RESEARCH ARTICLE OPEN ACCESS

The Technical Efficiency of Artificial Intelligence and Robotics Integrated Precision Engineering and Technology Cluster

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ABSTRACT

The Precision Engineering and Technology Centre (PETC) have Common Facility Centre on Product Design, Product development and testing of Automotive Components for use of all 40 Automotive Components Manufacturers at Tirumudivakkam, Chennai, Tamil Nadu, India. The objective is to study the technical efficiency for 5 input and 5 output variables related to traditional and AI and Robotics integrated Production Optimisation, that is before and after Cluster Development Approach. The methodology adopted is collection of primary data from 40 automotive components manufacturers at Chennai. It is found that all the 40 are using these Common Facility Centre with less service charge when compared to market price since they are all members in PETC. The technical efficiency of integrated AI is greater than traditional machines used by them individually. The Design Software's, Product Development Machines and Testing Machines are available in PETC, CFC so that 40 Automotive components Manufacturers can make use of with less service charge which leads to cost minimisation and profit maximisation. To conclude technical efficiency of AI based usage leads to cost minimization and profit maximization of individual Automotive Components Manufacturers when compared to traditional usage of machineries.

Keywords :- Artificial Intelligence and Robotics, Technical Efficiency, Precision Engineering and Technology Cluster
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I. INTRODUCTION

The Precision Engineering and Technology Centre (PETC) is a flagship initiative of TIEMA, established with the support of the Government of Tamil Nadu under the Precision Manufacturing Mega Cluster Scheme. PETC is dedicated to empowering Micro, Small, and Medium Enterprises (MSMEs) in the areas of innovation and new product development. [1]

Facilities and Infrastructure
PETC offers a wide array of advanced facilities, including:

- Product Design Centre
- Re-Engineering Lab featuring:
  - 3D Scanner (Hexagon)
  - 3D Metal & Plastic Printers (EOS Machines)
  - Commercial-grade 3D Printing
- Mechanical Testing Lab
- Electroplating Coating Thickness Measurement
- Coordinate Measuring Machine (CMM) – 1.8m x 1.2m
- Surface Roughness & Contour Measurement (ZEISS)
- Patent Support Centre
- Rental Office Space (10x10 feet)

Figure 1: Wire Cut EDM

Organizational Structure : PETC operates as a Special Purpose Vehicle (SPV) and is registered as a not-for-profit organization, offering services to MSMEs at subsidized rates. Its mission is to accelerate the growth and technological advancement of MSMEs in the precision engineering sector.

Membership Benefits: Membership is offered through a one-time lifetime contribution of ₹2,50,000. Members gain access to all facilities and services at preferential rates, fostering a collaborative ecosystem for innovation and technical excellence.

Metrology and Re-Engineering Capabilities available are as follows:

ZEISS CMM Contura 6206

- Table Size: 1.2 m × 1.8 m × 0.6 m
- Highlights: Offers high-precision measurement capabilities for complex components, with a large working envelope ideal for manufacturing and quality control tasks as shown in figure 2.

Figure 2: ZEISS CMM Contura 6206

Hexagon Smart Scan (12 MP Blue Light Scanner)

- Accuracy: 12 µm @ 200 GOV, 20 µm @ 500 FOV
- Camera: 12 MP High-Resolution
- Features:
  - STL export with low file size using AI
  - Colour comparison and GD&T callouts via INSPIRT software
  - High-accuracy scanning suitable for design validation and reverse engineering

CONTURECORD 1600 G-14

- Straightness Accuracy: 1 µm / 100 mm
- Z-Axis Range: 50 mm (Inductive Pickup)
- X-Axis Range: 100 mm
- Resolution: 0.1 µm / 5 mm; 1 µm / 25 mm

SURFCOM TOUCH 50

- Straightness Accuracy: 0.3 µm / 50 mm
- Z-Axis Range: 1000 µm
- Resolution: 0.1 nanometres @ ±40 µm range [2]

II LITERATURE SURVEY

Testing Facilities at PETC

PETC is equipped with advanced testing facilities to support precision engineering and product development, including:

- Mechanical Testing Laboratory
- ZEISS Axio Vert 5 Inverted Metallurgical Microscope as shown in figure 3
- Plating Thickness Measurement Systems

Figure 3: Metallurgical Microscope

Metallographic microscopes are used to identify defects in metal surfaces, to determine the crystal grain boundaries in metal alloys, and to study rocks and minerals. This type of microscope employs vertical illumination, in which the light source is inserted into the microscope tube below the eyepiece by means of a beam splitter. Light shines down through the objective and is focused through the objective onto the specimen.

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Industry-Relevant Training Programs

PETC offers customized training programs designed to upskill the workforce and drive business growth. These programs cover a wide range of industry-focused modules, including:

- Product Design
- Tool and Die Making
- Die Casting
- Reverse Engineering
- 3D Printing / Additive Manufacturing
  - *EOS P396* – for High-Precision 3D Plastic Printing for flexible and tool free production of polymer parts on demand to serial production for materials PA 2200, Thermoplastic Polyurethane (TPU)
  - *EOS M290* – for Industrial-Grade 3D Metal Printing for metal parts with consistent and repeatable part quality with materials like maraging steel (Tool Steel Grade), Alsi10mg (Aluminium), Titanium Alloy, Cu Alloy and Nickel Alloy.
- Design for Additive Manufacturing (DFAM)
- Fused Deposition Modelling (JK Print 300)

- Digital Light Processing (Elegoo Saturn) with materials black, white and clear resin.

