Development of Composite Sustainability Performance Index for Steel Industry

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IISI Vision

Steel is valued as a major foundation of a sustainable world. This is achieved by a financially sound industry, taking leadership in environmental, social and economic sustainability and seeking continuous improvement.

Steel – World Scenario

- Steel is the world's third largest commodity market
- Industry has undergone radical restructuring and has become more global, more efficient and more financially viable
- World crude steel output reached 1,239.5 million metric tons in 2006
- The top three steel producing countries in 2006 were China (418 mmt), Japan (116 mmt), United States (98 mmt) and India being 7th (44 mmt).

Sustainability Issues and Challenges

- Availability of Iron Ore and Coking Coal
- Energy Efficiency, CO2 emissions and climate change
- Development of new generation products
- Technology & innovation
- Consolidation, market demand, price fluctuation
- Financial robustness and cost competitiveness
- Stakeholder engagement and community initiatives
- Skilled and trained workforce
- Health and Safety of employees
- Value creation for stakeholders

Sustainability Management

- Guided by IISI vision
- Policies
- Systems & Standards
- Management tools
- Measurement and Indicators
- Sustainability Assessment, monitoring, review, feedback
- Transparency and Reporting
- Sustainable manufacturing approaches- environment, social, economic

Composite Sustainability Performance Index

- **Aim**: To create aggregate measure for sustainability assessment of industry using composite Index
- Calculation of a composite indicator to monitor progress in the implementation of sustainability practices in one of the steel plant
- Simplified and quantified information
- New approach provide for better integration of decision making
- Provides framework for Sustainability Management

Composite Sustainability Performance Index

- Environment: pilot environment performance index (WEF, 2002), index of environment friendliness (Statistics Finland, 2003), eco-indicator 99 (Pre Consultants, 2001), Life cycle index (Khan, 2004), Korean Complex environment Index, Ecological Footprint, ETHIBEL, BOVESPA, DGSI,FTSE4Good, SRI, GEM.
- Economy: combined consumption level index, Human resources development index, composite basic needs indices, composite leading indicators (OECD, 2002), internal market index (JRC, 2002), Index of economic freedom, Business climate indicator.
- Society: Physical quality of life , Index of social progress , Human suffering index, quality of life rankings , human development index(UNDP, 1990-2003), overall health system attainment.
- Sustainability: Dow Jones sustainability index (DJSI, 2003), index of balanced sustainable development (Seljak, 2001).

Steps for Construction of Composite Index

Step 1. Developing a theoretical framework

Step 2. Selecting sub-indicators

Step 3. Brainstorming/Multivariate analysis

- Assessing the quality of the data for sub -indicators
- Assessing the relationship between the indicators

