A Frugal Approach for Productivity Improvement: Evidence from the Manufacturing Industry

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Abstract:

The aim of the study presented here is the development and validation of a frugal framework for enhancing productivity in needle-thread-constrained manufacturing environments. Productivity stands as a pivotal factor in shaping the competitive edge for firms wrestling with cheapening costs, more excellent quality, and on-time delivery amidst the dwindling availability of raw materials, human resources, space, and energy. The research methodology is according to several types of stages: firstly; existing literature and case study were used to define the gaps in lean and improvement situations. This was followed by the usage of the Delphi technique for gathering expert opinion regarding them. Out of these, some principles of frugal innovation were chosen, those validated by experts for application in improving productivity in resource- scarce environments. And in its very next stage, a DfSC (Design-for-Six Sigma) frugality framework was constructed. In addition, an "OCEAN" frugal framework (Opportunity–Conceive–Evolve–Action–Nurture) was developed and utilized in an industrial case study. The study dealt with the application of an OCEAN frugal framework at a tractor-manufacturing plant. A bottleneck machine type CLG-27 of the hydraulic machine shop was identified as the place for application; a comparison was made before and after the experiment. The results establish that employing frugal methods even without extensive investment in capital can power up production. Simply by redistributing its operations, bringing down the frequency of setups and harnessing idle resources, the production per day increased from 800 units to well over 1050 units by retaining Cp and Cpk within appropriate limits as the extra necessity for a third shift was no more, set-up time reduced a little, and operational cost decreased. Needless to argue that frugal ways ought to complement the tools of Lean to uphold low-cost options through sustainable means relevant to improving manufacturing industries.

Keywords: *Frugal Approach, Productivity Improvement, Manufacturing Industry, Lean Practices, Resource Constraints, OCEAN Framework*

I. INTRODUCTION

With the extreme production pressure, organizations today are in a dilemma with respect to increasing their productivity while managing costs at the same time. Moreover, they come under pressure to increase quality by being innovative in the face of competition from competitors from other parts of the world. The revolutionary technological breakthroughs, constantly shifting market dynamics, and global extent of the supply chain make manufacturers work on the template of decorative strategies for sustainable growth. One such strategy is frugal innovation. Frugal innovation helps in getting more from less resources [1]. Frugality as encapsulated in the referring set of ideas might have been borrowed from contexts, with necessitated resource constraints implying that entities of concern-accomplish their desires using meager or limited inputs into the production equations. In former times, pursuing ways of frugality may have primarily been recognized as a practice that successfully suited small and/or emerging markets within the developing word; however, some new paradigms are now suggesting frenetic adaptations whereby manufacturing organizations, as the behemoths in their own fields, could greatly benefit from frugal approaches [2]. Manufacturing highlights the distinct scale of these benefits, as the physical establishments involved run fully on production processes demanding extensive machinery, energy, materials, and human capital. By taking on the frugal approach, manufacturers would best be served concerning their reduction in waste, lowering of operating costs, and improvement in overall operational performance-whilst the quality of output did not have to incur a decrease [3].

Frugality in productivity improvement occurs on varied axes. The first emphasis is on process optimization, wherein the examination of existing workflows reveals inefficiencies and suggests streamlined procedures that eliminate redundancy and recurrent resource expenditure [4]. In essence, such techniques as lean manufacturing, Six Sigma, and just-in-time production are quite close to frugality, given their leanings toward efficiency, minimization of waste, and improvement per se. Secondly, frugality requires innovative problem-solving with cost-effective and sustainable solutions. Resourceful thinking and action using available resources, even modular or scallable solutions on comparatively smaller but timely, incremental innovations, foster much greater overall productivity than costly technology or more large-scale investments [5]. In terms of human resource management and organizational culture, frugality also needs to be taken into account. Commitment, capacity building, and knowledge exchange form the core of frugal productivity enhancement, for it is the

well-versed and equipped people who can identify inefficiencies and propose practical resource-efficient solutions. The concept of frugality in this sense is not unrestrained human capital investment but maximization of the value created through the available skills and experience [6]. Promoting a culture of resource-centered progress and continuous innovation leads to innovation, resilience, and adaptability, which is a secret ingredient that will underpin productivity in a colorfully-organized manufacturing environment.