In -House Post Process Facilities

- ✓ Wire cut EDM in figure 1.
- ✓ Sand Blasting / Shot Peening
- ✓ Muffle Furnace (degree C) in figure 4
- ✓ Vacuum Casting as shown in figure 5.

Figure 4: Muffle Furnace

Muffle furnace as shown in figure 4, refers to a type of jacketed enclosure that is used to heat a material to significantly high temperatures while keeping it contained and fully isolated from external contaminants, chemicals or substances. Muffle furnaces are usually lined with stainless steel, making them largely corrosion resistant.

Figure 5: Vacuum Casting

Customized Training Solutions

PETC provides tailored training solutions to meet the specific requirements of both industry and academic partners. Their expert team works closely with clients to develop custom design modules that align with organizational goals—whether it's upskilling existing employees, onboarding new hires, or addressing unique technical challenges.

III OBJECTIVE OF THE STUDY

1.To study and compare constant returns to scale technical efficiency (crtse) of Traditional and AI + Robotics Integrated.
2.To study and compare variable returns to scale technical efficiency (vrtse) of Traditional and AI + Robotics Integrated .
3.To study and compare scale efficiency (which is crtse divided by vrtse) of Traditional and AI + Robotics Integrated .

IV MATERIALS AND METHODS

The methodology of the study is collection of 5 Input variables like Employment in Nos (En), Capital Investment in Crores (Cc), Testing Facilities (Tf), Energy Efficiency (Ee) and Environmental /Social Management (Esm) and 5 output variables like Market Reach (Mr), Export Competitiveness (Ec), Quality Capability (Qc), Profit Margin (Pm) and Turnover in Rs. Crores (Tc) from 40 Automotive Components Manufacturers. The data are analysed using Output Oriented Multi Stage Data Envelopment Analysis (DEA) to find constant returns to scale (crste), variables return to scale (vrste) and scale efficiency for before (b) and after (a) Cluster Development Approach that is Traditional and Integration of Artificial Intelligence and Robotics.

CONCEPTUAL FRAME WORK

Input Variables (5) →	Output Variables (5) →	Technical Efficiency

Source: Developed by Researcher

Figure 6: Conceptual Framework

The Conceptual Framework is shown in figure 6.

V RESULTS AND DISCUSSION

The name of Automotive Components Manufacturers [6] and the year of establishment are given in figure 7.

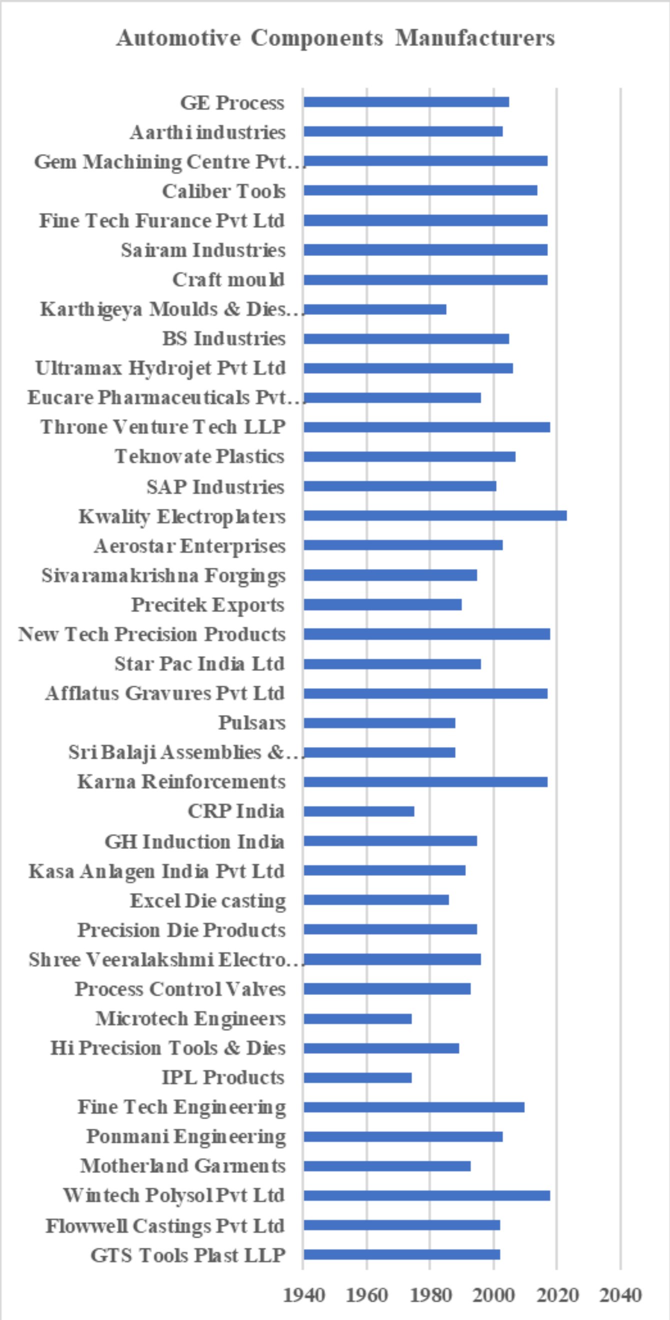

Figure 7: Name of Automotive Components Manufacturers and the year of establishment