Step 4. Weighting

Step 5. Data collection

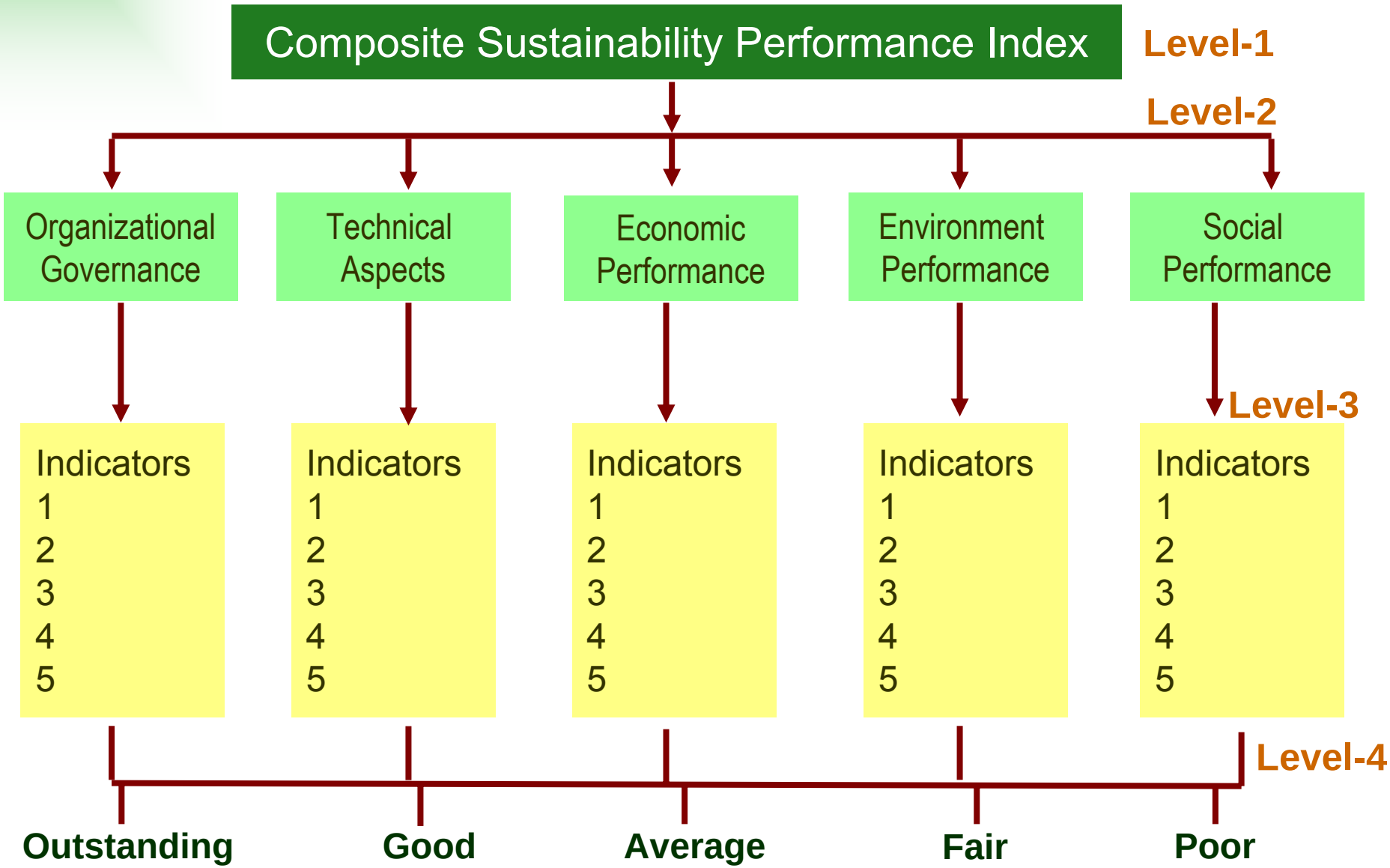
Step 6. Normalisation of data

Step 7. Aggregation

Step 8. Testing for Robustness and Sensitivity

Step 9. Presentation

AHP Model for Composite Sustainability Performance Index



Generic Hierarchy of CSPI Evaluation

Identification & categorization of indicators

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Finalize key indicators using cutoff value

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Collection of quantitative data for indicators

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Weighting of Indicators using AHP

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Apply Liberatore five point Rating system

Z score method to calculate Weighted normalized score

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Calculation of sub-index

↓

Evaluate CSPI

Sustainability Indicators

- Five Dimensions of Sustainability

Environment	-	(15 indicators)
Economic	-	(5 indicators)
Social	-	(14 indicators)
Organisational Governance	-	(12 indicators)
Technical Aspects	-	(14 indicators)

- Brainstorming session was conducted amongst 15 experts for identification of key sustainability issues
- Experts were asked to rate on 5- point Likert Scale, the level of importance of each indicator
  1= not important, 5 = very important
- Cut-off value = 3.00

Sustainability Indicators

Organizational Governance

- Leadership
- Strategic planning & resource management
- Cost competitiveness
- Management tools
- Innovation & knowledge management
- Technology & investment
- Human resource management
- Order generation, market development & customer satisfaction
- Material management
- Research & Development
- Process management
- Information technology

Sustainability Indicators

Environment

- Particulate Matter stack emission load (kg/tcs)
- Percent utilisation of total solid wastes (%)
- Specific energy consumption (Gcal/tcs)
- Specific Raw material consumption (tonnes/tcs)
- Specific water consumption (m3/tcs)
- Specific carbon dioxide emission (t/tcs)
- Specific effluent load (Kg/tcs)
- Specific refrigerant consumption (Kg/tcs)
- Specific power consumption (Kwh/tcs)

Sustainability Indicators

Environment

- Specific refractory consumption (Kg/tcs)
- Percentage green cover of total plant area (%)
- Specific hazardous waste generation (Kg/tcs)
- Specific heavy metals discharge load (Kg/tcs)
- Average noise level in the periphery of plant dB(A)
- Overall average opacity around the plant (%)

Sustainability Indicators

Society

- Nos. of fatal accidents
- Accident frequency rate
- Absenteeism rate (% of total man days available)
- Nos. of employees trained (man-days / employee/ year)
- Expenditure on peripheral development
- Employee satisfaction
- Quality of life

Sustainability Indicators

Society

- Employment generation
- Non-discrimination, diversity & opportunity
- Freedom of association
- Child , forced labour & human rights issues
- Suppliers & contractors practices
- Concern for local communities
- Customer health & safety

Sustainability Indicators

Technical Aspects

- Coke rate (Kg/thm)
- BF productivity
- Labour productivity
- Export tonnage ratio
- Defects (%)
- Special grades production (%)
- New product development (% of saleable steel)
- Market performance (% increase in domestic share with previous year)

Sustainability Indicators

Technical Aspects

- Customer satisfaction index
- Saving through suggestions & QC projects (Rs/tcs)
- Cost reduction (Rs/tcs)
- Equipment availability (%)
- Order compliance (%)
- No. of complaints

Sustainability Indicators

Economic

- Gross margin / turnover ratio
- Net profit / average capital employed
- Net profit / total income or revenue
- Investment in new processes and products (% of revenues)
- Turnover / Inventory ratio