Available evidence indicates that frugal practices can significantly enhance manufacturing productivity. Studies from many industries show a twofold impact from the adoption of these principles implicating substantial reductions of production costs, cycle times, and energy consumption on the one hand and betterments in product quality and operations' agility on the other. For example, it is reported that manufacturers have enhanced productivity by around 20–30% purely through optimizations in the use of materials, rendering the supply chains more efficient and adopting energy-efficient measures without larger capital expenditures [7]. Often, frugal innovations enhance environmental sustainability because resource efficiency leads to lesser waste generation, emissions, and conscientious consumption behavior, all supporting global sustainability objectives. The relevance of frugality is hardly overstated in the context of emerging markets whereas capital, infrastructure, and technology are scarce [5]-[7]. Frugality enables companies to effectively compete by not only focusing on creating value and efficiency but also by being innovative and adaptable, as opposed to investing and leveraging sheer size as a means to create value. In addition, an argument can be made for the appropriateness of frugal strategies in developed economies where the resources are abundant, however, for another reason-cost-consciousness, greater operational resilience, greater long-term competitive advantages-justifying a wide range of applications [8].

From the benefits accrued, challenges are also born from a frugality approach in production. It is just necessary for an organization to strike an intricate balance between its exhaustive drive for efficiency and the quest for quality standards and employee satisfaction. A misdirected cost-reducing strategy or an ill-thought-out amount of resource availability could result in the product's quality if not met and if not a result-ill-treated workforce and reduced innovation capability [9]. Hence, a prudent exercise in incorporating successful strategies to harness the frugal economy would be most possible through deliberate planning, support of all stakeholders, and a substantial amount of monitoring of well-coordinated avenues to ensure that returns from resource optimization are turned into positive, sustainable outcomes. The study would focus on frugal principles in the manufacturing sector offering empirical evidence of their use toward increased productivity. By analyzing cases in the field and identifying operational ways, it aims to offer real motivating factors, corresponding stumbling blocks, and key lesson learned in order to advance the productivity improvement literature and serve as a guide for manufacturing managers contemplating the implementability of frugal strategies. Indeed, an understanding of the role played by frugality under manufacturing productivity is key toward the achievement of sustainable growth, operational excellence, and the gaining of an edge in such an increasingly complex, resource's carce business game, agitates towards owning the smallholder-frugal or "screwowner-strategic" roles [10].

II. RELATED WORK

From a simple cost-reduction philosophy to a strategic approach, frugal innovation has empowered the ability of organizations to compete in resource-challenged climates effectively. Initial work that mapped the sequential shift from cost-driven models to frugal and reverse innovation social outcomes included ramifications on global competences [1]. Speedy, affordable means of delivering solutions to working scenarios have been displayed by firm practices on times of crises, such as the COVID-19 pandemic; hence, frugal innovations supported the adaptation of health care [2]. Research suggests that merging productivity indices with resource frugality leads to enhanced performance at no mammoth capital investment costs [3]; electric vehicles have, however, shown frugal innovations' capability at the same time in communities [4]. Knowledge acquisition frameworks may help in the shaping of a frugal manufacturing system, especially in emerging markets [5] argued that the product-lifecycle-based approach supports modular, supplier-aligned frugal system [6]. Frugal innovation is progressively seen as spreading accessible green technologies globally [7], with applications to emerging market penetration strategies [8] and lean-oriented management systems [9]. In a broad perspective, innovation underscores organizational transformation and capability building [10], the quest for affordable yet high-impact innovation [11], and the presentation of frugal innovation as a strategic management theme [12]. Studies show that frugal solutions can be globally diffused and locally finalized [13], impacting evolving innovative pathways [14]. Case-based research examines how grassroots and localized innovations emerge under scarcity [15]–[17] and with smart decision-making, it also supports the manufacturing networks [18]. Product design research argues that system architectures are needed to reconsider frugal outcomes [19], so too are social sustainability advantages critically discussed, both in the enhancement of access to affordable energy and in enhancing livability [20]. Frugal partnerships and frugalism would not only render consumer behaviors loyal to frugal suggestions [21] but also intensify diffusion and enactment development as of collaborative industry initiatives [22], [23]. Digital entrenchment and training is suited to support frugal business models [24], and technology-based services could assist in disseminating frugal innovation solutions [25]. Frugal innovation is increasingly embedded into emerging markets [26] and promoted by flexible, low-resource business philosophies [27]. Grassroots entrepreneurial efforts confirm how frugal approaches bolster outcomes for sustainable development [28], while resource-constrained innovation models find a theoretical footing [29]. Another view of frugal strategies reveals that they promote effective resource use [30], and trigger the possibility of reverse innovation [31], whilst acknowledging the comparative strength of smaller firms in innovation [32]. Conceptual developments frame frugal innovation as a paradigm shift [33]

