CHAPTER 10

Prioritising Circular Economy Indicators in the Indian Textile Industry: A Delphi - GINA Approach

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ABSTRACT

The Indian textile industry is recognized as the major contributor to global water pollution and a significant generator of solid waste. The field, however, does not have a coordinated framework of deploying the Circular Economy (CE) practices. The paper puts forward a structured prioritization system of the CE indicators based on hybrid Delphi and Grey Influence Analysis (GINA) system. Based on two periods of professional consultation with 18 industry experts and scholarly professionals, a primary set of 15 initial indicators was narrowed down to six consensus-based indicators. This was followed by the application of GINA to evaluate the direct and the indirect systemic relationships between these indicators. The results indicate that Chemical Toxicity Reduction (CTR: 0.5058) has the highest priority then energy and carbon reduction (ECR: 0.4540) and also water consumption reduction rate (WCR: 0.4504). These findings demonstrate environmental compliance, energy transitioning, and water stewardship as three drivers to the promotion of the CE implementation in the Indian textile industry.

Keywords: Circular economy, Textile industry, Grey influence analysis (GINA), Delphi method, Sustainability.

1.0 Introduction

1.1 Background and context

Textile industry is one of the most polluted and resource consuming industries across the world. It uses about 93 billion cubic metres of water each year and generates about 92^{-} million tonnes of solid waste (Ellen MacArthur Foundation, 2017). The textile sector in India is the second highest employer and has a contribution of nearly 2.3 percent to the gross domestic product, yet 13 percent of the total export earnings (Ministry of Textiles, India, 2024). However, this economic value is overshadowed by serious consequences on the environment. The processes of dyeing and finishing in the country release about 40,000 -50,000 metric tonnes of dyes and chemicals in the water bodies annually (FICCI, 2022).

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The traditional linear model of production, take, make, dispose, has made the textile industry one of the most important contributors of microplastic contamination, greenhouse gas (GHG), and chemical pollution. It is estimated that about 10 per cent of all GHG emissions are caused by textile production, which is more than the collective contribution of international air travel and international shipping (UNEP, 2023). With over 7,000 textile mills and huge informal garment industry, India is facing severe sustainability challenges, such as water shortages in production hubs, poor effluent treatment and growing amount of textile waste due to the lack of recycling facilities.

1.2 The circular economy paradigm

Circular Economy (CE) paradigm is a revolutionary way of producing that provides restorative and regenerative systems in contrast to the linear modalities of production. The CE model, based on the ideas of minimized input of resources used, the long life of product, and the ability to recycle the materials after their usefulness, has gained impressive momentum in the field of global policy and industrial discussion (Geissdoerfer et al., 2017). In the textile context, CE covers design towards recyclability, chemical stewardship, water recirculation, energy transition and capacity building among the stakeholders.

Even with the increased awareness, Indian textile enterprises are still struggling with the prevalent implementation challenges. They are deficient in standardized CE performance measures being used within the Indian context as well as lack of technical ability of operating in circles by small and medium enterprises (SMEs) and lack of regulatory incentives. Lack of an industry-authenticated prioritization framework hinders the firms to identify the CE initiatives that bring the best systemic utility.

1.3 Problem statement

Past studies have suggested generic CE models and indicators, but none of them has prioritized CE indicators specifically to the Indian textile industrial sector using a methodology that considers uncertainty and the subjectivity of experts. Current sets of indicators are either modified to fit in the West manufacturing environment or are too general to provide practical advice to Indian textile companies. The associated lacuna leads to incomplete and inefficient CE adoption, inefficiency in resource allocation, and performance benchmarking.

1.4 Research objectives

The aim of the proposed study is twofold in nature; (1) to determine and establish the most important CE indicators applicable to the Indian textile industry by the consensus of the experts on a two-round Delphi methodology; and (2) to rank these indicators based on their systemic effect with the help of the Grey Influence Analytics (GINA), thus, identifying the direct and indirect causal relationships.

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1.5 Contributions of the study

To the industry players, the study provides a prioritized and data-driven model of CE indicators specific to Indian textiles. To the decision-maker, it provides a roadmap of gradual implementation with support of quantitative influence coefficients. To scholars, it reveals that GINA is applicable in complicated, multi-criteria sustainability choices that are defined by inexact information. To policy-makers, the results aid in the regulatory design to hasten CE transitions in one of the most strategically important sectors in India.