Composite Indicators & weighting methods

Method	Composite Indicators
Equal weights	Environment Sustainability Index Composite Leading Indicators
Principal Component Analysis/ factor Analysis	Internal Market Index Business climate indicator General indicator of science and technology
Data Envelopment analysis	Human development Index : a suggestion Synthetic meta-index for sustainable development Composite indicators of health system performance
Unobserved component models	Governance indicators
Distance to targets	Human development Index
Public Opinion	Health System achievement Index
Analytic Hierarchy Process	EU New Economy Policy Indicators
Conjoint Analysis	Indicator of quality of life in the city of Istanbul

Analytic Hierarchy Process (AHP)

- AHP is a multiple step analytical process of judgment which synthesizes a complex arrangement into a systematic hierarchial structure
- Allows both quantitative and qualitative criteria
- Decomposing the dataset into smaller elements
- Construction of hierarchy
- Conducting pair-wise comparative judgments
- Measurement and data collection
- Determining Normalized weights
- Synthesis-finding solution to the problem

Intensity of Preference

Factor of Preference (p)	Importance
1	Equally preferred
2	Equally to moderately preferred
3	Moderately preferred
4	Moderately to strongly preferred
5	Strongly preferred
6	Strongly to Very Strongly preferred
7	Very strongly preferred
8	Very to Extremely Strongly preferred
9	Extremely preferred

Pair-wise Comparison Matrix for Sustainability

Dimensions of Sustainability	OG	TA	ECO	ENV	SOC
Organizational Governance (OG)	1.00	1.00	0.33	3.00	2.00
Technical Aspect (TA)	1.00	1.00	0.50	2.00	2.00
Economic (ECO)	3.00	2.00	1.00	3.00	3.00
Environment (ENV)	0.33	0.50	0.33	1.00	1.00
Society (SOC)	0.50	0.50	0.33	1.00	1.00

Pair-wise Comparison and Normalized Matrix

	OG	TA	ECO	ENV	SOC
Organisational governance (OG)	1.00	1.00	0.33	3.00	2.00
Technical aspects(TA)	1.00	1.00	0.50	2.00	2.00
Economic (ECO)	3.00	2.00	1.00	3.00	3.00
Environment(ENV)	0.33	0.50	0.33	1.00	1.00
Society(SOC)	0.50	0.50	0.33	1.00	1.00
	5.83	**5.00**	**2.50**	**10.00**	**9.00**

	OG	TA	ECO	ENV	SOC	Relative Weights
Organisational governance (OG)	0.17	0.20	0.13	0.30	0.22	0.205
Technical aspects(TA)	0.17	0.20	0.20	0.20	0.22	0.199
Economic (ECO)	0.51	0.40	0.40	0.30	0.33	0.390
Environment(ENV)	0.06	0.10	0.13	0.10	0.11	0.100
Society(SOC)	0.09	0.10	0.13	0.10	0.11	0.106

Consistency Test

The Consistence Index (*CI*) of *n* criteria
CI = (λ_{max} –n)/n-1 where λ_{max} is the largest eigen value of an n x n pair-wise comparison matrix.

The Consistency ratio is calculated using the formula:
CR = CI/RI

The acceptable CR range varies according to the size of matrix i.e. 0.05 for a 3 x 3 matrix, 0.08 for a 4 x 4 matrix and 0.1 for all larger matrices n>=5 (Saaty, 2000).

Weights for Sustainability Indicators

Composite Sustainability Performance Index — Level-1

Level-2

Organizational Governance (0.181)	Technical Aspects (0.175)	Economic Performance (0.329)	Environment Performance (0.140)	Social Performance (0.175)

Level-3

Organizational Governance (0.181)	LW/GW	Technical Aspects (0.175)	LW/GW	Economic Performance (0.329)	LW/GW	Environment Performance (0.140)	LW/GW	Social Performance (0.175)	LW/GW
LEAD	(0.095/ 0.017)	CR	(0.092/ 0.016)	GMTR	(0.231/0.076)	PMEL	(0.137/0.019)	NFA	(0.141/0.025)
SPRM	(0.080/ 0.015)	BFP	(0.088/ 0.015)	NPACE	(0.379/ 0.125)	PUSW	(0.111/ 0.016)	AFR	(0.084/ 0.015)
CC	(0.080/ 0.014)	LP	(0.069/ 0.012)	NPRR	(0.146/ 0.048)	SEC	(0.111/ 0.016)	ABR	(0.043/ 0.007)
MT	(0.049/ 0.009)	ER	(0.056/ 0.010)	INPP	(0.083/ 0.027)	SRMC	(0.119/ 0.017)	NET	(0.052/ 0.009)
IKM	(0.071/ 0.013)	DEF	(0.113/ 0.020)	TIR	(0.162/ 0.053)	SWC	(0.079/ 0.011)	EPD	(0.104/ 0.018)
TI	(0.072/ 0.013)	SGP	(0.039/ 0.007)			SCDE	(0.069/ 0.010)	ES	(0.077/ 0.013)
HRM	(0.057/ 0.010)	NPD	(0.033/ 0.006)			SEL	(0.059/ 0.008)	QOL	(0.090/ 0.016)
OGMDCS	(0.175/ 0.032)	MP	(0.113/ 0.020)			SRC	(0.022/ 0.003)	EG	(0.117/ 0.021)
MM	(0.044/ 0.008)	CSI	(0.079/ 0.014)			SPC	(0.046/ 0.006)	NDDO	(0.049/ 0.009)
RD	(0.045/ 0.008)	SSSQC	(0.036/ 0.006)			SRFC	(0.031/ 0.004)	FOA	(0.052/ 0.009)
PM	(0.186/ 0.034)	CR	(0.085/ 0.015)			PGC	(0.037/ 0.005)	CFL	(0.053/ 0.009)
IT	(0.045/ 0.008)	EA	(0.088/ 0.015)			SHWG	(0.044/ 0.006)	SCP	(0.031/0.005)
		OC	(0.064/ 0.011)			SHMDL	(0.040/ 0.006)	CLC	(0.076/0.013)
		COMP	(0.047/0.008)			ANL	(0.032/ 0.005)	CHS	(0.031/ 0.005)
						OAO	(0.062/ 0.009)		