and are aimed at being illustrated by regional in-depth cases of innovation [34], national innovation system perspectives [35], and empirical process explorations [36]. Practical frameworks such as jugged underscore the need for an improvised problem-solving methodology [37]; herein, service-led technological integration aims at achieving improved business operational ability [38]. Transported firmly within the frugal value concept, manufacturing studies invariably suggest the pursuit of cost-effective structural efficiency through tools of engineering, OEE-based monitoring, and systematic production strategies [39]–[41]. Several works demonstrate that the customization to reduce inefficiencies enhances a company's competitive standing [42], whilst IEOM case studies affirm how functional efficacy indeed follows [43]. Lean deployment and time-study applications could conclude with efficiency enhancements through well-deemed lean concepts; case and various applications in the given context have amply proved these combinations [45]. Sustainability, digital tools in the mechanism for product feedback incorporation, lean-frugal integration in high-value gains in small-scale manufacturing industries are frugal contexts.

Table 1: Review of Literature on Frugal Innovation and Productivity Improvement in Manufacturing and Other Sectors

S.No	Focus Area	Sector / Application	Key Findings	Gaps / Comments
1	Frugal & reverse innovation mapping	Manufacturing / Global Competitiveness	Mapped frugal and reverse innovation field; emphasized strategic role in global competitiveness	Limited practical framework for implementation in manufacturing
2	Fast & frugal innovations during COVID-19	Healthcare / Pandemic Response	Highlighted rapid frugal innovation to address resource constraints during pandemic	Focused on healthcare; manufacturing application not explored
3	Productivity indices with resource frugality	Manufacturing	Demonstrated case study linking productivity improvement with resource-efficient practices	Limited to case study; no general framework proposed
4	Frugal innovation in low-speed EVs	Automotive / China	Showed how frugal innovations meet market demand with cost-effective solutions	Specific to EV industry; general manufacturing application not discussed
5	Knowledge acquisition in frugal manufacturing systems	Manufacturing / Emerging Markets	Highlighted planning methods for frugal product development	Focused on knowledge acquisition; productivity metrics not evaluated
6	Modular product structure and supplier selection	Product Lifecycle Management	Linked modular design to frugal supplier selection using PLM tools	Mainly design perspective; process-level frugality not addressed
7	Frugal innovation in green technology diffusion	Manufacturing / Sustainability	Showed global diffusion patterns of frugal green technologies	Focused on sustainability; operational productivity improvement not emphasized
8	Frugal innovation as strategy	Emerging markets	Frugal innovation enables market penetration and cost-effective solutions	Strategic focus; lacks process-level implementation details
9	Lean management process	Manufacturing	Discussed lean tools for productivity improvement	Lean-focused; frugal approach integration not covered
10	Emerging innovation challenge	India / Global	Discussed India-driven innovation challenges	Not specific to productivity or frugal approaches
11	Innovation strategies	Global / Emerging Markets	Introduced concept of frugal innovation as “innovation for the bottom of the pyramid”	Conceptual; lacks structured methodology for manufacturing