2.0 Literature Review

2.1. Circular economy performance frameworks

CE performance assessment has received extensive academic interest, especially in the creation of sound indicator systems. Geissdoerfer *et al.* (2017) carried out an initial review of the definitions and dimensions of the performance of CE and developed the notion that the effectiveness of CE should be gauged through the reduction of inputs, material recycling, and preservation of value.

Further studies by Moraga *et al.* (2019) proposed a taxonomy of CE indicators based on the foundation of the Ellen MacArthur Foundation, which includes the waste, resource, energy, and environmental dimensions. Their paper underscores that the CE indicators should be measurable, contextual and also aligned with internationally accepted reporting standards like the Global Reporting Initiative (GRI).

In the case of agri-food and manufacturing industries, Veloso *et al.* (2025) suggested a three-step hierarchical area of CE indicators that included strategic, operational, and auxiliary metrics. Baratsas *et al.* (2022) have gone on to elaborate a quantitative, holistic evaluation model integrating 23 categories of CE that include waste, energy, water and supply chain performance. Both papers identify the gap of sector specific CE assessment as far as developing economies like India are concerned in which the infrastructural limitations and regulatory frameworks vary significantly compared with those in Europe and North America.

2.2 CE in the textile industry

The textile industry offers special challenges related to CE because of the complicated fibre structure, the chemical treatment, and international supply chains. Niinimaki *et al.* (2020) audited the environmental impact of the fashion industry comprehensively, estimating that fast fashion produces about 92 million tonnes of textile waste yearly, and fast fashion has a significant GHG and water footprint. Their results highlight the importance of CE indicators that concern the design circularity, chemical reduction, and take-back systems.

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FICCI (2022) recorded that small dyeing facilities in small clusters like Tiruppur and Surat emit millions of litres of untreated effluents per day, which leads to serious contamination of groundwater. The study of chemical waste compliance by the Kumar et. al. (2023) researcher in the Indian processing units revealed that less than 30% of the textile SMEs comply with the effluent treatment standards as per the Environment Protection Act, 1986. These results strengthen the need to consider chemical toxicity reduction as a CE indicator in the Indian textile industry.

2.3 Key CE indicators for textile industry

A literature review produced five preliminary CE indicators that were to be used in the Indian textile industry. These indicators are on the dimensions of resource efficiency, environmental compliance, product design, supply chain and capacity-building.

Table 1: Preliminary CE Indicators Identified from Literature Review

S.No.	Indicator Name	Category	Key Research References
1	Water Consumption Reduction Rate	Resource Efficiency	Niinimäki *et al.*, 2020; Baratsas *et al.*, 2022
2	Energy and Carbon Reduction	Energy Management	Geissdoerfer *et al.*, 2017; Moraga *et al.*, 2019
3	Chemical Toxicity Reduction	Environmental Compliance	Kumar *et al.*, 2023; Hussain *et al.*, 2024
4	Waste Water Treatment and Reuse	Water Management	FICCI, 2022; Ghosh *et al.*, 2021
5	Textile Recycling and Upcycling Rate	Waste Management	Niinimäki *et al.*, 2020; Dissanayake & Sinha, 2015
6	Percentage of Recycled Material Used	Resource Efficiency	Baratsas *et al.*, 2022; Sandin & Peters, 2018
7	Design for Recyclable Products	Product Design	Bocken *et al.*, 2016; Royo *et al.*, 2023
8	Carbon Footprint Monitoring Score	Environmental Compliance	Gonçalves *et al.*, 2022; Voukkali *et al.*, 2023
9	Extended Producer Responsibility	Regulatory Compliance	CPCB, 2022; Sazdovski *et al.*, 2024
10	Green Procurement Compliance	Supply Chain	Chin *et al.*, 2020; Mallick *et al.*, 2023
11	Reverse Supply Chain Management	Reverse Logistics	Kazancoglu *et al.*, 2021; Roy *et al.*, 2023
12	Eco-label Certification	Market Credibility	Versino *et al.*, 2023; Circular Economy Alliance, 2025
13	ISO 14001 Environmental Certification	Environmental Management	ISO 14001, 2025
14	Employee Training on CE Practices	Capacity Building	Straub *et al.*, 2023
15	Supplier and Worker CE Awareness	Stakeholder Engagement	Circular Economy Alliance, 2025; Chin *et al.*, 2020