LW : Local Weights, GW : Global Weights

Theoretical Methodology

Sub-Index = SI_i
where i= dimensions of sustainability i.e. OG, TA, ECO, ENV & SOC

Sub-Index for Organizational governance (OG) : SI_{OG}
Sub-Index for Technical Aspects (TA) : SI_{TA}
Sub-Index for Economic Performance (ECO) : SI_{ECO}
Sub-Index for Environment Performance (ENV) : SI_{ENV}
Sub-Index for Societal Performance (SOC) : SI_{SOC}

Global weights : GW_{ij} where j = indicator 1, 2, 3 ……, n.
Local Weights : LW_{ij}

Weight for sustainability (1st level): WS_i where i=OG, TA, ECO, ENV & SOC.
Local weight for criteria's (2nd level): LW_{ij} where i= OG, TA, ECO, ENV & SOC and j=1, 2……, n indicators

Methodology # 1 for Normalization – Liberatore rating

Methodology # 1 : Liberatore Score method
Rating is decided based on target & benchmark by expert

Liberatore rating (LR_{ij})	O Outstanding	G Good	F Fair	A Average	P Poor
Liberatore rating value: LR_v	0.513	0.261	0.129	0.063	0.034

$SILR_i$ = Sub-Index based on Liberatore Score
Liberatore Score : LS_{ij}

$$GW_{ij} = WS_i * WL_{ij}$$
$$LS_{ij} = LR_v * GW_{ij}$$

Liberatore Maximum Score ($LMAX_{ij}$) = $0.513 * GW_{ij}$

$$SILR_i = 10 *(\Sigma LS_{ij} / \Sigma LMAX_{ij})$$

Liberatore's Five Point rating scale

Rating scale	O	G	A	F	P
Outstanding (O)	1.000	3.000	5.000	7.000	9.000
Good (G)	0.333	1.000	3.000	5.000	7.000
Average (A)	0.200	0.333	1.000	3.000	5.000
Fair(F)	0.143	0.200	0.333	1.000	3.000
Poor (P)	0.111	0.143	0.200	0.333	1.000
	1.787	4.676	9.533	16.333	25.000

Outstanding (O)	0.560	0.642	0.524	0.429	0.360	0.503
Good (G)	0.187	0.214	0.315	0.306	0.280	0.260
Average (A)	0.112	0.071	0.105	0.184	0.200	0.134
Fair(F)	0.080	0.043	0.035	0.061	0.120	0.068
Poor (P)	0.062	0.031	0.021	0.020	0.040	0.035

