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Evaluation of Leagile Criteria Using DEMATEL Approach

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***Abstract*—**There is drastic change in manufacturing era in last two decades. It has become mandatory for the industries to become aware of latest and advanced manufacturing technologies and strategies. Leagile manufacturing focuses on minimizing the wastes and meeting customers' requirements in minimum time possible. However, it becomes difficult to implement all leagile tools simultaneously in industry. In this paper, 17 main criteria of leagile manufacturing have been found and DEMATEL (Decision Making Trial and Evaluation Laboratory) approach has been applied to analyze importance of criteria and casual relations among these criteria.

***Keywords*—**Agile, DEMATEL approach, lean, leagilemanufacturing.

I. Introduction and Literature Review

LEAGILE is a combination of both lean and agile manufacturing. Lean tries to eliminate all those activities which do not add value to the product. Lean Manufacturing tries to eliminate different types of wastes that include overproduction, motion, transportation, defects, inventory, etc. Agility can be defined as business wide practice that enables enterprise to respond to sudden changes and meet widely varied customer requirements. Postponement is delaying of operational activities in a system until customer orders are received rather than completing activities in advance and then waiting for orders.

For better understanding of leagility concept, it is necessary to study both concepts; lean and agile. Implementation of lean manufacturing in industries fully started from Womack's famous book 'The machine that changed the world' [1]. The lean manufacturing concept focuses on maximum customer satisfaction by providing quality products at reasonable cost. The need of lean capability has become mandatory for all organizations in order to survive in the market [2]. VSM is found to be important tool by enhancing the value of the product and eliminating all those activities which do not add value to the product [3]. Lean manufacturing involves various tools and techniques which have ultimately objective of achieving maximum customer satisfaction by proving quality products to customers. Lean and agile manufacturing are most widely used strategies in the current scenario [4].

Agility means using market knowledge as well as virtual corporation to exploit profitable opportunities in volatile market. Leagile system has characteristics of both lean and agile manufacturing systems. Reference [5]-[7], defined agile manufacturing as the capability of organization to exploit market opportunities in cost effective manner [20].

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II. Identification of Leagile Manufacturing Criteria's

17 leagile manufacturing criteria are identified and listed in Table I.

TABLE I
List of Leagile Criteria

S.No	Leagile Manufacturing Criteria	Authors
1	Six Sigma	[8]-[11]
2	Supplier Development	[12]-[15]
3	Information Technology	[16]-[19]
4	Kaizen	[20]-[23]
5	Remuneration and Increment Policies	[24]-[26]
6	Training and Motivational Programs	[27], [28]
7	Poke Yoke	[10], [15]
8	FMEA (Failure Mode and Effect Analysis)	[29]-[31]
9	ERP (Enterprise Resource Planning)	[32]-[35]
10	Group Technology	[36], [37]
11	Organizational Culture	[38]-[40]
12	Innovation and R & D	[41], [42]
13	TQM	[43]-[46]
14	Reconfiguration capabilities	[10], [15], [21]
15	Concurrent Engineering	[47]-[49]
16	Supply Chain Management (SCM)	[10], [11], [15]
17	CIM (Computer Integrated Manufacturing)	[39], [46], [49]

III. Questionnaire Based Survey

The questionnaire consist of 17 leagile criteriawhich have been found out through literature review. For evaluating the questionnaire, 5 point Likert scale was used. 1 stands for no influence, 2 stands for low influence, 3 stands for medium influence, 4 stands for high influence and 5 stands for very high influence.

A. Survey Administration

Self-contact, e-mail and postal methods were used for analysis of survey. In total, questionnaires were sent to 100 Indian companies.

B. Survey Responses and the Respondents' Profile

37 filled questionnaires were received out of 100 sent questionnaire. Seven questionnaires were incompletely filled and were removed. So, only 30 of them are considered for analysis. This gives a response rate of 30%, which is not very

low for analyses.

C. Results of Survey

The main purpose of this questionnaire-based survey was to find the pre-requirements (i.e. leagile criteria's) for the transition to Leagile manufacturing. Major finding of this survey is that only 30% companies are interested in transition to leagile manufacturing system.

IV. DEMATEL Technique

DEMATEL (Decision Making Trail and Evaluation Laboratory), has been most widely used technique to solve complex decisions.

Step1. Obtain the experts' opinion and construct average matrix A.

