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A Study on Complexity in Manufacturing Systems and Assessment

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Abstract

Manufacturing complexity is not easily defined. The ability to measure manufacturing complexity will permit benchmarking of systems and allow assessment of system design changes on complexity. This project is to identify and classify existing complexity measures, identify the essential elements of a good measure, and propose a measure of manufacturing complexity.

Complexity in manufacturing systems remains a challenge and leads to operational issues and increased production cost. In this project, drivers of complexity and typical symptoms of complex manufacturing systems are identified. A comprehensive review of studies published within the last two decades to assess manufacturing system complexity are presented. The key contributions of this review are:

1) a classification of complexity assessment methods based on perceived complexity symptoms.

2) a comprehensive review of assessment methods with cross-evaluation to identify appropriate use based on available data;

3) recommendations for the wider academic and industrial community, based on research trends identified in the literature, as to how complexity assessment should be addressed in the future.

It is concluded that the assessment of complexity is necessary so that it can be controlled effectively however the industry suffers from a lack of practical tools to support in this endeavor.

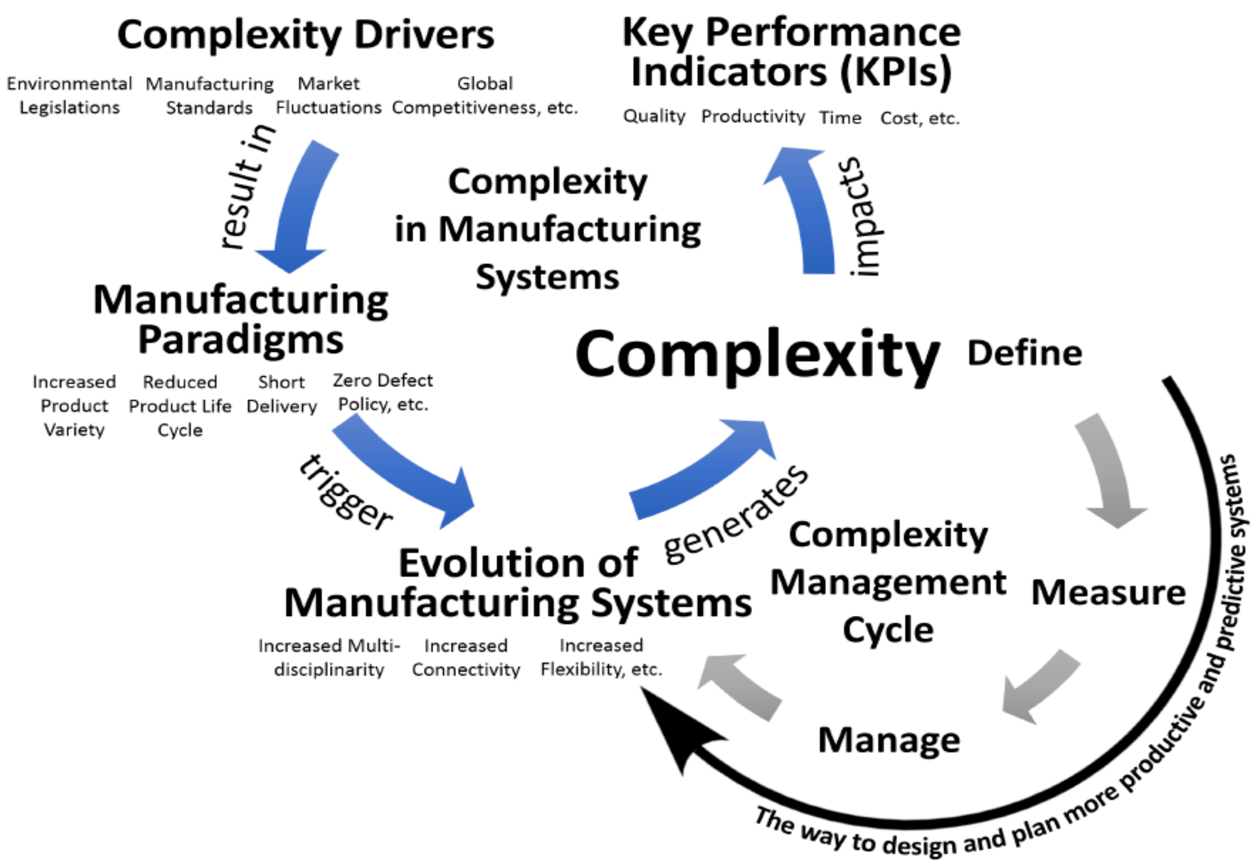
Keywords : Complexity , Manufacturing , Component , KPI(key performance indicator) , SKU.