Environment Performance Indicators

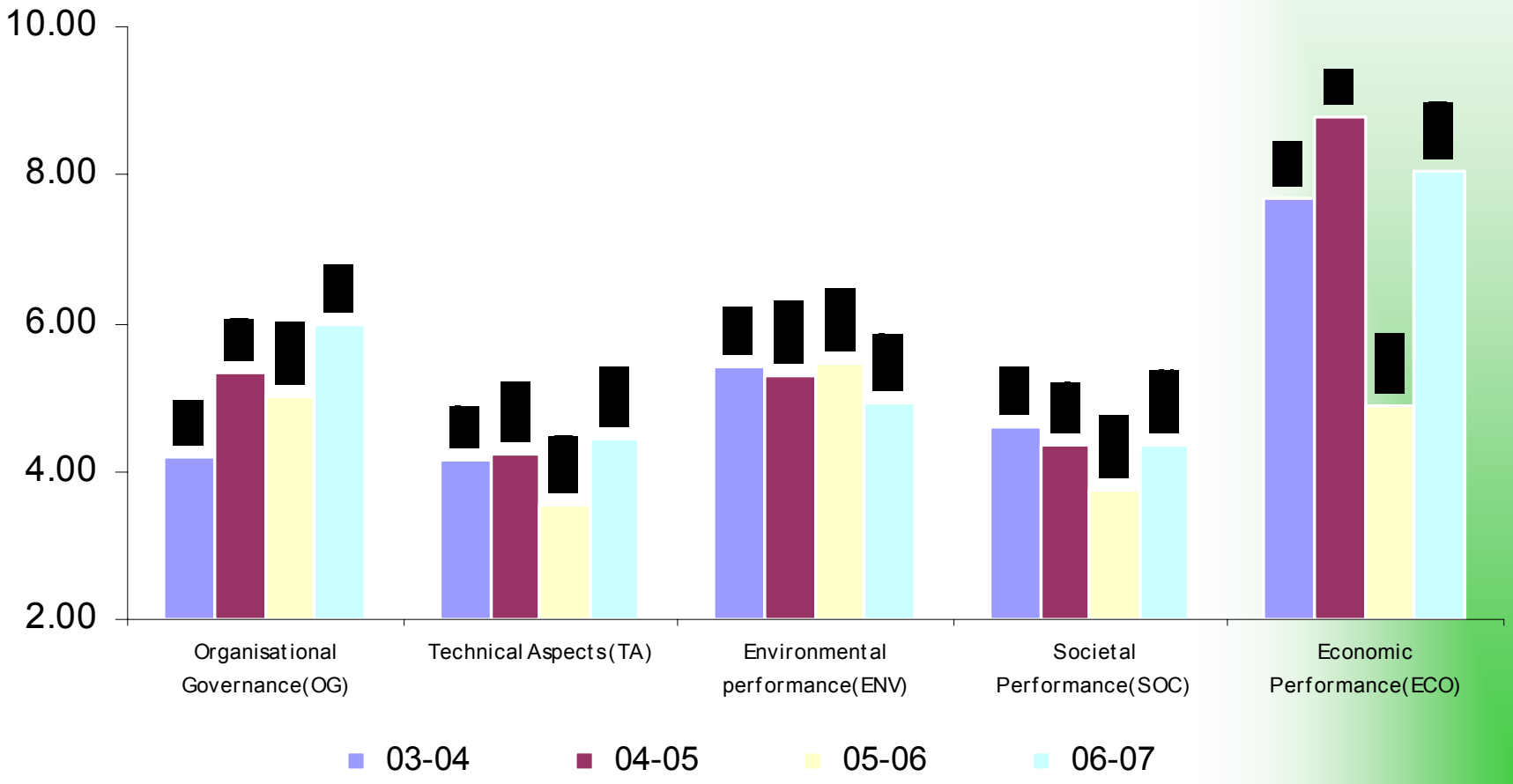
Indicators	Local Weights (Lw_{ij})	Global Weights (Gw_{ij})	Overall Rating (Lr_{ij})	Rating Value (LR_v)	Score (Ls_{ij})	Maximum Score ($LMAX_{ij}$)
Particulate Matter stack emission load (Kg/tcs)	0.137	0.019	O	0.513	0.010	0.0099
Percent utilisation of total solid wastes (%)	0.111	0.016	A	0.129	0.002	0.0080
Specific energy consumption (Gcal/tcs)	0.111	0.016	G	0.261	0.004	0.0080
Specific Raw material Consumption (tonnes/tcs)	0.119	0.017	G	0.261	0.004	0.0086
Specific water consumption (m3/tcs)	0.079	0.011	O	0.513	0.006	0.0057
Specific carbon dioxide emissions (t/tcs)	0.069	0.010	A	0.129	0.001	0.0050
Specific effluent load (kg/tcs)	0.059	0.008	G	0.261	0.002	0.0043
Specific refrigerant consumption (kg/tcs)	0.022	0.003	G	0.261	0.001	0.0016
Specific power consumption(Kwh/tcs)	0.046	0.006	A	0.129	0.001	0.0033
Specific refractory consumption (kg/tcs)	0.031	0.004	A	0.129	0.001	0.0022
Percentage green cover of total plant area (%)	0.037	0.005	O	0.513	0.003	0.0026
Specific Hazardous waste generation (kg/tcs)	0.044	0.006	A	0.129	0.001	0.0032
Specific Heavy metals discharge load (gm/tcs)	0.040	0.006	G	0.261	0.001	0.0029
Average Noise level in the periphery of plant	0.032	0.005	G	0.261	0.001	0.0023
Overall average Opacity around the plant (%)	0.062	0.009	A	0.129	0.001	0.0044
				Sum =	0.039	0.0721

$SILR_i = 10 * (\sum LS_{ij} / \sum LMAX_{ij})$ $SILR_{ENV}$ 5.395

Sub-Index – Based on Liberatore rating

Dimensions of Sustainability	03-04	04-05	05-06	06-07
Organisational Governance(OG)	4.21	5.31	5.024	5.98
Technical Aspects (TA)	4.17	4.221	3.561	4.441
Environmental performance(ENV)	5.40	5.306	5.464	4.917
Societal Performance(SOC)	4.59	4.36	3.764	4.372
Economic Performance(ECO)	7.67	8.8	4.875	8.071