III. RESEARCH OBJECTIVES

- To study the current scenario of manufacturing industries to improve productivity with the frugal approach.
- To identify themes for the applicability of the frugal approach and its validation.
- To develop a framework for the frugal approach in the manufacturing industrial process.
- To apply & validate framework on industrial project based on analysis of PQCDSM parameters.

IV. RESEARCH METHODOLOGY

This section developed a framework of Methodology of economically improvised method. I have synthesized something as fundamental as the meaning of the word "synthesize." Synthesis implies the ability to analyze and evaluate information from variably diverse sources and build connections between the different elements of information just assembled, blurring boundaries between what is formerly known and what has just become known to create brand new knowledge or understanding. Such a process involves learning. This knowledge and understanding may be written or communicated to reflect on what they have learned. Credential of writing, spelling errors, punctuation, and minimal words are not the concern; one that the reader does not gravitate in absorbing the written expressions.

The study has led to an understanding that for frugal application in productivity improvement in manufacturing processes, a proper concept framework is needed. Even as productivity improvement rests primarily on the application of lean tools, there is no specific standard practice to improve productivity frugally. A literature review reveals that frugality does suit these sectors-ever-wastebusting principles designed for all kinds of large industries such as product design, health care, banking, telecommunication, etc. To picture a proper picture of frugal application in a manufacturing context, expert elicitation constituted the primary data.

The case study was conducted at the hydraulic machine shop of Mahindra & Mahindra Ltd., Nagpur. The study revealed that with all the lean tools at hand, the productivity improvement did not yield more than 10% incremental improvement. It was specifically picked as only here lean insights had a good deal to do with the case. The study also revealed that lean tools are being practiced on the process levels, but no tools are available to systematically operationalize frugality for productivity improvement. Semi-structured interviews with industry experts further confirmed that application of a frugal approach on the process level is quite limited in manufacturing.

This learning on the basis helped to identify themes of appealing frugal practices by the correlation of industrial problem bank data and statistics together. So validation of proposed themes by the Delphi technique regards them as useful in various types of manufacturing scenarios. The themes provide support for strategic decision-making under situations of flexibility so that industrial professionals may tackle the problems of resource scarcity in a focused manner.

Detailed consideration of the findings suggested the development of a structured frugal framework titled "OCEAN". The "OCEAN" framework would serve as a systematic way to implement frugal practices in manufacturing toward improving productivity by resource extractions. The "OCEAN" framework has flexibility in that it can accommodate various levels of implementation of manufacturing processes as per the requirement of the given situation.

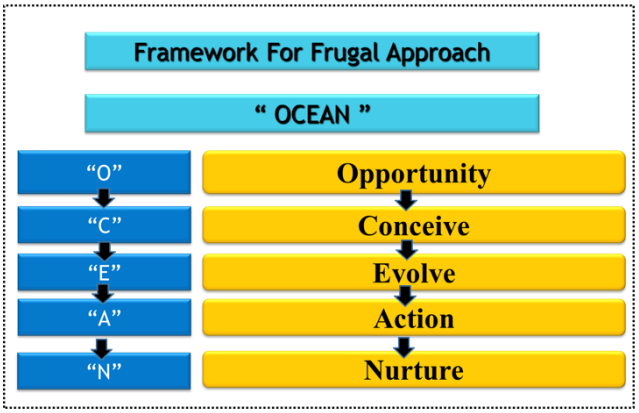

Figure 1: OCEAN Framework for frugal approach

Steps of Proposed Framework for frugal OCEAN.

The OCEAN framework, as envisaged in the model, encompasses five systematic steps directing its application in manufacturing industries seeking productivity enhancement through the frugal innovation process. Beginning with identifying opportunities, these steps address the process improvement initiatives.