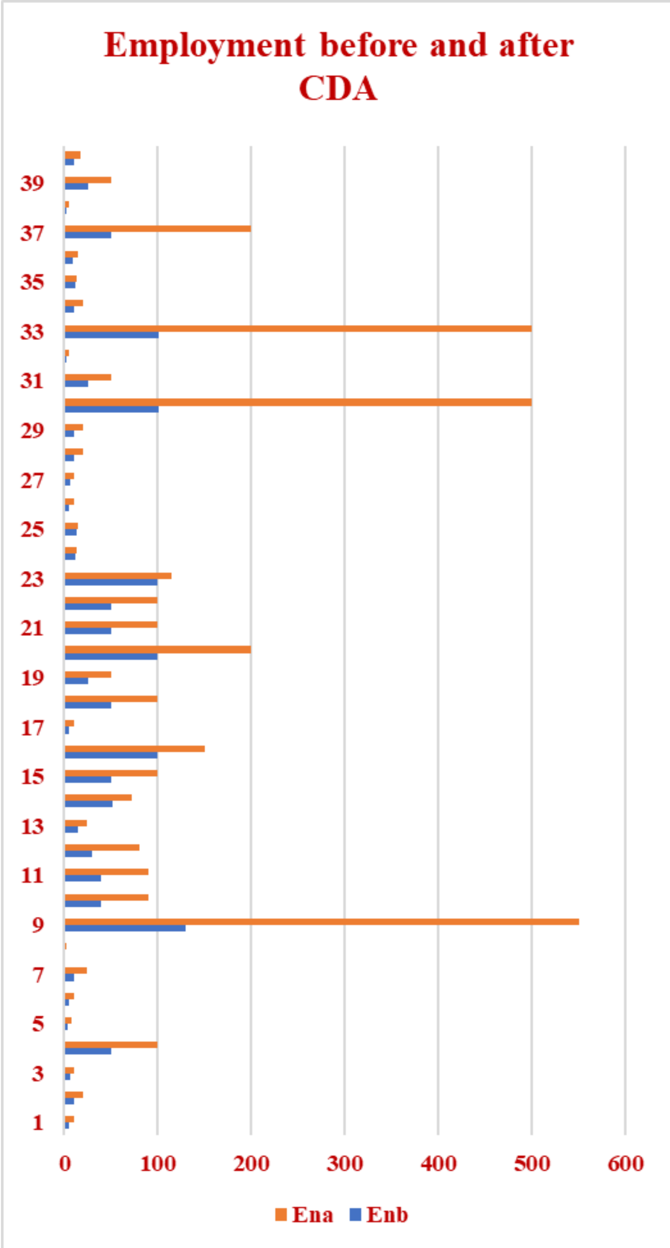

Figure 8: Employment in Automotive Components Manufacturers

Figure 8: gives Increase in Employment in Automotive Components Manufacturers before and after Cluster Development Approach.

Figure 9 exposes Increase in Capital Investment in Automotive Components Manufacturers before and after Cluster Development Approach.

