company culture. For example, leadership balance between protecting themselves and their bosses rather than trying to achieve company's behaviors. Other cultural norms such as workers exposure, fear, stress incentive alignment, communication, deficient employees have various effects on the working environment both positively and negatively at different phase of the product development. part of the compiled table of finding is attached in the table below.

Table 3. Lean Cultural Inhibitors throughout Product cycle

Cultural Lean Inhibitor	Description					
		Value	Value Stream	Flow	Pull	Perfection
Fear	Fear is evident throughout product development which causes anxiety in making decisions, behavior forecasting and consequence avoidance.		✓	✓	✓	
Leadership Balance	Leaders spend much time and effort protecting themselves and their bosses rather than emulating the company's defined leadership behaviors (see Appendix C).	✓	✓	✓		
Rewards	The current rewards are not aligned to lean behaviors. There is a strong reinforcement in rewarding the "firefighter".		✓	✓	✓	✓
Leadership Character	Many leaders have strong opinions on how to progress their organizations which affects the decision making process and allows little input from the working level.	✓	✓			
Deficient Employees	Rather than dealing directly with deficient employees, the employee is passed on to another area in hopes that others will resolve the issues.			✓		✓
Stress	Internal company surveys show stress as the number one concern among employees, although, leadership actions do not reduce stress.		✓	✓		
Exposure	Employees are encouraged to be involved in high exposure situations in order to show ones firefighting abilities.				✓	
Incentive Alignment	Merits and bonuses are not aligned to performance. For example, if a program was well-executed in a year with poor financial results, the merit/bonus is low. And if a program was poorly executed in a year with good financial results, the merit/bonus is good.	✓		✓	✓	

7.4 System Dynamics Effects

Its important to understand how inhibitors prevents success and effect on the system both in long and short term. Once lean is continuously practiced, the actual performance improves thus reducing the performance gap. Inhibitor have the opposite effect on lean capability. Like, designs that keeps changing frequently causes the pressure to do work to increase in order to fix the problem due to management mandate or increased fear. The critical factor for this automotive manufacturer in this system dynamic representation is the pressure to do work or firefighting. If management doesn't not realize the impact of increasing the pressure, lean capability will never be achieved because issues like launch design takes long to be achieved. By understanding system feedback that decrease or increases the level of lean capability then transition to lean can be planned and optimized in order to achieve maximum capability in practicing lean throughout the enterprise.

8. CONCLUSION

I started this study with the purpose of identifying potentials in a lean manufacturing system; to do this I introduced three phases in order to see potentials at different levels, but also to see the interdependencies between them. Through a critical case study, I identified losses and how to realize them, and showed how the three phases are interdependent. This corroborated my research purpose to combine the three levels to understand the interplay in the lean. Practicing lean principles is absolutely necessary for the success of the company in any industry. In order to practice in lean principles, develop new definitions for the lean practice in product development and apply them in ana enterprise a lean transition process will require that action be taken to integrate lean in the sector for the company to yield significant quantity of information flow. Also, to support transition process and aim positive implication of in cooperating lean process into the company, the practice should be relative to the lean principles of value, value stream, flow, pull and perfection.

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