The first division of the concept of Opportunity aims at pointing out the profound faults in the processes characterized as areas of potential improvement. Such process barriers may be very high manpower costs, exorbitantly high capital costs, waste energy, too high a rate of product rejections, and so forth. The conversion of such challenges to opportunities for adopting any frugal approach is given emphasis here. This entire step is neither more than the opportunity to turn problems slightly far away from the constraints, nor only an attitude to convert constraints into opportunities for applying frugal approaches. The critical activities come under this heading: problem identification, choosing a suitable frugal topic affecting the selected Delphi questions, framing and defining the context for the problem, justification of the problems with

specifications, and character analyses of the present system. The Opportunity is characterized by six sub-steps that share a well-structured manner suitable for systematic problem recognition and definition.

2 Step 2: Conceive

The Conception step refers to the development of absolvent ideas to tackle problems that were identified using frugal principles. It launches the formulation of resource-efficient solutions with raft analysis of the problem statement as the cause and effect sequence. The Conception step is, however, divided into the two remaining subsidiary steps that make sure the user examines the problems thoroughly and innovates new frugal solutions.

3 Step 3: Evolve

A phase such as an Evolve is considered to be the root cause analysis and deliberation of the issues. Industrial experts collect the data, find their path to possible root cause(s), and validate what really influences productivity. The Evolution is truly systematic in identifying non-targeted solutions to the root issues. The "Evolve" step has one more sub-step to guide the user through the root cause examination conclusively.

4 Step 4: Action

The first step is the actualization of the actions devised and applied to resolve the identified root cause. These actions should directly lead to decreased manpower requirements, lower costs, lower energy consumption, and reduced rejection with high efficiency. The content of the Action step includes only one essential sub-step that looks unto solution deployment and immediate problem resolution.

5 Step 5 Covenant

Lastly, with all measures firmly in place and something implemented, Nurturing becomes imperative in planning for sustainability. That goes for assessing performance, on the lookout for potentialities for improvement, conducting the trial installation of a target, pressing for a follow-up that compromises quality, and constantly carrying out scheduled reviews in preventing any possibility for recurrence. The four substep of nurturance assured the maintenance of sustainable improvements over time. Corrective actions are carried out each time there is a deviation from what is expected so as to strengthen the resourcefulness of the frugal approach.

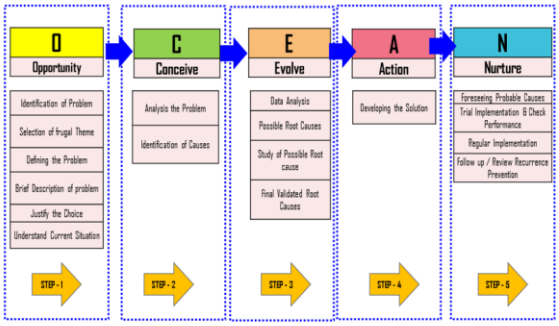

Figure 2: "OCEAN" Frugal framework with seventeen sub steps

Step - 1						Step -2		Step -3				Step -4	Step -5			
O						C		E				A	N			
Opportunity						Conceive		Evolve				Action	Nurture			
Identification of Problem	Selection of frugal Theme	Defining the Problem	Brief Description of problem	Justify the Choice	Understand Current Situation	Analysis the Problem	Identification of Causes	Data Analysis	Possible Root Causes	Study of Possible Root cause	Final Validated Root Causes	Developing the Solution	Foreseeing Probable Causes	Trial Implementation & Check Performance	Regular Implementation	Follow up / Review Recurrence Prevention
Guided Points						Guided Points		Guided Points				Guided Points	Guided Points			
Opportunity for Improvement Evolving untouched areas	Much More with Much Less No Fault Forward Save more be stronger Man less shop Zero Accident Work Passion Sustainability	Aspiration Outcomes Resources Timeline Team Charter	Specification Data Based Quantifiable	Impact on business Gain	Detailing at micro level	Use of tools and techniques	Data based	Use of tools and techniques	Brain Storming	Revised analysis	Experienced industry expert comment	Less Resource Low investment Simple Solution Intact functionality No compromise on intends Need of value creation	Alternative Thinking Accepting no limits Driving Positive Change	Result and Performance Check	Consistent performance	Standardization future Planning