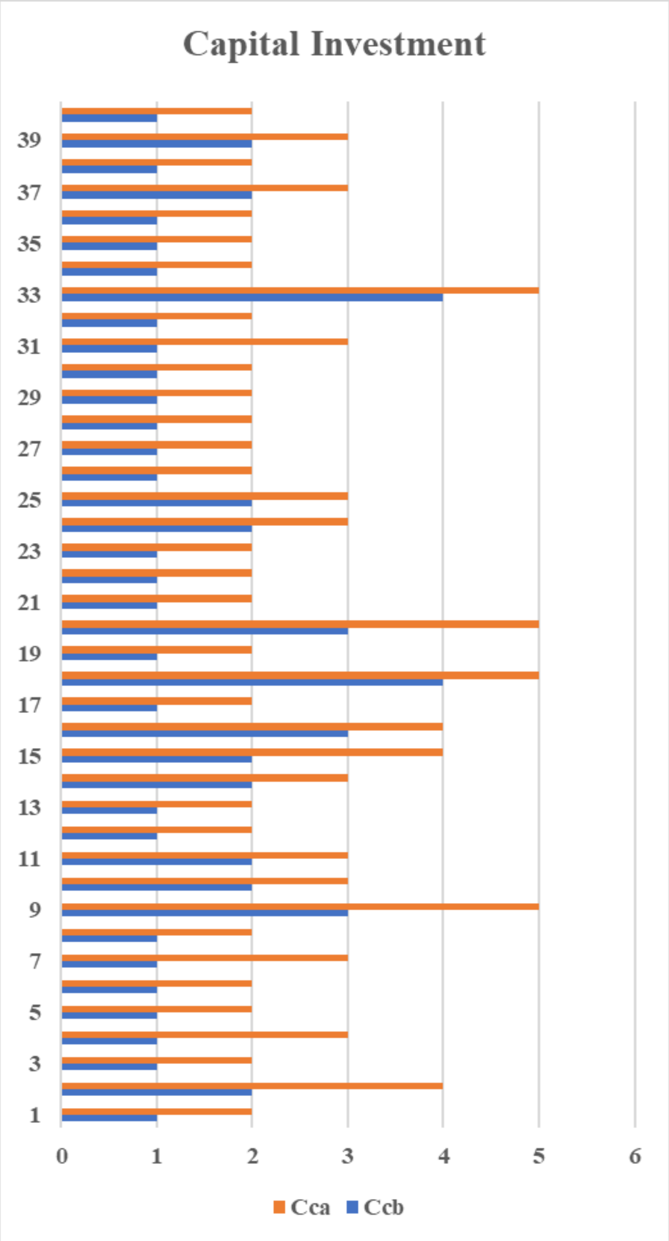

Figure 9: Capital Investment in Automotive Components Manufacturers

Figure 10: reveals increase in Turnover in Automotive Components Manufacturers before and after Cluster Development Approach,

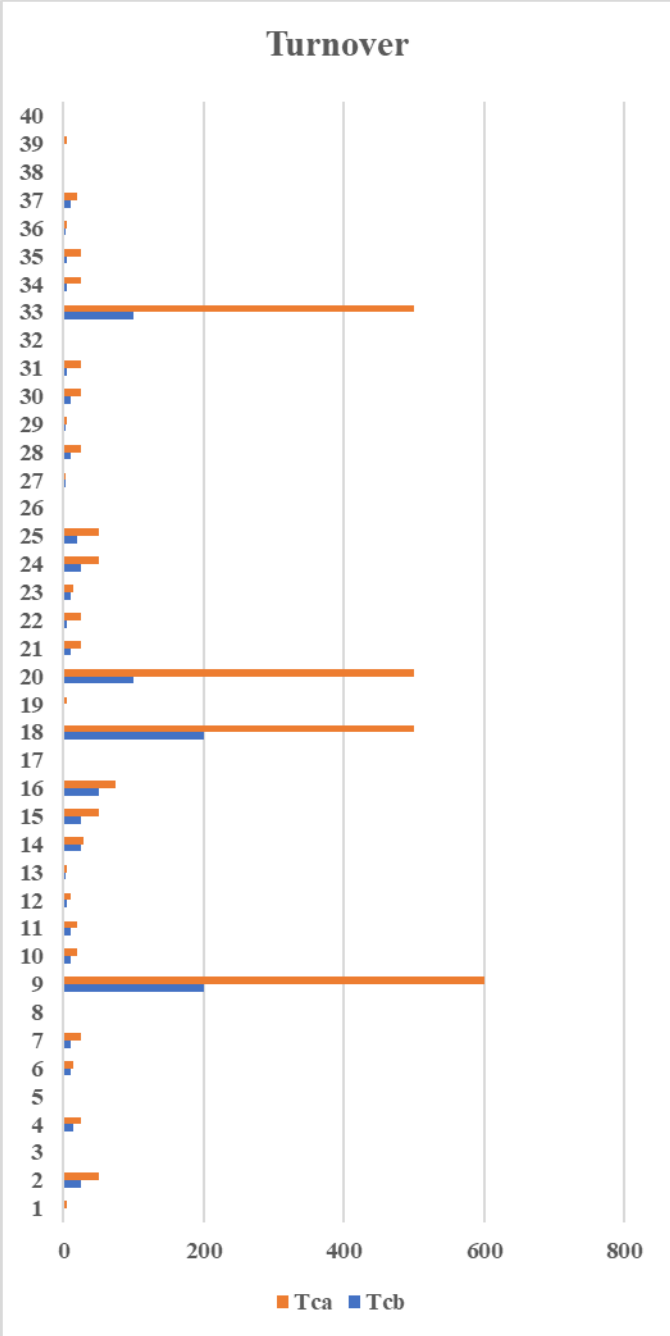

Figure 10: Turnover in Automotive Components Manufacturers

The Technical Efficiency is calculated in table 1 and peer weights in table 2 for the input and output variables for traditional and AI integrated production optimisation.

DATA ENVELOPMENT ANALYSIS
BCC-O Model

$$\max_{\emptyset, \lambda, S^+, S^-} Z_0 = \emptyset + \varepsilon \vec{1} S^+ + \varepsilon \vec{1} S^-$$

Subject to

$$\emptyset Y_0 - Y\lambda + S^+ = 0$$
$$X\lambda + S^- = X_0$$
$$\vec{1}\lambda \geq 1, \quad \lambda, S^+, S^- \geq 0$$

Computing Methodology

Initially we consider First DMU as the studied DMU and the Linear Programming (LP) Model is formulated as given below