A group of experts are selected and asked to make the direct level of influence between 1 and 5 based on pair-wise comparison.

$$a_{ij} = \sum_{i}^{n} x_{ij}^{k} \quad where\ k = 1,2,3,4,.....n$$

Step2. Compute the normalized initial direct relation matrix D

$$D = A * S$$

$$S = 1/\max 1 \le n \sum_{j=1}^{n} a_{ij}$$

Each element in matrix falls between 0 and 1, where n is the number of respondents.

Step3. Determine Total Relation Matrix is defined as $T = D(I - D)^{-1}$, where I is the identity matrix.

Step4. Calculate the sums of rows and columns of matrix T. In the total-influence matrix T, the sum of rows and the sum of columns are represented by vectors r and c, respectively.

Step5: Determine C + Rand C–R and compute threshold value which is average of all values of Total Relationship matrix T.

V. Calculations and Results

TABLE II
Assessment Data of General Manager

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		3	2	1	3	4	2	3	4	4	1	2	3	2	4	3	3
2	2		3	4	3	5	3	2	4	3	1	2	3	1	3	2	3
3	4	3		4	4	2	3	4	3	1	4	2	4	1	4	3	3
4	4	3	4		4	3	3	3	4	1	4	3	2	4	1	4	3
5	4	3	3	4		4	1	4	1	4	4	3	1	1	4	4	3
6	1	2	4	3	1		2	3	2	3	2	3	4	2	1	3	2
7	3	2	4	1	2	3		3	2	3	4	2	3	3	2	2	1
8	3	2	2	2	3	4	2		1	2	3	2	4	2	3	4	2
9	3	2	3	4	1	5	2	1		2	3	2	2	3	2	4	2
10	3	4	2	3	4	3	2	1	3		3	4	2	4	2	3	1
11	5	3	2	4	3	4	2	3	3	2		2	3	4	3	2	3
12	4	3	4	3	2	3	1	4	3	4	4		3	4	3	4	2
13	2	3	2	4	3	4	3	2	4	3	4	3		4	2	1	2
14	1	4	2	1	2	1	1	2	3	4	2	4	3		1	2	2
15	2	3	3	2	4	5	1	2	1	2	3	2	1	2		3	1
16	3	2	4	3	2	3	3	2	4	1	3	1	3	1	2		1
17	4	3	2	1	2	3	2	3	2	1	3	2	4	1	3	2	2

TABLE III
Initial Average Matrix A for Leagile Criteria

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1	0	3.8	1.9	1.4	2.9	3.5	1.8	2.6	3.6	3.8	1.2	2.1	2.7	1.7	3.4	2.7	3.2	42.3
2	1.8	0	2.8	3.5	2.8	4.8	2.7	1.8	3.8	2.9	1.2	1.8	2.8	1.2	3.1	1.8	2.7	41.5
3	3.5	2.8	0	3.4	3.5	1.8	2.8	3.7	3.1	1.1	3.5	1.9	3.8	1.2	3.7	2.8	3.1	45.7
4	3.8	2.7	3.8	0	3.8	2.7	2.8	2.8	3.7	1.2	3.8	2.8	1.2	3.8	1.1	3.8	2.6	46.4
5	3.8	2.8	3.9	2.8	0	3.7	1.3	3.8	1.1	3.8	3.9	2.7	1.2	1.2	3.7	3.7	2.8	46.2
6	1.2	1.9	3.8	2.8	1.2	0	1.8	2.7	1.9	2.7	1.2	2.4	3.8	2.2	1.2	2.7	1.9	35.4
7	2.8	1.8	3.7	1.2	2.5	2.7	0	2.8	2.1	2.9	3.8	1.9	2.9	3.2	1.8	1.7	1.2	39
8	2.9	1.9	2.1	1.5	2.8	3.8	1.3	0	1.2	2.1	2.7	1.9	3.8	2.2	2.7	3.5	1.7	38.1
9	2.9	1.9	2.7	1.3	1.2	4.5	1.4	1.2	0	2.1	2.8	1.8	2.1	3.2	1.8	3.6	1.8	36.3
10	2.7	3.8	1.6	2.8	3.7	2.7	1.1	1.1	2.9	0	2.8	3.7	2.2	3.8	1.9	2.8	1.1	40.7
11	4.7	2.8	1.5	3.5	2.7	3.6	1.2	2.7	2.7	2.1	0	1.8	3.2	3.8	2.7	1.8	2.9	43.7
12	3.8	2.9	3.5	2.5	1.8	2.7	1.1	3.7	2.6	3.6	3.8	0	2.8	3.7	2.8	3.7	1.9	46.9
13	1.9	2.8	1.9	3.5	2.7	3.7	2.8	1.1	3.5	2.8	3.8	2.8	0	3.6	1.9	1.2	1.8	41.8
14	1.8	3.8	1.8	1.2	1.8	1.2	1.2	1.9	2.9	3.7	1.9	3.5	2.8	0	1.1	1.8	1.9	34.3
15	1.8	2.8	2.9	1.2	3.8	4.8	1.1	2.1	1.1	1.1	2.7	1.8	1.2	1.8	0	2.8	1.1	34.1
16	2.7	1.8	3.7	2.8	1.8	2.6	2.9	2.2	3.7	1.2	2.8	1.2	2.8	1.2	1.9	0	1.3	36.6
17	3.8	2.9	1.6	1.1	1.6	2.7	1.2	2.8	1.8	1.1	2.8	1.8	3.8	1.1	2.8	1.8	0	34.7
	45.9	43.2	43.2	36.5	40.6	51.5	28.5	39	41.7	38.2	44.7	35.9	43.1	38.9	37.6	42.2	33	