Figure: 3: OCEAN" Frugal framework with Guided Points

OVERVIEW OF "OCEAN" FRUGAL FRAMEWORK WITH GUIDED POINTS

Table 2: Opportunity sub steps guided points

Step 1 Opportunity					
Identification of Problem	Selection of frugal Theme	Defining the Problem	Brief Description of problem	Justify the Choice	Understand Current Situation
Guided Points					
Opportunity for Improvement Evolving untouched areas	Much More with Much Less No Fault Forward Save more be stronger Man less shop Zero Accident Work Passion Sustainability	Aspiration Outcomes Resources Timeline Team Charter	Specification Data Based Quantifiable	Impact on business Gain	Detailing at micro level

Table 3: Conceive and Evolve sub steps guided points

Step -2 Conceive		**Step -3 Evolve**			
Analysis the Problem	Identification of Causes	Data Analysis	Possible Root Causes	Study of Possible Root cause	Final Validated Root Causes
Guided Points					
Use of tools and techniques	Data based	Use of tools and techniques	Brain Storming	Revised analysis	Experienced industry expert comment

Table 4: Action and Nurture sub steps guided points

Step – 4 Action	**Step -5 Nurture**

Developing the Solution	Foreseeing Probable Causes	Trial Implementation & Check Performance	Regular Implementation	Follow up / Review Recurrence Prevention
Guided Points ⬇				
Less Resource Low investment Simple Solution Intact functionality No compromise on intends Need of value creation	Alternative Thinking Accepting no limits Driving Positive Change	Result and Performance Check	Consistent performance	Standardization future Planning

Developing the Solution emphasizes minimal resource needs, minimal investment, simplicity, intact functions, no compromise on objectives, and value creation, ensuring the right application of the frugal approach. Downward Causality points to alternative thoughts as well as no boundary for driving positive changes for identifying potential problems effectively. Trial Implementation & Check Performance is reserved for evidence-based testing of the result post-implementation. Regular Implementation is concerned with maintaining performance, allowing management to keep confidence in the continuity of performance improvement. Finally, Follow-up/Review & Recurrence Prevention involves the consolidation and future planning of recording and sharing lessons learned from earlier implementation, for horizontal deployment, hence readily solving similar future problems using the frugal approach.

V. RESULT AND DISCUSSION

STEPS FOR IDENTIFICATION OF THEMES FOR FRUGAL APPROACH

With the collected information from the identified manufacturing industries total 1603 nos. of problem list prepared. This complete data analysed with statistical graphs and inference has been drawn