Sub-Index for Sustainability – Method # 1



Methodology # 2 for Normalization – Z Score method

Z Score method – indicative of improvement in trend

- Indicators Value: IV_{ijt} where t = year 1, 2, 3 .....n
- Average Indicator Value: AIV_{ij}
- Normalized Score (NS_{ij})
- Weighted Normalized Score (WNS_{ij})
- $SIZS_i$ = Sub-Index based on normalized Z score
- $AIV_{ij} = \Sigma IV_{ijt} /n$

- NS_{ij} = + or - $(IV_{ijt} - AIV_{ij})/\sigma$;(+) or (-) chosen based on type of indicators
- $WNS_{ij} = GW_{ij} * NS_{ij}$
- $SIZS_i = 100* (\Sigma WNS_{ij} /n)$

Environment Performance Indicators

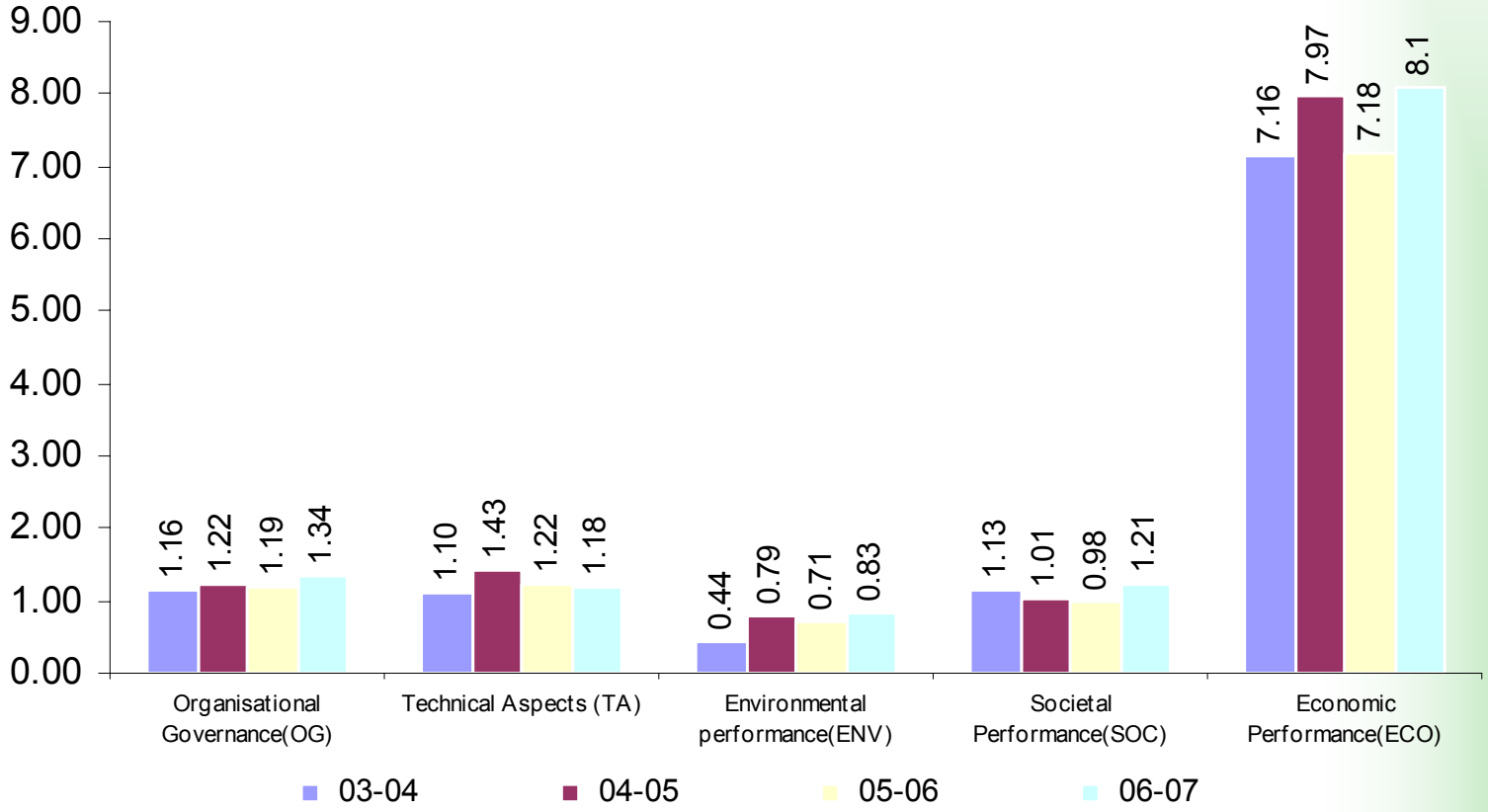
Environmental performance (ENV) - Weight (WS_{ENV}): 0.140	Unit	Indicators Value			Sign	Avg	Std. dev	Norm. Score	Weighted score
		2001-02	2002-03	2003-04	(+/-)	AIV_{ii}	(σ)	$(IV_{iit} - AIV_{ii})/\sigma$	$(WNS_{ii} = GW_{ii} * NSij)$
Particulate Matter stack emission load (Kg/tcs)	kg/tcs	1.5	1.32	1.1	(-)	1.31	0.20	1.03	0.0199
Percent utilisation of total solid wastes	%	68.5	77.6	79	(+)	75.03	5.70	0.70	0.0109
Specific energy consumption (Gcal/tcs)	Gcal/tcs	7.07	6.84	6.86	(-)	6.92	0.13	0.50	0.0078
Specific Raw material Consumption (tonnes/tcs)	t/tcs	3.24	3.07	3.16	(-)	3.16	0.09	-0.04	-0.0007
Specific water consumption (m3/tcs)	m3/tcs	4.74	3.54	3.98	(-)	4.09	0.61	0.18	0.0019
Specific carbon dioxide emissions (t/tcs)	t/tcs	2.69	2.6	2.6	(-)	2.63	0.05	0.58	0.0056
Specific effluent load (kg/tcs)	kg/tcs	0.1713	0.1977	0.1948	(-)	0.19	0.01	-0.47	-0.0039
Specific refrigerant consumption (kg/tcs)	kg/tcs	0.013	0.011	0.08	(-)	0.03	0.04	-1.15	-0.0036
Specific power consumption(Kwh/tcs)	kwh/tcs	436	422	402	(-)	420.00	17.09	1.05	0.0068
Specific refractory consumption (kg/tcs)	kg/tcs	14.36	14.3	13.7	(-)	14.12	0.36	1.15	0.0050
Percentage green cover of total plant area (%)	%	15	16	16	(+)	15.67	0.58	0.58	0.0030
Specific Hazardous waste generation (kg/tcs)	kg/tcs	1.5	1.6	1.7	(-)	1.60	0.10	-1.00	-0.0062
Specific Heavy metals discharge load (gm/tcs)	gm/tcs	10	8	8	(-)	8.67	1.15	0.58	0.0033
Average Noise level in the periphery of plant (dB)	dB	55	55	54	(-)	54.67	0.58	1.15	0.0052
Overall average Opacity around the plant	%	94	94.5	96	(+)	94.83	1.04	1.12	0.0097

