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Use of Multiple Criterion Decision making Model in Lean Manufacturing for New Product Development

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Abstract:
Lean manufacturing has the revolutionized approach of manufacturing and that can do the same for the new product development (NPD). Today ‘lean culture’ has become necessary and important tool in all types of industries to eliminate all kinds of wastes in the manufacturing process.In this work, a case study was carried out in an automobile industry for reducing the product development lead time. In the process of doing so, lean new product development with IT support was identified as an effective product development strategy. One of the multiple criterion decision making model namely analytical hierarchy process (AHP)is used in this application.
***Keywords**: Computer Aided Engineering (CAE); Lean New product Development; Traditional product development, analytical hierarchy process Remanufacturing, Multi criteria decision making model*

1.INTRODUCTION

NPD is the process of identifying the product strategy, program management, collecting the requirements, product development, sourcing for involvement of suppliers and maintaining the production ramp-up. As per Aberdeen research, the top challenges high tech companies report is cost pressure from customers. The second largest challenge reported by all companies is faster product commoditization / shorter life cycle. The different strategies that can be followed for new product development are concurrent engineering, remanufacturing, traditional new product development, and ultimately lean new product development.In this research work initially the best product development strategy is identified through a multidimensional decision making technique analytical hierarchical process (AHP).Then the case of product development of parabolic leaf spring of an automobile is considered for the analysis and optimization of design variables for demonstrating the accomplishment of lean new product development.

2.LITERATURE REVIEW

Many research projects have been done on elimination of wastes in the process, but not much of research work, on elimination of waste in new product development process. Conventional product lifecycle begins with conceptual design, engineering design, analysis, prototype modeling, estimation of cost, designing of sequence of operations, manufacture of parts, marketing the products, and selling. But it requires toomuch of time to complete the entire process from the design level to launch of product.In traditional new product development, theprocess information is not available among various groups in the process and behaves as an island of information inaccessible to those who need it. The scattered information in the NPD process leads to waste in the process and increases process time. The evolution of information technology (IT)

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in general and internet technologies in particular has affected all aspects of new product development processes. In some instances these technologies result in speedy and more frequent communications within existing processes. Hence, it is necessary for all industries to adopt lean manufacturing concept in the NPD processto reduce the product development lead time. Eliminating waste within the NPD process will enhance the value and ensure full customer satisfaction and reduce the overall lead time. James – Moore and Gibbons [1997] described the principles of Lean manufacturingwhich are widely used in the aircraft manufacturing industries.Hines et.al.[2004]explained the concept of lean production(LP) since it converts complexity of the system into the easier one.Barker [1994] explained about the time based value adding framework for the development activities and continuity in improvement. Ahlstrom [1998] explained about the improvement of manufacturing performance in the industries andvalue stream mapping (VSM) and other lean concepts are adopted in a larger integrated steel mill.Datta et.al. [1992] studied the short comings of the existing manufacturing systems available and developed an AHP model to account for the justification of machine selection. The proposed AHP model can take into account tangible as well as intangible factors.Daugherty [1981]discussed the composite leaf spring applications in heavy duty automobiles. Breadmore and Johnson [1986] revealed the composite structure applications in an automobile structure.Hawang and Han [1986] discussed the fatigue behavior of Glass Fiber Reinforced Plastic (GFRP) epoxy composite in an automobile body structures. Yu and Kim [1988] explained the design characteristics of double tapered beam for the suspension leaf spring of the automobile.Rajendran and Vijayarangan [2001] discussed about the composite mono leaf spring which is used in automobiles.Clarke and Borowski[2005] discussed the residual stress developed on the spring of the automobiles.Muthubhaskaran (2018 & 2019) et al have discussed about ranking of lean tools and a frame work of lean readiness evaluation. He has also analyzed the possibilities of improvement in quality using QC tools.

3.ANALYTICAL HIERARCHY PROCESS

In order to justify the selection of an effective strategy for the new product development process, a multi criteria dimensional modeling is applied for the decision making process. The AHP technique is used toidentify the effective strategy of similar requirements among different alternatives. The wastes corresponding to product development function are associated with the main wastes of lean production system. In this method, it ranks various methodologies in conjunction with various features of a score which is taken from the relative preferences of synthesis of each alternatives with respect to the other criteria at various stages by the way of individual calculation factors and sub-factors. Each and every stage, neighboring values of each candidate alternative with respect to the upper immediate values are evaluated from pair-wise comparisons.These values are compiled based on views of experts from case industry in this field. Six criteria like inventory, defects, overproduction, processing, transportation, and human are considered. By considering their sub criteria which is shown in table 1, the best strategy is selected.