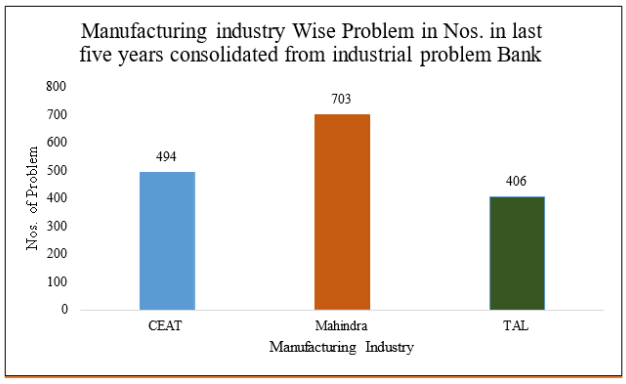

Figure 4: Manufacturing industry Wise Problem in Nos. in last five years

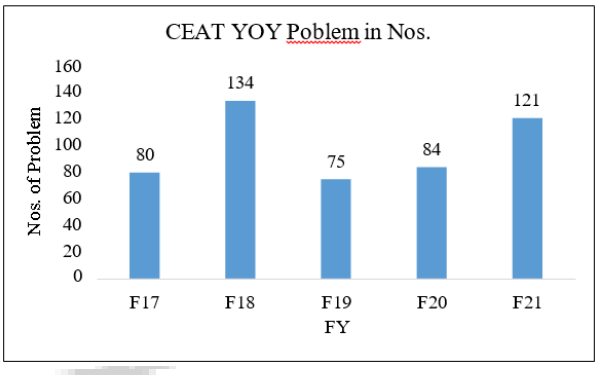

Figure 5:CEAT industry problem in nos. in last five Years

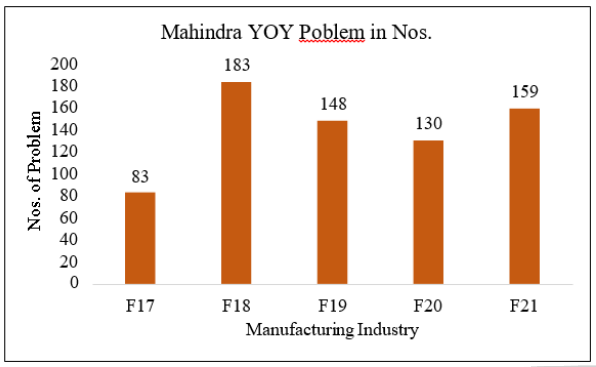

Figure 6: Mahindra industry problem in nos. in last five years

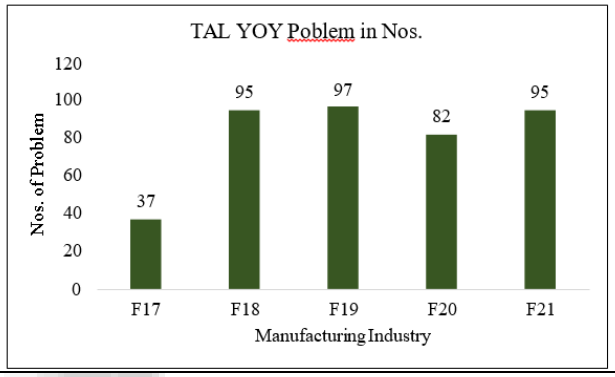

Figure 7: TAL industry problem in nos. in last five years

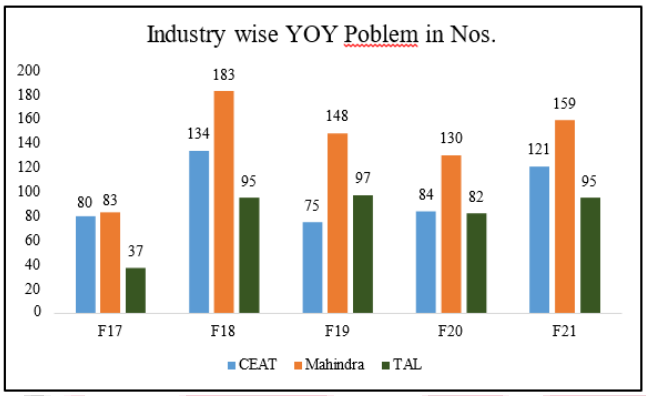

Figure 8: All 3 industries year on year nos. of problems

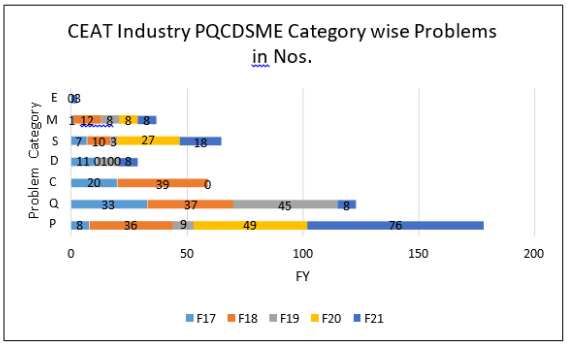

Figure 9: CEAT problems in PQCDSM

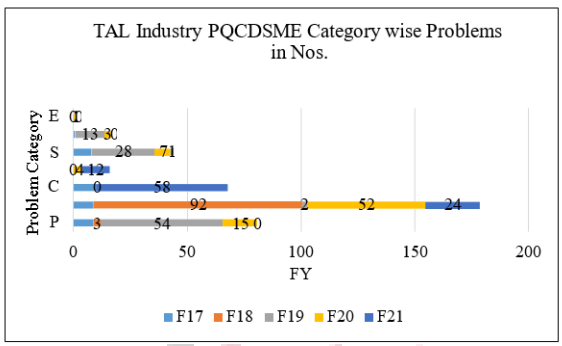

Figure 10: TAL problems in PQCDSM

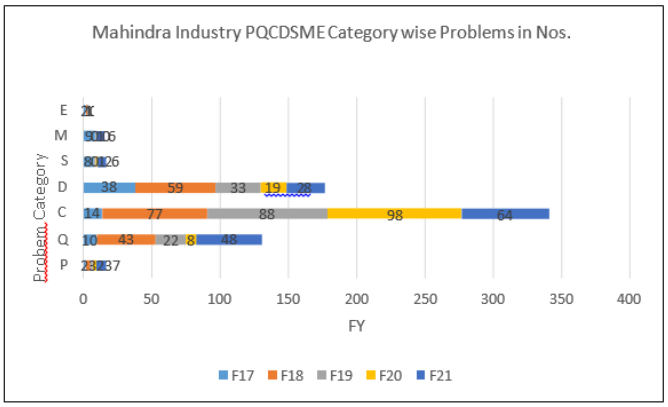

Figure 11: Mahindra problems in PQCDSM

Table 5: Identified themes for concern areas of industrial problems

SR. No	Concern Areas of Industrial Problems	Identified Theme
1	Productivity	Much More with Much Less
2	Quality	No Fault Forward
3	Cost	Save more be stronger
4	Delivery	Man less shop
5	Safety	Zero Accident
6	Morale	Work Passion
7	Environment	Sustainability

As manufacturing industry is working in resource constrained environment, Frugal approach can be useful to overcome these problems. Based on concern areas of problem available in manufacturing industry's themes for the applicability of the frugal are identified and is shown in below table no 5

VI. CONCLUSION AND FUTURE WORK

This research work demonstrates the successful application of the frugal approach "OCEAN" framework in the hydraulic machine shop at Mahindra & Mahindra Ltd., Nagpur, highlighting its potential for productivity improvement in the manufacturing industry. By compiling for manufactured products, we worked to solve particular challenges of third shift creation; new machinery creation; and high values task realization from the very fundamental of "greatness without the abundance" of the frugal approach. Validation of the above-mentioned improvements through PQCDSM-validated quantifiable proofs of the strong belief in the working perfectionism of the frugality system. In the future, sharing this purported success in the mass production sector shall involve any number of advances and, particularly, resource-constrained environments wherein the optimization of the available resources is of utmost importance. Estimating resource limitations actually wallows in applying resource constraints as opportunities to maneuver out of the box in terms of skill and tactics efficiently in the quest for sustainable entrepreneurship. In so doing, frugality could pick growth as the main entities' partner by growing all these product lines, maintaining their affordability, and managing poverty upliftment. Though this also helps to bring some level of direction to improvement with respect to frugal system efficacy among experts, so that the gradually amended system could position itself well with the demands of industry. Within their dynamic resource-bound environs, industries are thus continuing to wholly espouse structured measures in frugal management such as OCEAN, for inducing innovative design maturity and operational excellence towards sustainable pace-everything in matter of solid, stable bounce towards sustainable competitive advantage and cost efficiency.

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