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2.4 GINA methodology in prior studies

The rigorous mathematical framework of the systems with incomplete or uncertain information is offered by the Grey Systems Theory which was initially developed by Deng (1989). Grey Influence Analysis (GINA) owes its name to a combination of grey number aggregation and matrix inversion methods that can be used to calculate the entire set of influence coefficients in order to provide a complete representation of the direct and indirect causal pathways between system variables. Compared to the Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach, GINA supports the linguistic input of a range of professionals with varying backgrounds, which eliminates the necessity to undergo normalisation processes to remove variability in professional judgements.

The sustainability indicators prioritised by Mehrjerdi and Shafiee (2021) in the context of supply chains were performed by the application of grey-based DEMATEL, which proves the effectiveness of the grey relational methods in the situation with multiple experts. Surprisingly more recently, Mardani *et al.* (2023) found that GINA is better than crisp-number approaches to dealing with uncertainty in performance appraisal of the circular economy. Taking the position of this literature, the current study utilizes GINA to the textile circular economy sector, specifically to the Indian context.

3.0 Research Methodology

3.1 Research design

Mixed-method research design was taken sequentially. Phase 1 entailed a systematic literature review to develop fifteen candidate indicators of the circular economy (CE). Phase 2 used the Delphi technique in two round of delphi to reach the expert consensus on the narrowed down six core indicators. Phase 3 was the implementation of GINA that can measure systemic influence relationships between the six validated indicators.

3.2 Expert panel composition

Purposive sampling was used to recruit 18 experts which were based on three inclusion criteria: (i) an academic degree at least a postgraduate degree in sustainability, engineering, supply chain or other similar areas; (ii) a minimum of five years working in the textile, fashion or sustainability domain; and (iii) a domain expertise. The panel members comprised of eight scholars, six sustainability managers in the industry, three sustainability supply chain consultants, and one regulatory official.

3.3 Delphi method: Two round consensus process

Round 1 (Expert Survey 1) involved experiments that asked experts to rank the relevance and applicability of all fifteen initial CE indicators on a five-point Likert scale (1

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= Not Important 5 = Critically Important) in the Indian textile industry scenario. The inter-quartile range (IQR) was used to evaluate convergence; a mean of 4.00 or more, IQR of 1.5 or less were kept. This sorting produced six main indicators, namely Water Consumption Reduction rate (WCR), Energy and Carbon Reduction (ECR), Chemical Toxicity Reduction (CTR), Design for Recyclable Products (DRP), Green Procurement Compliance (GPC) and Supplier and Worker CE Awareness (SWA).

Table 2: Expert Panel Profile

Category	Count	Percentage (%)
Academic Researchers (PhD/Faculty)	8	44.4%
Industry Sustainability Managers	6	33.3%
Supply Chain Consultants	3	16.7%
Regulatory / Government Official	1	5.6%
Total	**18**	**100%**

Round 2 (Influence Survey 2) asked the same professionals to rate the pairwise effect on each of the six indicators retained on the others using a five-point linguistic scale of No Influence (NI) to Very High Influence (VHI). The following linguistic tests were then translated into grey numbers, which could be used in GINA.

3.4 Grey Influence Analysis (GINA)

The implementation of GINA followed a series of steps as illustrated below:

- **Step 1-**Linguistic to Grey Number Rating: Expert linguistic ratings were converted into grey interval numbers using the following scale: NI= [0,0], LI= [2,5], MI= [4,7], HI= [6,9], VHI= [8,10].
- **Step 2 -**Grey Aggregation: In each pairwise cell, summing lower and upper bounds across all experts in each round on Delphi generated aggregate lower (L) and upper (U) grey matrices.
- **Step 3 -**Normalisation: Both aggregate matrices were summed by column, and each value was divided by the column sum to produce normalised grey matrices.
- **Step 4-** Matrix Idealisation: There were three types of models which were implemented in the three Delphi rounds: (Critical Model, Round 1, 3 experts; Ideal Model, Round 2, 4 experts; Typical Model, Round 3, 3 experts) with their respective identity structures of the (I -A) calculation.
- **Step 5-** Matrix Inversion: (I -A) of each round was inverted and the overall influence matrix T = (I -A) -1 -I was calculated.
- **Step 6-** Grey Responsible Coefficient: The normalisation of Row sums of T per round gave the GRC of each indicator to each round.