Max $\emptyset_0$

Subject to

$Y_{11}\lambda_1 + Y_{12}\lambda_2 + \ldots\ldots\ldots Y_{40}\lambda_{40} \geq Y_{11}$ Output Constraints
$Y_{21}\lambda_1 + Y_{22}\lambda_2 + \ldots\ldots\ldots Y_{40}\lambda_{40} \geq Y_{21}$ Output Constraints
$Y_{31}\lambda_1 + Y_{32}\lambda_2 + \ldots\ldots\ldots Y_{40}\lambda_{40} \geq Y_{31}$ Output Constraints
$Y_{41}\lambda_1 + Y_{42}\lambda_2 + \ldots\ldots\ldots Y_{40}\lambda_{40} \geq Y_{41}$ Output Constraints
$Y_{51}\lambda_1 + Y_{52}\lambda_2 + \ldots\ldots\ldots Y_{40}\lambda_{40} \geq Y_{51}$ Output Constraints

$X_{11}\emptyset_0 - X_{11}\lambda_1 - X_{12}\lambda_2 - \ldots X_{40}\lambda_{40} \geq 0$ Input Constraints
$X_{21}\emptyset_0 - X_{21}\lambda_1 - X_{22}\lambda_2 - \ldots X_{40}\lambda_{40} \geq 0$ Input Constraints
$X_{31}\emptyset_0 - X_{31}\lambda_1 - X_{32}\lambda_2 - \ldots X_{40}\lambda_{40} \geq 0$ Input Constraints
$X_{41}\emptyset_0 - X_{41}\lambda_1 - X_{42}\lambda_2 - \ldots X_{40}\lambda_{40} \geq 0$ Input Constraints
$X_{51}\emptyset_0 - X_{51}\lambda_1 - X_{52}\lambda_2 - \ldots X_{40}\lambda_{40} \geq 0$ Input Constraints
$X_{61}\emptyset_0 - X_{61}\lambda_1 - X_{62}\lambda_2 - \ldots\ldots\ldots X_{40}\lambda_{40} \geq 0$ Input Constraints
$\lambda_1 + \lambda_2 + \ldots \lambda_{40} = 1.$
$\lambda_1, \lambda_2, \ldots \lambda_{40} \geq 0$, $\emptyset_0$ is unrestricted.

By solving the above equations and continuously changing the studied DMUs the value of λ_i's and $\emptyset_i$'s [3]

Table 1 gives Technical Efficiency of before and after Cluster Development Approach.

Note: crste = technical efficiency from CRS DEA
vrste = technical efficiency from VRS DEA
scale = scale efficiency = crste/vrste

Table 1: Technical Efficiency of before and after CDA

firm	crste	vrste	scale		firm	crste	vrste	scale	
1	1.000	1.000	1.000	-	1	1.000	1.000	1.000	-
2	1.000	1.000	1.000	-	2	1.000	1.000	1.000	-
3	1.000	1.000	1.000	-	3	1.000	1.000	1.000	-
4	0.809	1.000	0.809	irs	4	1.000	1.000	1.000	-
5	1.000	1.000	1.000	-	5	1.000	1.000	1.000	-
6	1.000	1.000	1.000	-	6	1.000	1.000	1.000	-
7	1.000	1.000	1.000	-	7	1.000	1.000	1.000	-
8	1.000	1.000	1.000	-	8	1.000	1.000	1.000	-
9	1.000	1.000	1.000	-	9	1.000	1.000	1.000	-
10	1.000	1.000	1.000	-	10	0.919	1.000	0.919	drs
11	1.000	1.000	1.000	-	11	0.919	1.000	0.919	drs
12	1.000	1.000	1.000	-	12	1.000	1.000	1.000	-
13	0.707	0.707	1.000	-	13	1.000	1.000	1.000	-
14	1.000	1.000	1.000	-	14	1.000	1.000	1.000	-
15	1.000	1.000	1.000	-	15	1.000	1.000	1.000	-
16	0.727	0.727	1.000	-	16	1.000	1.000	1.000	-
17	1.000	1.000	1.000	-	17	1.000	1.000	1.000	-
18	1.000	1.000	1.000	-	18	1.000	1.000	1.000	-
19	0.737	0.737	1.000	-	19	1.000	1.000	1.000	-
20	1.000	1.000	1.000	-	20	1.000	1.000	1.000	-
21	1.000	1.000	1.000	-	21	1.000	1.000	1.000	-
22	1.000	1.000	1.000	-	22	1.000	1.000	1.000	-
23	1.000	1.000	1.000	-	23	1.000	1.000	1.000	-
24	1.000	1.000	1.000	-	24	1.000	1.000	1.000	-
25	1.000	1.000	1.000	-	25	1.000	1.000	1.000	-
26	1.000	1.000	1.000	-	26	1.000	1.000	1.000	-
27	1.000	1.000	1.000	-	27	1.000	1.000	1.000	-
28	1.000	1.000	1.000	-	28	1.000	1.000	1.000	-
29	1.000	1.000	1.000	-	29	1.000	1.000	1.000	-
30	1.000	1.000	1.000	-	30	1.000	1.000	1.000	-
31	1.000	1.000	1.000	-	31	1.000	1.000	1.000	-
32	1.000	1.000	1.000	-	32	1.000	1.000	1.000	-
33	0.777	1.000	0.777	drs	33	0.961	1.000	0.961	drs
34	0.771	0.773	0.997	irs	34	1.000	1.000	1.000	-
35	1.000	1.000	1.000	-	35	1.000	1.000	1.000	-
36	1.000	1.000	1.000	-	36	1.000	1.000	1.000	-
37	0.671	1.000	0.671	drs	37	0.988	1.000	0.988	drs
38	1.000	1.000	1.000	-	38	1.000	1.000	1.000	-
39	0.667	1.000	0.667	drs	39	0.984	1.000	0.984	drs
40	1.000	1.000	1.000	-	40	1.000	1.000	1.000	-
mean	0.947	0.974	0.973		mean	0.994	1.000	0.994	