Introduction

In the last century, the global manufacturing industry has been shaped by various economic, technological and socio-political progresses, socio-environmental regulations, heterogeneity and above all, globalization of markets and increased competitiveness. Consequently, new manufacturing paradigms including increased demand for high-variety production, reduced product life-cycles, and mass customization have emerged. This requires manufacturing enterprises to constantly improve their production systems in terms of flexibility, reliability, and responsiveness to satisfy customer demands.

To meet production targets of increasingly complex products with higher quality requirements and reduce time to market, the manufacturing industry employs highly automated production systems composed of numerous sub-systems of various nature, including: machining and processing systems, material handling devices and material storage and retrieval units.These advancements and modifications have increased complexity of manufacturing organisations all the way down to the shop floors. An increase in manufacturing systems complexity was reported to negatively impact all aspects of manufacturing, in terms of: production quality, reliability, throughput and production time, and disturbs the system's efficiency at design, operation, maintenance, and management levels. Moreover, complexity and the occurrence of failure within manufacturing systems are tightly coupled. An increase in complexity in manufacturing systems is only acceptable if it enhances capabilities, functions, usability, and performance of the system, but should otherwise be eliminated or reduced. Therefore, complexity and its impact on the system key performance indicators (KPIs) should be identified and quantified to remain profitable and competitive, and to respond rapidly to the volatile markets and rising product variety. In order to achieve this, an analysis and assessment of complexity identifying its impacts is vital. This highlights critical managerial aspects, and thus enables the development of strategies to manage system complexity.

Figure 1 summarises the existence and evolution of complexity in the manufacturing industry along with its cause-effect reltionships.



Measuring Complexity:

Past literature reveals that existing measures of complexity are not inclusive and some have data requirements that are intensive. Many have focused on the elements of static complexity, while few have included the concepts of dynamic complexity. This paper proposes a quantitative measure for manufacturing complexity based upon the structural, or static, elements of a production system.

Dynamic complexity is not considered in this research, since dynamic complexity measures uncertainty during operations and this research focuses on system design.

Part routings create static complexity. If there is only one routing and every part must take it, there is no complexity. However, if there are multiple routings for every part, then there is a high complexity level.

Product Structure Complexity Measure:

There are four components of product structure complexity that seem to contribute to complexity. These are:

1. the number of end items,

2. the number of manufactured items in the end items' bill of materials,

3. the number of levels in a product structure, and

4. the degree of part commonality.

The number of end items and the number of manufactured items in the end items' bill of materials, should increase the complexity of scheduling and material control. The number of level in the product structure also independently contribute to the level of complexity. This has been explored before in terms of the depth of the bill of materials. Intuitively, there are fewer relationships to manage when there are only two levels in the bill-of-materials, so that all of the relationships are from the component to the parent.

Objective of study:

- To study the factors affecting complexity
- Evaluate the problems associated with complexity.
- Identify different strategies or techniques that will help to reduce the complexity.
- Make recommendation and implement assessment tool to take a informed decision considering all aspects of manufacturing impact.

Complexity in Tyre Manufacturing Plant:

Tyre is a complex product consisting of several raw materials. With globalization and constantly changing business environment different product lines are required as per requirement.

- Premiumization
- Increase in Higher inch sizes
- OE Specific Requirement
- EV Tyres
- Exports to more regions

Meeting this demand leads to high number of SKU to be maintained in a plant with frequent changeover which leads to high complexity in plants (more changeover, more SKUs, setup etc.…) impacting Plant Productivity.