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- **Step 7-** Grey Influence Coefficient (GIC): GIC was fixed at 1/n =1/6 = 0.1667 across all indicators as per the equality of weights of GINA.
- **Step 8 -**Total Grey Coefficient (TGC): TGC= GRC + GIC of each indicator.
- **Step 9-** Final Aggregation on the Simpson Rule final GRC was obtained by adding (R1GRC + R2GRC + 4(R3GRC)/6) and the final TGC was obtained based on which the ultimate ranking of indicators was determined.

Table 3: Delphi Round 1 — Indicator Consensus Results

Abbreviation	Indicator	Mean Score	IQR	Retained?
WCR	Water Consumption Reduction Rate	4.22	1.0	Yes
ECR	Energy and Carbon Reduction	4.28	0.75	Yes
CTR	Chemical Toxicity Reduction	4.39	1.0	Yes
DRP	Design for Recyclable Products	4.11	1.25	Yes
GPC	Green Procurement Compliance	4.17	1.0	Yes
SWA	Supplier and Worker CE Awareness	4.06	1.5	Yes
—	Waste Water Treatment and Reuse	3.89	1.75	No
—	Waste Generation Rate	3.72	2.0	No
—	Textile Recycling and Upcycling Rate	3.78	2.0	No
—	Carbon Footprint Monitoring Score	3.44	2.25	No

Note: Only the top 10 indicators are shown. Full results available in Expert Survey 1 (Appendix A).

4.0 Data Analysis

4.1 Delphi round 1: Screening of indicators

Following the Round 1 of the Delphi survey, the expert consensus scores were obtained on all the fifteen initial indicators. It met the dual retention criteria (mean>4.0 and IQR=1.5): Chemical Toxicity Reduction (4.39), Energy and Carbon Reduction (4.28), Water Consumption Reduction Rate (4.22), Green Procurement Compliance (4.17), Design for Recyclable Products (4.11), and Supplier and Worker CE Awareness (4.06). The other nine indicators did not pass the consensus criteria and were dropped in the further analysis.

4.2 GINA computation results

After the second wave of consultant consultation, the influence rating of the six indicators that were retained was aggregated, turned into grey numbers and subjected to GINA computational sequence. The resulting aggregated grey influence matrix that encompasses all the expert inputs in all the three model idealisations, namely the Critical, Ideal and Typical, is shown in Table 4.

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The GINA final results, consisting of round by round GRC values, the GRC overall, and GIC, Total Grey Coefficient (TGC), and rank of each indicator are presented in Table 5.

Table 4: Grey Influence Input Matrix — Expert Consensus (Linguistic Ratings)

	WCR	ECR	CTR	DRP	GPC	SWA
WCR	NI	HI	VHI	VHI	HI	MI
ECR	HI	NI	VHI	VHI	HI	MI
CTR	VHI	VHI	NI	HI	MI	LI
DRP	VHI	HI	HI	NI	VHI	MI
GPC	HI	MI	LI	VHI	NI	HI
SWA	MI	LI	MI	HI	HI	NI

Note: Illustrated for Expert 1 (Dr. Kavitha Menon, Critical Model). NI=No Influence, LI=Low Influence, MI=Moderate, HI=High, VHI=Very High Influence.

Table 5: Final GINA Results — Total Grey Coefficients and Rankings

Indicator	R1 GRC (Critical)	R2 GRC (Ideal)	R3 GRC (Typical)	GIC	Final GRC	TGC	Rank
WCR	0.8664	0.1667	0.1673	0.1667	0.2837	0.4504	**3**
ECR	0.8897	0.1673	0.1668	0.1667	0.2874	0.4540	**2**
CTR	1.2050	0.1660	0.1660	0.1667	0.3391	0.5058	**1**
DRP	0.1445	0.1683	0.1680	0.1667	0.1641	0.3308	**4**
GPC	-0.9766	0.1664	0.1668	0.1667	-0.0238	0.1429	**5**
SWA	-1.1289	0.1653	0.1651	0.1667	-0.0505	0.1161	**6**

Note: TGC=Final GRC + GIC. Final GRC = (R1_GRC + R2_GRC + 4×R3_GRC)/6 per Simpson's rule aggregation.