able 2: Peer Weights of before and after CDA

Peer Weights B	Peer Weights A
firm peer weights:	firm peer weights:
1 1.000	1 1.000
2 1.000	2 1.000
3 1.000	3 1.000
4 1.000	4 0.882 0.118
5 1.000	5 1.000
6 1.000	6 1.000
7 1.000	7 1.000
8 1.000	8 1.000
9 1.000	9 1.000
10 1.000	10 0.257 0.269 0.257 0.216
11 0.189 0.811	11 0.387 0.188 0.131 0.241 0.053
12 1.000	12 1.000
13 0.169 0.831	13 1.000
14 0.261 0.739	14 1.000
15 1.000	15 1.000
16 0.250 0.750	16 1.000
17 0.019 0.981	17 1.000
18 1.000	18 1.000
19 0.713 0.287	19 1.000
20 1.000	20 1.000
21 1.000	21 1.000
22 1.000	22 0.500 0.500
23 1.000	23 1.000
24 1.000	24 1.000
25 1.000	25 1.000
26 1.000	26 1.000
27 1.000	27 1.000
28 1.000	28 1.000
29 1.000	29 1.000
30 1.000	30 1.000
31 1.000	31 1.000
32 1.000	32 1.000
33 0.733 0.267	33 0.148 0.852
34 0.253 0.334 0.058 0.355	34 0.250 0.750
35 0.176 0.380 0.444	35 1.000
36 0.602 0.398	36 1.000
37 1.000	37 1.000
38 1.000	38 1.000
39 0.610 0.390	39 1.000
40 1.000	40 1.000

It is found from table 1 and 2 that there is increase in constant returns to scale technical efficiency, variable returns to scale technical efficiency and scale efficiency on after Cluster Development Approach when compared to before Cluster Development Approach.

Malmquist Productivity Index

Output orientated Malmquist DEA is given in table 3.[4]

Table 3: Output orientated Malmquist DEA

year = 1

firm no.	crs te rel to tech in yr ************************ t-1	t	t+1	vrs te
1	0.000	0.025	0.050	0.025
2	0.000	0.050	0.100	0.050
3	0.000	0.075	0.150	0.075
4	0.000	0.100	0.200	0.100
5	0.000	0.125	0.250	0.125
6	0.000	0.150	0.300	0.150
7	0.000	0.175	0.350	0.175
8	0.000	0.200	0.400	0.200
9	0.000	0.225	0.450	0.225
10	0.000	0.250	0.500	0.250
11	0.000	0.275	0.550	0.275
12	0.000	0.300	0.600	0.300
13	0.000	0.325	0.650	0.325
14	0.000	0.350	0.700	0.350
15	0.000	0.375	0.750	0.375
16	0.000	0.400	0.800	0.400
17	0.000	0.447	0.924	0.447
18	0.000	0.450	0.900	0.450
19	0.000	0.475	0.950	0.475
20	0.000	0.500	1.000	0.500
21	0.000	0.525	1.050	0.525
22	0.000	0.550	1.100	0.550
23	0.000	0.575	1.150	0.575
24	0.000	0.600	1.200	0.600
25	0.000	0.625	1.250	0.625
26	0.000	1.000	2.031	1.000
27	0.000	0.675	1.350	0.675
28	0.000	0.700	1.400	0.700
29	0.000	0.725	1.450	0.725
30	0.000	0.750	1.500	0.750

31 0.000 0.775 1.550 0.775
32 0.000 1.000 1.905 1.000
33 0.000 0.825 1.650 0.825
34 0.000 0.850 1.700 0.850
35 0.000 0.875 1.750 0.875
36 0.000 0.900 1.800 0.900
37 0.000 0.925 1.850 0.925
38 0.000 1.000 2.065 1.000
39 0.000 0.975 1.950 0.975
40 0.000 1.000 2.000 1.000