TABLE IV
NORMALIZED INITIAL DIRECT RELATION MATRIX D

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	0.074	0.037	0.027	0.056	0.068	0.035	0.05	0.07	0.074	0.023	0.041	0.052	0.033	0.066	0.052	0.062
2	0.03	0	0.054	0.068	0.054	0.093	0.052	0.035	0.074	0.056	0.023	0.035	0.054	0.023	0.06	0.035	0.052
3	0.07	0.054	0	0.066	0.068	0.035	0.054	0.072	0.06	0.021	0.068	0.037	0.074	0.023	0.072	0.054	0.06
4	0.07	0.052	0.074	0	0.074	0.052	0.054	0.054	0.072	0.023	0.074	0.054	0.023	0.074	0.021	0.074	0.05
5	0.07	0.054	0.076	0.054	0	0.072	0.025	0.074	0.021	0.074	0.076	0.052	0.023	0.023	0.072	0.072	0.054
6	0.02	0.037	0.074	0.054	0.023	0	0.035	0.052	0.037	0.052	0.023	0.047	0.074	0.043	0.023	0.052	0.037
7	0.05	0.035	0.072	0.023	0.049	0.052	0	0.054	0.041	0.056	0.074	0.037	0.056	0.062	0.035	0.033	0.023
8	0.06	0.037	0.041	0.029	0.054	0.074	0.025	0	0.023	0.041	0.052	0.037	0.074	0.043	0.052	0.068	0.033
9	0.06	0.037	0.052	0.025	0.023	0.087	0.027	0.023	0	0.041	0.054	0.035	0.041	0.062	0.035	0.07	0.035
10	0.05	0.074	0.031	0.054	0.072	0.052	0.021	0.021	0.056	0	0.054	0.072	0.043	0.074	0.037	0.054	0.021
11	0.09	0.054	0.029	0.068	0.052	0.07	0.023	0.052	0.052	0.041	0	0.035	0.062	0.074	0.052	0.035	0.056
12	0.07	0.056	0.068	0.049	0.035	0.052	0.021	0.072	0.05	0.07	0.074	0	0.054	0.072	0.054	0.072	0.037
13	0.04	0.054	0.037	0.068	0.052	0.072	0.054	0.021	0.068	0.054	0.074	0.054	0	0.07	0.037	0.023	0.035
14	0.03	0.074	0.035	0.023	0.035	0.023	0.023	0.037	0.056	0.072	0.037	0.068	0.054	0	0.021	0.035	0.037
15	0.03	0.054	0.056	0.023	0.074	0.093	0.021	0.041	0.021	0.021	0.052	0.035	0.023	0.035	0	0.054	0.021
16	0.05	0.035	0.072	0.054	0.035	0.05	0.056	0.043	0.072	0.023	0.054	0.023	0.054	0.023	0.037	0	0.025
17	0.07	0.056	0.031	0.021	0.031	0.052	0.023	0.054	0.035	0.021	0.054	0.035	0.074	0.021	0.054	0.035	0