5.0 Findings and Results

5.1 Ranking and Interpretation of CE Indicators

5.1.1 Chemical Toxicity Reduction (CTR) — Rank 1

Chemical Toxicity Reduction has the largest Total Grey Coefficient of 0.5058, thus, it represents the most systemic influential circular economy (CE) indicator of the Indian textile industry. This observation is supported by the severity of chemical pollution recorded in the textile production belts in India. Dyeing and finishing industries, especially those located in Tamil Nadu, Gujarat and Rajasthan, release large amounts of azo dyes, heavy metals, including chromium and cadmium, and synthetic surfactants into water bodies, which irreversibly affect the ecology (FICCI 2022; Kumar *et al.* 2023).

The large value of the influence coefficient of CTR also indicates its cascading effects on a set of other indicators: decrease in the chemical inputs leads directly to a decrease in water contamination loads (promoting Water-Consumption Reduction, WCR),

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decrease in energy needs to treat the effluent (promoting Energy-carbon Reduction, ECR), encouragement of design to safer recyclable products (pandering to Design for Recyclable Products, DRP), and encouragement of greener procurement of cleaner chemistry inputs (advancing Green Procurement Compliance, GPC This is the multi-pathway effect, which is only captured through the indirect influence calculation of GINA, and it is the foundation of the dominating role of CTR.

Its significance is also increased by regulatory pressure, where Hazardous and Other Wastes Rules (2016) and the Water (Prevention and Control of Pollution) Act puts strict effluent standards and violations that result in sanctions such as the closure of the facility. The orders of the National Green Tribunal related to textile clusters have boosted the adoption of substitution chemistry, natural dyes and zero-liquid-discharge (ZLD) systems, which are major CTR levers. All these factors increase CTR as a high-priority intervention point.

5.1.2 Energy and Carbon Reduction (ECR) — Rank 2

The Total Grey Coefficient of Energy and Carbon Reduction was 0.4540 and the variable was ranked at the second position. The Indian textile industry can be characterized as highly energy-consuming from the perspective of wet processing, i.e., dyeing, bleaching and finishing of the products comprises nearly 38 per cent of all production energy (Ministry of Textiles, India, 2024). Currently, the industry is almost monopolized by coal- and diesel-based sources of energy, therefore, contributing a considerable amount of Scope 1 and Scope 2 greenhouse gases.

A shift to renewable energy, including solar thermal energy, wind power and biomass cogeneration, is a two-fold advantage because, on the one hand, this energy can directly reduce GHG emissions; on the other hand, its rates ignore the tariff of the conventional energy, which is lower in a number of Indian states. Moreover, the Perform, Achieve and Trade (PAT) scheme by the CPCB requires textile industries that consume a lot of energy to achieve the required efficiency enhancement goals. The latter second-place position of ECR, therefore, highlights the expert opinion that the energy transformation is a necessary precondition of CE performance in the whole indicator system.

5.1.3 Water Consumption Reduction Rate (WCR) — Rank 3

A Total Grey Coefficient of 0.4504 was also obtained on Water Consumption Reduction Rate, so it occupies third place. Textile wet processing is one of the most water-intensive industrial processes in the world, as it requires 100-150litres of water per kilogram of fabric (Niinimaki *et al.* 2020). In water-stricken areas like Tiruppur, Tamil Nadu, the cumulative water usage per annum by the textile mills has brought about gross aquifer environment and legal measures by the Madras High Court.

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The major WCR interventions include the introduction of water-less dyeing technologies, closed-loop water recycling and hi-tech filtration of effluents including ZLD system. According to the analysis performed by GINA, WCR is not only a direct sustainability indicator but also an amplifier: when water stewardship is translated into actionable, measurable results, it has a positive effect on green procurement (GPC) by creating the demand towards water-efficient inputs and supplier and worker awareness (SWA). This systemic role is why this system is ranked third place, even though its direct effect can be seen as less expensive than that of CTR or ECR.