mean 0.000 0.528 1.057 0.528

year = 2

firm	crs te rel to tech in yr			vrs
no.	************************			te
	t-1	t	t+1	
1	0.013	0.025	0.000	0.025
2	0.025	0.050	0.000	0.050
3	0.038	0.075	0.000	0.075
4	0.050	0.100	0.000	0.100
5	0.063	0.125	0.000	0.125
6	0.075	0.150	0.000	0.150
7	0.088	0.175	0.000	0.175
8	0.114	0.227	0.000	0.227
9	0.113	0.225	0.000	0.225
10	0.125	0.250	0.000	0.250
11	0.138	0.275	0.000	0.275
12	0.150	0.300	0.000	0.300
13	0.163	0.325	0.000	0.325
14	0.175	0.350	0.000	0.350
15	0.188	0.375	0.000	0.375
16	0.200	0.400	0.000	0.400
17	0.213	0.425	0.000	0.425
18	0.225	0.450	0.000	0.450
19	0.238	0.475	0.000	0.475
20	0.250	0.500	0.000	0.500
21	0.263	0.525	0.000	0.525
22	0.275	0.550	0.000	0.550
23	0.288	0.575	0.000	0.575
24	0.300	0.600	0.000	0.600
25	0.313	0.625	0.000	0.625
26	0.448	0.813	0.000	0.813
27	0.338	0.675	0.000	0.675
28	0.350	0.700	0.000	0.700
29	0.362	0.725	0.000	0.725
30	0.375	0.750	0.000	0.750
31	0.388	0.775	0.000	0.775
32	0.552	1.000	0.000	1.000
33	0.412	0.825	0.000	0.825
34	0.425	0.850	0.000	0.850
35	0.438	0.875	0.000	0.875
36	0.450	0.900	0.000	0.900
37	0.462	0.925	0.000	0.925
38	0.475	0.950	0.000	0.950
39	0.488	0.975	0.000	0.975
40	0.500	1.000	0.000	1.000

mean 0.263 0.522 0.000 0.522

[Note that t-1 in year 1 and t+1 in the final year are not defined]

MALMQUIST INDEX SUMMARY

year = 2

firm	effch	techch	pech	sech	tfpch
1	1.000	0.500	1.000	1.000	0.500
2	1.000	0.500	1.000	1.000	0.500
3	1.000	0.500	1.000	1.000	0.500
4	1.000	0.500	1.000	1.000	0.500
5	1.000	0.500	1.000	1.000	0.500
6	1.000	0.500	1.000	1.000	0.500
7	1.000	0.500	1.000	1.000	0.500
8	1.136	0.501	1.136	1.000	0.570
9	1.000	0.500	1.000	1.000	0.500
10	1.000	0.500	1.000	1.000	0.500
11	1.000	0.500	1.000	1.000	0.500
12	1.000	0.500	1.000	1.000	0.500
13	1.000	0.500	1.000	1.000	0.500
14	1.000	0.500	1.000	1.000	0.500
15	1.000	0.500	1.000	1.000	0.500
16	1.000	0.500	1.000	1.000	0.500
17	0.950	0.492	0.950	1.000	0.467
18	1.000	0.500	1.000	1.000	0.500

19	1.000	0.500	1.000	1.000	0.500
20	1.000	0.500	1.000	1.000	0.500
21	1.000	0.500	1.000	1.000	0.500
22	1.000	0.500	1.000	1.000	0.500
23	1.000	0.500	1.000	1.000	0.500
24	1.000	0.500	1.000	1.000	0.500
25	1.000	0.500	1.000	1.000	0.500
26	0.813	0.521	0.813	1.000	0.423
27	1.000	0.500	1.000	1.000	0.500
28	1.000	0.500	1.000	1.000	0.500
29	1.000	0.500	1.000	1.000	0.500
30	1.000	0.500	1.000	1.000	0.500
31	1.000	0.500	1.000	1.000	0.500
32	1.000	0.538	1.000	1.000	0.538
33	1.000	0.500	1.000	1.000	0.500
34	1.000	0.500	1.000	1.000	0.500
35	1.000	0.500	1.000	1.000	0.500
36	1.000	0.500	1.000	1.000	0.500
37	1.000	0.500	1.000	1.000	0.500
38	0.950	0.492	0.950	1.000	0.467
39	1.000	0.500	1.000	1.000	0.500
40	1.000	0.500	1.000	1.000	0.500
mean	0.995	0.501	0.995	1.000	0.499

MALMQUIST INDEX SUMMARY OF ANNUAL MEANS

year	effch	techch	pech	sech	tfpch
2	0.995	0.501	0.995	1.000	0.499
mean	0.995	0.501	0.995	1.000	0.499

MALMQUIST INDEX SUMMARY OF FIRM MEANS

firm	effch	techch	pech	sech	tfpch
1	1.000	0.500	1.000	1.000	0.500
2	1.000	0.500	1.000	1.000	0.500
3	1.000	0.500	1.000	1.000	0.500
4	1.000	0.500	1.000	1.000	0.500
5	1.000	0.500	1.000	1.000	0.500
6	1.000	0.500	1.000	1.000	0.500
7	1.000	0.500	1.000	1.000	0.500
8	1.136	0.501	1.136	1.000	0.570
9	1.000	0.500	1.000	1.000	0.500
10	1.000	0.500	1.000	1.000	0.500
11	1.000	0.500	1.000	1.000	0.500
12	1.000	0.500	1.000	1.000	0.500
13	1.000	0.500	1.000	1.000	0.500
14	1.000	0.500	1.000	1.000	0.500
15	1.000	0.500	1.000	1.000	0.500
16	1.000	0.500	1.000	1.000	0.500
17	0.950	0.492	0.950	1.000	0.467
18	1.000	0.500	1.000	1.000	0.500
19	1.000	0.500	1.000	1.000	0.500
20	1.000	0.500	1.000	1.000	0.500
21	1.000	0.500	1.000	1.000	0.500
22	1.000	0.500	1.000	1.000	0.500
23	1.000	0.500	1.000	1.000	0.500
24	1.000	0.500	1.000	1.000	0.500
25	1.000	0.500	1.000	1.000	0.500
26	0.813	0.521	0.813	1.000	0.423
27	1.000	0.500	1.000	1.000	0.500
28	1.000	0.500	1.000	1.000	0.500
29	1.000	0.500	1.000	1.000	0.500
30	1.000	0.500	1.000	1.000	0.500
31	1.000	0.500	1.000	1.000	0.500
32	1.000	0.538	1.000	1.000	0.538
33	1.000	0.500	1.000	1.000	0.500
34	1.000	0.500	1.000	1.000	0.500
35	1.000	0.500	1.000	1.000	0.500
36	1.000	0.500	1.000	1.000	0.500
37	1.000	0.500	1.000	1.000	0.500
38	0.950	0.492	0.950	1.000	0.467
39	1.000	0.500	1.000	1.000	0.500
40	1.000	0.500	1.000	1.000	0.500
mean	0.995	0.501	0.995	1.000	0.499