Table 1: factors contributing for product development strategy

Criteria	Sub Criteria
Inventory	Development work and design work in process (WIP)
	Delays for process approvals
	Time waiting for others inputs
Defects	Design & development rework
	Defects in requirements
	Misinterpretation of information
Over Production	Extra/Low priority features in design
	Too much detail and Unnecessary information

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	Redundant development
Motion	Excessive mental motion
	Task switching
	Effort to find needed information
Processing	Excessive reviews & paperwork
	Serial process with excessive iterations
	unnecessary data, translating data, formats conversion
Human	Inomplete, ambiguous, lack of direct access information
	Under utilization
	Over utilization

3.1 AHP algorithm

Stage 1: Hierarchy setting.
Stage 2: Pair wise characteristic comparison.
Stage 3: Identify priority vector.
Stage 4: Alternatives comparison.
Stage 5: Evaluate priority vector for alternatives.
Stage 6: Attain the overall priority vector.

The above said procedures are carried out in the following stages.

Main Criteria: Inventory

Sub Criteria: Development work and design work in process:

	LNPD	CE	TPD	RM
LNPD	1	2	3	5
CE	½	1	3	4
TPD	1/3	1/3	1	2
RM	1/5	¼	½	1

Priority vector:

$$\begin{array}{l} \text{LNPD} \\ \text{CE} \\ \text{TPD} \\ \text{RM} \end{array} \begin{pmatrix} 0.49 \\ 0.28 \\ 0.14 \\ 0.08 \end{pmatrix}$$

Sub criteria: Time waiting for others inputs:

	LNPD	CE	TPD	RM
LNPD	1	2	3	6
CE	½	1	1	3
TPD	1/3	1	1	4
RM	1/6	1/3	¼	1

Priority vector:

$$\begin{array}{l} \text{LNPD} \\ \text{CE} \\ \text{TPD} \\ \text{RM} \end{array} \begin{pmatrix} 0.50 \\ 0.23 \\ 0.19 \\ 0.07 \end{pmatrix}$$

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Sub criteria: Delays for process approvals:

	LNPD	CE	TPD	RM
LNPD	1	2	2	4
CE	1/2	1	1	3
TPD	½	1	1	2
RM	¼	1/3	½	1

Priority vector:

LNPD0.44
CE 0.23
TPD 0.22
RM 0.1

INVENTORY AMONG THE SUB FACTORS:

	Development work and design work in process	Time waiting for others inputs	Delays for process approvals
Development work and design work in process	1	½	4
Time waiting for others inputs	2	1	5
Delays for process approvals	¼	1/5	1

Priority Vector:

Development work and design work in process0.31
Time waiting for others inputs 0.59
Delays for process approvals0.1

Sub criteria: Misinterpretation of information

Priority Vector:

LNPD 0.43
CE 0.38
TPD 0.13
RM 0.06

Main Criteria:Defects

Sub criteria: Design and development rework

Priority Vector:

LNPD0.51
CE0.32
TPD0.12
RM0.05

Sub criteria: Defects in requirements

Priority Vector:

LNPD 0.37
CE 0.29
TPD 0.25
RM 0.09

Defects among subfactors:

Priority Vector:

Design and development rework 0.63
Defects in requirements 0.22
Misinterpretation of information 0.15

Main Criteria: over production:

Sub criteria: Extra /low priority features in design

Priority Vector:

LNPD 0.41
CE 0.40
TPD 0.11
RM 0.08

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Sub criteria: Too much detail and unnecessary information

Priority Vector:
LNPD 0.07
CE 0.12
TPD 0.39
RM 0.41

Sub criteria: Redundant development

Priority Vector:
LNPD 0.4
CE 0.40
TPD 0.11
RM 0.08

AMONG SUB FACTORS:

Priority Vector:
Extra/low priority features in design0.43
Too much detail and unnecessary infor0.44
Redundant development0.13

Main Criteria: Motion:

Sub Criteria: Excessive mental motion

Priority Vector:
LNPD 0.54
CE0.28
TPD0.07
RM0.11

Sub criteria: Task switching:

Priority Vector:
LNPD 0.42
CE 0.37
TPD 0.14
RM 0.07

Sub criteria: Effort to find needed information:

Priority Vector:
LNPD 0.42
CE 0.37
TPD 0.14
RM 0.07

AMONG SUBFACTORS:

Priority Vector:
Excessive mental motion 0.43
Task switching 0.44
Effort to find needed information 0.13

Main Criteria: Processing

Sub criteria: :Serial process with excessive iterations

Priority Vector:
LNPD 0.17
CE 0.56
TPD 0.16
RM 0.12

Sub criteria: Excessive reviews and paper work

Priority Vector:
LNPD0.12
CE 0.39
TPD0.37
RM 0.12

Sub criteria: Unnecessary/translating data, format conversion

Priority Vector:
LNPD 0.12
CE 0.08
TPD 0.46
RM 0.35

AMONG SUBFACTORS

Priority Vector:
Serial process with excessive iterations0.22
Excessive reviews and paper work 0.15
Unnecessary/translating data, format conversion 0.63