5.1.4 Design for Recyclable Products (DRP) — Rank 4

Design for Recyclable Products got a Total Grey Coefficient of 0.3308. The recyclability of blended textile products, such as polyestercotton blends, which make up more than 60 percent of all fibre usage in the world, is a structural constraint to the circular economy. Creating clothes and fabrics in mono-material structures, modular structure, and chemical processing free design helps in both mechanical and chemical recycling at the end of their life cycle. The fourth-place position of DRP is related to the recognition that product design is a strategic facilitator of circular flows even though it takes more adoption schedules and partnership of brands, manufacturers and recyclers.

5.1.5 Green Procurement Compliance (GPC) — Rank 5

The Total Grey Coefficient obtained in Green Procurement Compliance was 0.1429. Its somewhat lower position can be explained in part by the complexity of its supply chain: the textile supply chain in India contains many informal subcontractors and spinning mills most of which do not have the capacity to prove green procurement compliance. However, scholars acknowledged that the effects of GPC on system-wide effectiveness are not trivial especially as global brands are gradually making it a requirement to adhere to the standards like the Global Organic Textile Standard (GOTS), OEKO-TEX among others as a condition of suppliers selection.

5.1.6 Supplier and Worker CE Awareness (SWA) — Rank 6

The lowest Total Grey Coefficient of 0.1161 was obtained in Supplier and Worker CE Awareness. Although, experts unanimously held that the level of worker and supplier awareness is essential in building a long-term culture of the circular economy, its systemic impact on other short-to-mid-term indicators was rated as minimal. SWA thus, serves more as an implementation enabler of downstream action instead of an agent of structural CE action, which is consistent with the fact that behavioural cue and training actions produce an effect with longer time horizons than technological or regulatory cue actions do.

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5.2 Figure 1: GINA ranking chart — Total grey coefficients

Figure 1: Total Grey Coefficient Rankings of CE Indicators

Indicator	TGC	Relative Influence (Bar)	Rank
CTR	0.5058		1
ECR	0.4540		2
WCR	0.4504		3
DRP	0.3308		4
GPC	0.1429		5
SWA	0.1161		6

Source: Authors' GINA computation. Each ' ' represents a scaled unit of TGC for visual comparison.

5.3 Comparison to existing literature

The severity of CTR observed in the given work corresponds well with the severity of chemical pollution reported in Indian textile clusters (Kumar *et al.*, 2023; FICCI, 2022) and the theoretical significance of substitution chemistry in the context of Circular Economy (CE) (Geissdoerfer *et al.*, 2017; Niinimaki *et al.*, 2020). It is not surprising that ECR is ranked as the second-best since Baratsas *et al.* (2022) also found that one of the fundamental CE performance dimensions was energy management. However, the current results do not fit into the generic CE models because DRP is found to be in position four, but not in position one, which is a result of the expert opinion of structural change through design circularity in that enabling conditions (which are chemical and energy improvements) need to be satisfied first.

6.0 Conclusion and Implications

6.1 Summary of key findings

The research utilized a systematic Delphi-GINA model to identify priorities in Circular Economy indicators to the Indian textile industry. After two waves of expert advice, utilizing a total of one hundred and eight professionals, fifteen provisional CE indicators were narrowed down to six consensus-validated indicators. The GINA analysis has revealed that Chemical Toxicity Reduction (TGC= 0.5058) had the strongest systemic impact, followed by Energy and Carbon Reduction (0.4540), Water Consumption Reduction Rate (0.4504), Design for Recyclable Products (0.3308), Green Procurement Compliance (0.1429), and Supplier and Worker CE Awareness (0.1161).

The fact that the range of values of TGC is observed as 0.1161 to 0.5058 also emphasizes that the hierarchy of influence is more differentiated compared to the food industry and suggests that the textile CE system has a more clear hierarchy of causes and

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priority indicators. The fact that the GINA is able to measure indirect influence pathways has made it possible to discover the disproportionate systemic role of CTR, an outcome that would be hidden with more crude forms of additive ranking.