[Note that all Malmquist index averages are geometric means]

Five indices are presented for each firm in each year. These are

1. Technical Efficiency Change (relative to a CRS Technology)
2. Technology Change
3. Pure Technical Efficiency Change (i.e relative to a VRS technology)
4. Scale Efficiency Change,

5. Total Productivity Change (TFP) Change.

As per table 3 there is increase in efficiencies of Output orientated Malmquist DEA.

Stochastic Frontier Analysis [5]

Table 4: ols estimates (Before CDA)
coefficient standard-error t-ratio
beta 0 -0.44818916E+02 0.87821735E+01 -0.51033968E+01
beta 1 0.24308450E+00 0.15275017E+00 0.15913861E+01
beta 2 0.39182238E+02 0.63345274E+01 0.61855030E+01
sigma-squared 0.70795721E+03
log likelihood function = -0.18644598E+03

Source: Computed data

Tcb = -0.45 + 0.24 Enb + 0.39 Ccb …. [1]

P= 0.000, R^2 = 0.69

From table 4 and equation [1] it is found that for one unit increase in employment turnover increases by 0.24 % and for one unit increase in Capital Investment turnover increases by 0.39 % for before CDA.

Table 5: ols estimates (After CDA)
coefficient standard-error t-ratio
beta 0 -0.24069274E+03 0.39166721E+02 -0.61453380E+01
beta 1 0.35227549E+00 0.11368424E+00 0.30987188E+01
beta 2 0.10344400E+03 0.15401570E+02 0.67164578E+01
sigma-squared 0.63612199E+04
log likelihood function = -0.23035782E+03

Source: Computed data

Tca = -0.240 + 0.35 Ena + 103.44. Cca …. [2]

P= 0.000, R^2 = 0.75

From table 5 and equation [2] it is found that for one unit increase in employment turnover increases by 0.35 % and for one unit increase in Capital Investment turnover increases by 103.44 % for after CDA.

From the equation [1] and [2] it clearly reveals that there is increase in employment, capital investment and turnover after cluster development approach when compared to before cluster development approach.

The use of Artificial Intelligence and Robotics in Automotive Components Production leads to increase in turnover when compared to usage of traditional machines by 40 Automotive Components Manufacturers.

VI. CONCLUSIONS

The Precision Engineering and Technology Centre (PETC) have Common Facility Centre on Product Design, Product development and testing of Automotive Components for use of all 40 Automotive Components Manufacturers at Tirumudivakkam, Chennai, Tamil Nadu, India., The technical efficiency is calculated for 5 input and 5 output variables related to traditional and AI and Robotics integrated Production Optimisation, that is before and after Cluster Development Approach. It is found that all the 40 ACM use the common facility machines with less service charge when compared to market price since they are all members in PETC. The technical efficiency of integrated AI is greater than traditional usage of machineries. The Design Software's, Product Development Machines and Testing Machines are available in PETC, CFC so that 40 Automotive components Manufacturers can make use of with less service charge which leads to cost minimisation and profit maximisation. To conclude AI based usage leads to cost minimisation and profit maximisation of individual Automotive Components Manufacturers when compared to traditional usage of machineries.

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REFERENCES

[1] https://www.tiema.co.in/ assessed on 29.4.25

[2] Precision Engineering and Technology Centre, Tirumudivakkam, Technical Brochure assessed on 28.4.25

[3] Coelli, T. , Center for Efficiency and Productivity Analysis (CEPA) working papers, the University of New England, A guide for Data Envelopment Analysis pp.1-20.

[4] Coelli, T.J., Center for Efficiency and Productivity Analysis (CEPA) working papers, the University of New

England, A guide for Data Envelopment Analysis pp.21-50.

[5] Coelli, T.J, Center for Efficiency and Productivity Analysis (CEPA) working papers, the University of New England, A guide for Frontier Version 4.1, Data Envelopment Analysis pp.1-33.

[6] TCOT, Detailed Project Report on establishment of Mega Cluster for Precision Engineering at Thirumudivakkam, Chennai pp.1-119