TABLE V
TOTAL RELATIONSHIP MATRIX T

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
1	0.19[a]	0.25	0.21	0.18[a]	0.22	0.28	0.15[a]	0.21	0.24	0.23	0.2[a]	0.19[a]	0.2a	0.19a	0.22	0.23	0.2[a]	3.57
2	0.22	0.18[a]	0.23	0.22	0.22	0.3	0.17[a]	0.19	0.24	0.21	0.2a	0.18[a]	0.21	0.18a	0.21	0.21	0.19[a]	3.56
3	0.27	0.25	0.2[a]	0.23	0.25	0.27	0.18[a]	0.24	0.25	0.19[a]	0.26	0.2a	0.24	0.2[a]	0.24	0.24	0.21	3.91
4	0.28	0.25	0.27	0.17[a]	0.25	0.28	0.19[a]	0.23	0.26	0.2[a]	0.27	0.22	0.2[a]	0.24	0.2[a]	0.26	0.21	3.97
5	0.28	0.25	0.27	0.22	0.19[a]	0.3	0.16[a]	0.25	0.21	0.24	0.27	0.21	0.2[a]	0.2[a]	0.24	0.26	0.21	3.96
6	0.18[a]	0.19[a]	0.22	0.19[a]	0.17[a]	0.18[a]	0.14[a]	0.19[a]	0.19[a]	0.19[a]	0.18	0.17[a]	0.2[a]	0.18[a]	0.16[a]	0.2[a]	0.16[a]	3.07
7	0.23	0.2[a]	0.23	0.17[a]	0.2[a]	0.25	0.11[a]	0.2[a]	0.2[a]	0.2[a]	0.24	0.18[a]	0.2[a]	0.21	0.18[a]	0.2[a]	0.16[a]	3.37
8	0.22	0.2[a]	0.2[a]	0.17[a]	0.2[a]	0.26	0.14a	0.15[a]	0.18[a]	0.19[a]	0.21	0.17[a]	0.21	0.19a	0.19[a]	0.22	0.16[a]	3.27
9	0.21	0.19[a]	0.2[a]	0.16[a]	0.17[a]	0.26	0.13[a]	0.16[a]	0.15[a]	0.18[a]	0.21	0.16[a]	0.18[a]	0.2a	0.17[a]	0.22	0.15[a]	3.09
10	0.23	0.25	0.21	0.2[a]	0.23	0.26	0.14[a]	0.18[a]	0.23	0.16[a]	0.23	0.21	0.19[a]	0.23	0.19[a]	0.22	0.16[a]	3.51
11	0.28	0.24	0.21	0.22	0.22	0.29	0.15[a]	0.22	0.23	0.21	0.19[a]	0.19[a]	0.22	0.23	0.21	0.22	0.2[a]	3.72
12	0.28	0.25	0.26	0.22	0.22	0.29	0.16[a]	0.25	0.24	0.24	0.27	0.17[a]	0.23	0.25	0.23	0.26	0.19[a]	3.99
13	0.22	0.23	0.22	0.22	0.22	0.28	0.17[a]	0.18[a]	0.24	0.21	0.25	0.2[a]	0.16[a]	0.23	0.19[a]	0.2[a]	0.17[a]	3.59
14	0.19[a]	0.22	0.18[a]	0.15[a]	0.17a	0.2	0.12a	0.17[a]	0.2[a]	0.2a	0.19[a]	0.19[a]	0.18[a]	0.13[a]	0.15a	0.18[a]	0.15[a]	2.97
15	0.19[a]	0.2[a]	0.2[a]	0.15[a]	0.21	0.26	0.12[a]	0.17[a]	0.16[a]	0.15[a]	0.2[a]	0.16[a]	0.15[a]	0.16a	0.13a	0.2[a]	0.14[a]	2.95
16	0.22	0.19[a]	0.23	0.19[a]	0.18	0.24	0.16[a]	0.18a	0.22	0.16a	0.21	0.15[a]	0.19[a]	0.17a	0.17[a]	0.16[a]	0.15[a]	3.17
17	0.22	0.2[a]	0.18[a]	0.15[a]	0.17	0.23	0.12[a]	0.19a	0.18[a]	0.15a	0.2[a]	0.16[a]	0.2[a]	0.15[a]	0.18[a]	0.18[a]	0.12[a]	2.98
	3.91	3.72	3.72	3.22	3.49	4.42	2.51	3.37	3.62	3.32	3.77	3.11	3.35	3.33	3.27	3.65	2.91	