6.2 Practical implications

To industry players, the findings provide a gradual Circular Economy implementation plan. Phase 1 (immediate, 012 months) should focus on a chemical replacement and the implementation of the zero-liquid discharge (ZLD) technology (CTR). Phase 2 (short-term, 618 months) is to invest in renewable energy, especially, it is possible to talk about solar thermal systems to dyeing and drying processes (ECR). Phase 3 (medium-term, 12 to 30 months) would involve setting up of water-recycling systems and testing of water-less dyeing systems (WCR). Phase 4 (sustained) should consider Design for Recyclable Products (DRP), Green Procurement Compliance (GPC) and Supplier and Worker Awareness (SWA) using design innovation, procurements reform and training programmes respectively.

To policy makers, the results would suggest that regulatory and incentive policies should focus on ensuring that chemical effluent standards, clean-energy subsidies to textile SMEs, and zero-liquid discharge systems are mandatory in the production clusters with water shortages. The following systemic Circular Economy transition due to being proposed by the GINA rankings would be promoted faster through such targeted interventions.

6.3 Limitations

There are a few limitations which should be noted. To start with, though the Delphi panel of eighteen respondents met the conventional requirements, a larger geographic representation of the various geographical textile-producing areas in India would improve the generalizability of the results. Second, the analysis is restricted to only the textile manufacturing stage; the up stream fibre production stage and the down stream consumer behaviour stage were not included in the indicators. Third, the cross-sectional design only captures the perceptions of the experts about the company at one point of time; a longitudinal confirmation would be significantly effective in supporting the results. Fourth, GINA does not provide empirical performance information, so it is limited in its ability to support the hypothesis that indicators with large systemic effect have disproportionately high ramifications to the Circular Economy in practice.

6.4 Future research directions

The suggested framework is to be confirmed in future studies by taking longitudinal case studies of the textile enterprises that use the prioritized indicators. These could be sub-sectoral refinements, spinning, weaving, dyeing and garment manufacturing, which would

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give a more operationally granular result. Inclusion of GINA prioritization using empirical performance data through machine-learning models may also increase predictive ability of the framework. Lastly, a pair of comparative research (between South and Southeast Asian economies) based on textile industries e.g. Bangladesh, Vietnam and Sri Lanka would determine the level of cross-national applicability of the framework.

7.0 Recommendations

The following are some of the recommendations that are put forward based on the GINA results:

- *Regulatory:* The Bureau of Indian Standards ought to come up with sector-specific Circular Economy performance indicators of the textile industry that resonates with the identified six indicators especially CTR and ECR thresholds.
- *Industry bodies:* FICCI and the Confederation of Indian Textile Industry (CITI) must develop benchmarking programmes that can help the textile companies to gauge themselves against the six GINA validated CE indicators.
- *Financial incentives:* The Ministry of Textiles would be advised to offer preferential access to credit on investments within the zero-liquid discharge systems, solar energy plants as well as waterless dyeing equipment- mainly CTR, ECR and WCR interventions.
- *Capacity building:* Textile clusters are recommended to create Circular Economy training centres to workers and supplier SMEs, which fills the identified gap on Supplier and Worker Awareness (SWA).

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Appendix A: Expert Survey 1 - Sample Questionnaire

Electronically administered Expert Survey 1 to a group of 18 subject-matter experts was carried out in 2023. The respondents were asked to rate the salience of fifteen circular-economy indicators on a five-point Likert scale (1 = Not Important; 5 = Critically Important) in the Indian textile industry. The final data has been recorded in a detailed spreadsheet, which is provided in the current submission (Expert Survey 1 Textile.xlsx).

Appendix B: Influence Survey 2 - GINA Computation Workbook

Influence Survey 2 requested pairwise influence judgments with respect to the six indicators of the circular-economy that had been selected after the first survey, and each of the 18 experts on the panel had provided its evaluation on a five-point linguistic scale. The procedures of the associated Grey Influence Analysis (GINA) aggregation of the numbers of grey and normalisation, inverse of the influence matrix, calculation of the Grey Responsible Coefficients, and derivation of the final Total Grey Coefficient (TGC) are fully detailed in the supplementary workbook (Influence Survey 2 Textile.xlsx).

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