Main Criteria: Human

Sub criteria: Incomplete, ambiguous, lack of direct access to information

Priority Vector:
LNPD 0.38
CE 0.39
TPD 0.10
RM 0.12

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Sub criteria: Under utilization:

Priority Vector:

LNPD	0.39
CE	0.39
TPD	0.14
RM	0.08

Sub Critertia: Over utilization:

Priority Vector:

LNPD	0.09
CE	0.23
TPD	0.49
RM	0.19

AMONG SUBFACTORS:

Priority Vector:

Incomplete/ambiguous lack of direct access to information 0.17

Under Utilization 0.55

Over Utilization 0.29

AMONG MAIN FACTORS:

	Inventory	Defects	Over production	Motion	Processing	Human
Inventory	1	2	3	5	4	4
Defects	1/2	1	2	4	3	2
Over production	1/3	1/2	1	3	1	1
Motion	1/5	1/4	1/3	1	7/9	2/3
Processing	1/4	1/3	1	9/7	1	2
Human	1/4	1/2	1	3/2	1/2	1

Priority Vector:

Inventory	0.39
Defects	0.22
Over production	0.12
Motion	0.07
Processing	0.10
Human	0.10

INVENTORY

Product Development Strategy	Development work and design work in process	Delays for process approvals	Time waiting for others inputs	Among factors	Resultant value
LNPD	0.49	0.44	0.5	0.31	0.4615
CE	0.28	0.23	0.23	0.59	0.2455
TPD	0.14	0.22	0.19	0.1	0.1922
RM	0.08	0.1	0.07		0.0908

DEFECTS

Product development strategy	Design and development rework	Defects in requirements	Misinterpretation of information	Among factors	Resultant value
LNPD	0.54	0.37	0.42	0.63	0.4846
CE	0.29	0.3	0.41	0.22	0.3102
TPD	0.11	0.24	0.1	0.15	0.1371

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RM	0.06	0.09	0.07		0.0681

OVER PRODUCTION

Product development strategy	Extra/low priority features in design	Too much detail and unnecessary information	Redundant development	Among factors	Resultant value
LNPD	0.12	0.17	0.12	0.22	0.1275
CE	0.39	0.56	0.08	0.15	0.2202
TPD	0.37	0.16	0.46	0.63	0.3952
RM	0.12	0.12	0.35		0.2649

MOTION

Product development strategy	Excessive Mental Motion	Task switching	Effort to find needed information	Among factors	Resultant value
LNPD	0.09	0.39	0.38	0.29	0.226
CE	0.23	0.39	0.39	0.55	0.3059
TPD	0.49	0.14	0.1	0.17	0.3223
RM	0.19	0.08	0.12		0.1529

PROCESSING

Product development strategy	Excessive review and paper work	Serial process with excessive iterations	unnecessary data/translating data, formatting data	Among factors	Resultant value
LNPD	0.41	0.07	0.41	0.43	0.2604
CE	0.4	0.12	0.4	0.44	0.2768
TNPD	0.11	0.39	0.11	0.13	0.2332
RM	0.08	0.41	0.08		0.2252

HUMAN

Product development strategy	Incomplete/ambiguous, lack of direct access information	Under utilization	Over utilization	Among factors	Resultant value
LNPD	0.54	0.42	0.42	0.6	0.492
CE	0.28	0.37	0.37	0.17	0.316
TPD	0.07	0.14	0.14	0.23	0.098
RM	0.11	0.07	0.07		0.094

OVERALL PRIORITY VECTOR:

Product development strategy	Inventory	Defects	Over production	Motion	Processing	Human	Among factors	Overall priority vector
LNPD	0.4615	0.4846	0.226	0.2604	0.1275	0.492	39%	0.393895
CE	0.2455	0.3102	0.3059	0.2768	0.2202	0.316	22%	0.273693
TPD	0.1922	0.1371	0.3223	0.2332	0.3952	0.098	12%	0.20944

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$$\begin{array}{r} LNPD \\ CE \\ TPD \\ RM \end{array} \begin{pmatrix} 0.393895 \\ 0.273693 \\ 0.20944 \\ 0.12039 \end{pmatrix}$$

Conclusion:

In this work AHP methodology is utilized in order to select the best product development strategy by considering different criteria and sub criteria. From the result found, it is understood that overall priority vector of LNPD is attained as 39.38% followed by concurrent engineering methodology, it is suggested that lean new product development may be selected as suitable manufacturing method for the case industry and also LNPD is considered to be the best strategy for case industry as its priority vector is the highest among the various alternative.

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