$SIZS_i = 100^* (\sum WNS_{ij} /n)$ $SIZS_{ENV}$ **0.4313**

Sub-Index – Based on Z Score Method

Dimensions of Sustainability	03-04	04-05	05-06	06-07
Organisational Governance(OG)	1.16	1.22	1.19	1.34
Technical Aspects (TA)	1.10	1.43	1.22	1.18
Environmental performance(ENV)	0.44	0.79	0.71	0.83
Societal Performance(SOC)	1.13	1.01	0.98	1.21
Economic Performance(ECO)	7.16	7.97	7.18	8.1

Sub-Index for Sustainability – Method # 2



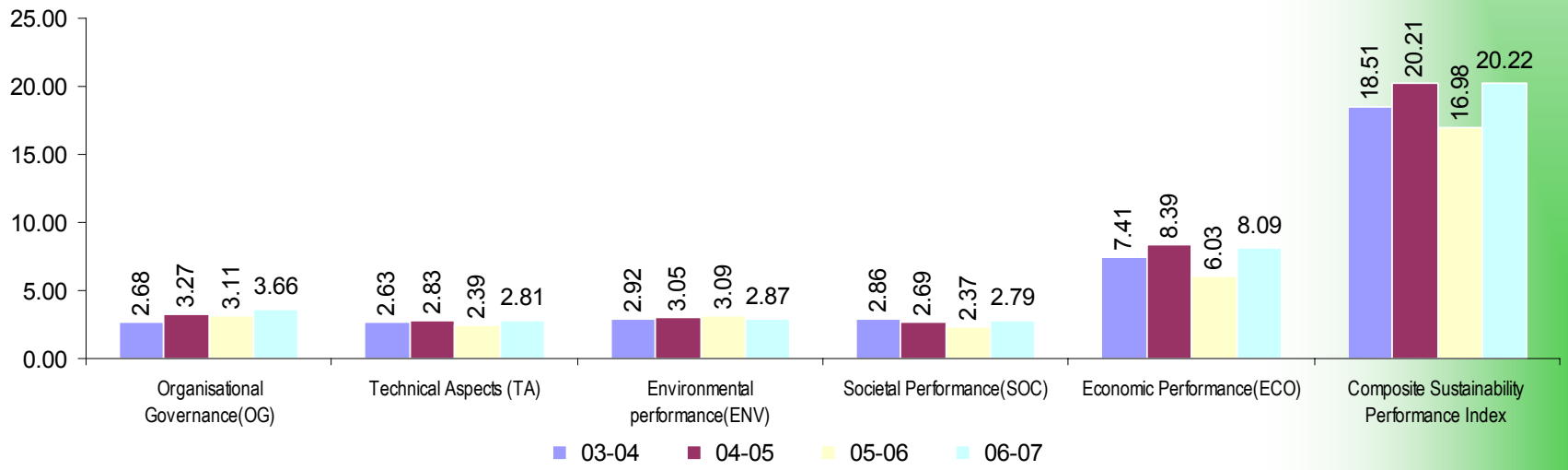
Aggregation: Composite Sustainability Performance Index