Research Methodology:

Research Study → Quantitative

Data Source → Secondary Data

Data Analysis→ Descriptive Analysis

Data Collected → Past Data of Organization

Organization → Apollo Tyres Ltd, Limda Plant

Limitation

1. This study belongs to Indian Tyre industry

2. As the data contains secondary, this will be limited to the specific industry.

Factors impacting complexity in manufacturing Plant:

1. *TBM – Daily Running SKU- Increase in Daily running SKUs increases Setups*
2. *Daily Curing SKUs / Compound [Extruder] - Higher ratio indicates higher capacity*
3. *Daily Running Compound [Extruder] - Higher no's impacts capacity*
4. *Daily Curing SKUs vs GT Code - Lower ratio increases GT codes*
5. *Daily Cur SKUs / Unique Treads - Higher ratio indicates higher capacity*
6. *Curing Cycle Time - Increase in cycle time reduces capacity*
7. *Curing Tyre Weight - Increase in tyre weight reduces capacity*

Ref study 1.
When daily running SKUs increased from 53 to 60 no's/day and no's of set up increased from 55 to 61 no's/day. Impacting daily appx 142 tyres because of increased setups.

Ref study 2.
When average tyre weight increased from 8.53 kg/tyre to 9.16 kg/tyre , curing cycle time increased from 13.42 min/tyre to 14.13 min/tyre (PV Category).As a result of this, over all curing capacity decreased to 21139 from 22047 tyres.

Manufacturing Complexity: Impact Assessment Tools:

Complexity Tools

- Tools for Capacity estimation in bottleneck equipment
  - Estimate present capacity & Constraints.
- Impact of daily SKUs Running
  - Estimate change in capacity due to addition / removal of SKUs / GT / Tread
- Tool for Mould Business Case
  - To decide procurement of additional moulds based on given criteria.

Complexity Impact Assessment tools can be used in following situations

- Impact of complexity on plant capacity - Extruder | TBM | Curing |Compound.
- Standardization – Toolbox for standard compound & components and mechanism for addition or removal of a compound / component.
- Rationalization – analysis on impact of removing or adding an SKU.
- Demand distribution based on complexity.
- Lot size assessment and business case.

For any new change map the complexity in the respective plant and initiate projects to manage complexity.

Sample: Complexity Tool:

INPUT:

Equipment / Product / Input Variant	UOM	Quadraplex / Tread / Value	Reference
Machine Availability	Min	1440	
Wtd. Avg. Decline Speed	MPM	28.37	
Wtd. Avg. Material Length / Tyre	M	2.01	Database
Daily Running Unique Compounds	Nos	7	
Die Change Time	Min	2.5	IE_Input
Compound Change Time	Min	20.0	IE_Input
Estimated Rework Generation In %	%	5.0%	IE_Input
Other Losses (Excluding Set Up)	%	6.1%	

Ratios (Based on best achieved - past one year)	UOM	Value	Details
Compound Repeat Ratio	Nos	1.55	
Tread Repeat Ratio	Nos	1.27	
Daily GT Codes / Tread	Nos	1.71	
Unique Tread Codes / Compound	Nos	4.24	
Nos Treads Codes / Die	Ratio	1.17	

OUTPUT:

Change in Capacity of Plant	YES
Updated Capacity Treads/Day	14395

Conclusions / Suggestions.

- Complexity is expected to increase due to changes in Business Environment – Changing product mix, moving to higher inch, stringent OE specific requirements & growing exports.
- Plant PPC to be the custodian of the Complexity assessment tools to evaluate the Complexity
- PPC to evaluate the complexity using tools and to advice on possible actions incase of any major component or SKU changes

a) Specific SKU's which adds to complexity due to low lot size, specific compound requirement, lack of moulds

b) Bottle neck equipment's which needs to be focused upon

c) Cycle time improvement required

- SCM to utilize the tools for annual budgeting exercise

a) Compound distribution across the plants

b) Mould Business Case

- Marketing to continue the process for product rationalization
- R&D Toolbox refinement process to continue inline with Complexity assessment tools
- Cost of Complexity to be calculated and evaluated for decision making once End to End costing exercise is done
- All the above-mentioned needs to be monitored & ensured for managing the increasing complexity. We propose one person centrally to be doing this till the processes are streamlined. Monthly MIS on the activities and a Quarterly meeting is also proposed, going forward.

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