Note: [a] values below threshold

TABLE VI
DEGREE OF TOTAL INFLUENCE OF LEAGILE CRITERIA

Criteria	Sum(C)	Sum R	Prominence(C+R)	Net Effect(C-R)	Group
C1	3.571	3.908	7.479	-0.337	Effect
C2	3.562	3.715	7.277	-0.153	Effect
C3	3.91	3.718	7.628	0.192	Cause
C4	3.972	3.216	7.188	0.756	Cause
C5	3.956	3.485	7.441	0.471	Cause
C6	3.073	4.415	7.488	-1.342	Effect
C7	3.371	2.511	5.882	0.86	Cause
C8	3.27	3.367	6.637	-0.097	Effect
C9	3.094	3.619	6.713	-0.525	Effect
C10	3.505	3.318	6.823	0.187	Cause
C11	3.716	3.768	7.484	-0.052	Effect
C12	3.994	3.106	7.1	0.888	Cause
C13	3.592	3.345	6.937	0.247	Cause
C14	2.965	3.329	6.294	-0.364	Effect
C15	2.945	3.267	6.212	-0.322	Effect
C16	3.17	3.648	6.818	-0.48	Effect
C17	2.977	2.908	5.885	0.069	Cause

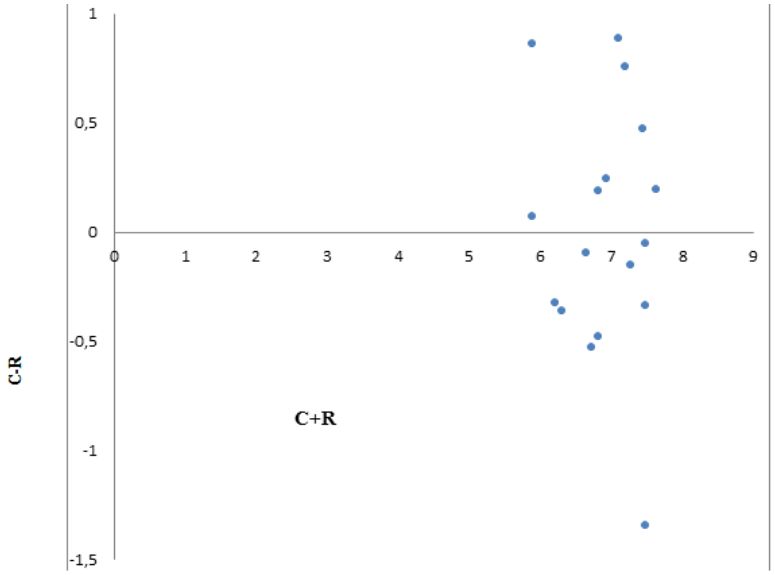

Fig. 1 Overall DEMATEL Prominence Casual Graph

The threshold value is calculated by taking average of all values of total relationship matrix and it is equal to 0.20.

VI. Conclusion and Implications

For successfully implementing leagile system, it will be convenient to categorize the leagile criteria. DEMATEL approach categorizes the criteria based on C-R values. The leagile criteria are classified in to cause and effect categories. If C-R value is positive, leagile criteria will fall under cause category and if C-R value is negative, leagile criteria will fall under effect category The Criteria 1 (Six sigma), 2 (Supplier Development), 6 (Training and development programs), 8 (FMEA), 9 (ERP), 11 (Organizational Culture), 14 (Reconfiguration capabilities), 15 (Concurrent Engineering), 16 (Supply Chain Management) represents effect group. The criteria 3 (Information Technology), 4 (Kaizen), 5 (Remuneration and Increment Policy), 7 (Poke Yoke), 10 (Group Technology), 12 (Innovation and R & D), 13 (TQM), 17 (CIM) are placed under cause group. The paper provides a comprehensive set of criteria and their interrelationships for implementing leagile manufacturing successfully. With the help of casual diagram, the complex problem can be easily solved and better decisions can be made with relative ease. The manager can better understand the implications involved and in better position to make sound and effective decisions.

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