Dimensions of Sustainability	03-04	04-05	05-06	06-07
Organisational Governance(OG)	2.68	3.27	3.11	3.66
Technical Aspects (TA)	2.63	2.83	2.39	2.81
Environmental performance(ENV)	2.92	3.05	3.09	2.87
Societal Performance(SOC)	2.86	2.69	2.37	2.79
Economic Performance(ECO)	7.41	8.39	6.03	8.09
Composite Sustainability Performance Index	**18.51**	**20.21**	**16.98**	**20.22**

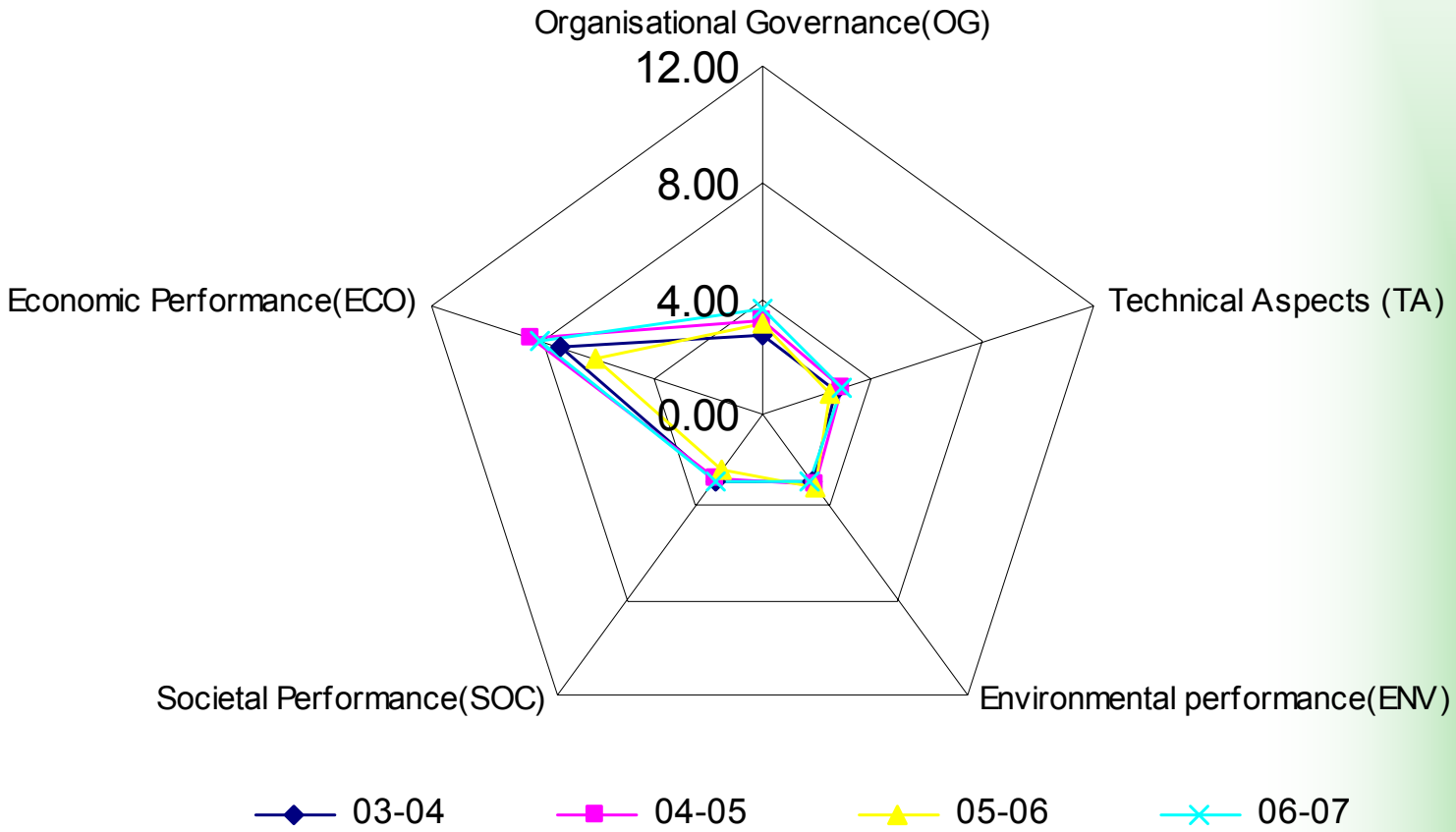
- $SI_i = (SILR_i + SIZS_i)/2$

where

- $SILR_i$ = Sub-Index based on Liberatore Score
- $SIZS_i$ = Sub-Index based on normalized Z score
- $CSPI = \Sigma SI_i$



Graphical Representation



Future Work

- Testing for robustness
- Uncertainty analysis
- Sensitivity analysis
- Collection of data from other steel industries
- Ranking of steel plants

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Thank You