Assessment of Systemic Greenness: A Case Study of Tyre Manufacturing Unit

Abstract

In this paper, we develop an assessment framework to evaluate the systemic greenness of a tyre manufacturing unit by capturing the interactions between the green practices implemented. By reviewing the existing literature, we develop a stakeholder-based green practices framework comprising of operation strategy practices, process practices, employee practices, regulatory practices, customer practices, competition practices, social practices, and supplier practices. The empirical data on the interactions of green practices between and within stakeholders are collected by conducting a detailed case study of a large radial tyre manufacturing unit in India. We use graph theoretic approach to incorporate the interactions between different green practices and assess the systemic greenness of the case organization. Based on the systemic greenness attained, we rank the green practices within stakeholders and also between the stakeholders. We conduct scenario analysis to develop a systemic greenness index and a scale to assist practitioners in evaluating and benchmarking the greenness performance. We also discuss implications for theory and practice along with the inherent limitations.

Keywords: Green practices; Systemic greenness; Assessment; Stakeholder theory; Graph theoretic approach; Tyre manufacturing; India

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1. Introduction

The rise in standard of living across the world has increased the consumption of goods and services in the market. On one hand, increased consumption demands efficient utilization of resources by reducing consumption of virgin materials and increasing use of recycled materials to ensure their availability for future generations (Kalaitzi et al., 2018). On the other hand, recycling of used materials introduces high variability in the supply chain in comparison to usage of virgin raw materials, resulting in low economic benefit (Sasson and Johnson, 2016; Kocabasoglu et al., 2007). Therefore, it is evident that environmental protection, societal consumption, and economic benefits are highly intertwined and have competing relationships within due to the different orientation of stakeholders involved (Halkos and Skouloudis, 2018; Varadarajan, 2018).

Assessment, both external (regulatory and licensing) and internal (accreditations and certifications), helps in striking an efficient tradeoff between these competing relationships and in moving the system to an optimal equilibrium (Wang et al., 2018; Huang and Wang, 2017). Consumers and regulatory authorities have been using assessment as a tool to impose pressure on companies to adopt sustainable practices by implementing Green Business Strategies (GBS) (Xu et al., 2017; Xie, 2015; Chen and Sheu, 2009). Zhu and Sarkis (2004) defined GBS as a complete plan of action for an organization which is attempting to transform itself into green, both internally within the organization and externally across the supply chain. GBS have taken multiple forms in literature under the terminologies green management (Molina-Azorín et al., 2009; Alfred and Adam, 2009), green manufacturing system(Yang et al., 2012; Chuang and Yang, 2013), green supply chain management (GrSCM) (Choudhary et al., 2019; Sarkis et al., 2011; Zhu and

Sarkis, 2004; Walton et al., 1998; Mitra and Datta; 2013; Luthra et al., 2015; Irani et al., 2017), sustainability (Kumar et al., 2019; He et al., 2018; Gunasekaran and Spalanzani, 2012), sustainable supply chain management (Kusi-Sarpong et al., 2019; Seuring and Muller, 2008) etc. For the purpose of this study, we define GBS assessment as a *"process through which the improvements of an initiative or practices that are in line of green business are evaluated by incorporating the impact of interactions of the initiatives on the final greenness attained*". However, existing empirical studies on greenness assessment have overlooked these interactions between different practices.

Hence, assessment of the extent of GBS implementation by incorporating these interactions is highly necessary for driving the organization and its supply chain towards optimal equilibrium for achieving sustainability. Therefore, the overarching research objective of this study is to develop a theoretical framework of green practices by uncovering the interactions between them for assessing the systemic greenness of an organization. To achieve the stated research objective, we will be answering the research questions stated below (RQ):

- **RQ 1:** What are the green practices that an organization can implement while adopting GBS? Which of the stakeholders are accountable for these different green practices?
- **RQ 2:** How can an organization assess the systemic greenness attained through GBS implementation by incorporating the interactions? Where is the organization lacking in its systemic greenness and how can it be improved?

To achieve this objective, we first identify a comprehensive set of green practices from literature and group them together under different stakeholders. The interactions between these practices and stakeholders are theoretically established.

Data on these interactions are collected by conducting a detailed case study of a radial tyre manufacturing unit in India. Thus, our contributions are two-fold. First, we use graph theoretic method to incorporate the interactions between different green practices into the assessment of systemic greenness. Second, we conduct scenario analysis to develop a scale for evaluating the greenness performance. Finally, our assessment delivers a systemic greenness index for the assessed unit and ranks the green practices within stakeholders and the different stakeholders.

We structure this paper into the following sections. A detailed literature review of the research conducted in the area of Green Business Strategy is presented in Section 2. Section 3 develops the framework based on green practices identified from the literature review. Section 4 provides an overview of the case organization which is the source of data for conducting the assessment. Section 5 explains the graph theoretic methodology used to assess the systemic greenness of the case organization. Section 6 discusses the assessment results obtained for the case organization. Finally, section 7 concludes the paper by listing the implications, limitations and future research directions.

2. Literature Review

The increased importance of Green Business in academic research is supported by large number of recent special issues published in various operations management journals (e.g. Omega (2006, 2014), International Journal of Production Research (2006, 2007, 2012), International Journal of Production Economics (2008, 2 issues in 2012, 2014, 2015), Journal of Operations Management (2007), Journal of Supply Chain Management (2014), etc.). More than 50 literature reviews published on sustainability from 2000 to 2019 further supports the academic attention towards this topic (Ghadimi et al., 2019; Shaharudin et al., 2019; Roy et al., 2018; Rajeev et al., 2017).

We have divided the literature survey into two parts. The first part reviews the literature on GBS implementation and identifies the green practices that are documented in them. The second part reviews GBS assessment literature and identifies the assessment methodology adopted, research questions answered, and green practices and performance measures documented in them. The literature has been collected from the online database of SCOPUS by searching for keywords such as Green Business Strategy, Environmental Management Strategy, Green Supply Chain Management, Sustainable Supply Chain Management, Low Carbon Emission Supply Chain, etc. This was followed by the screening of the literature by the authors to select the manuscripts which exclusively dealt with either GBS Implementation or the GBS Assessment.

GBS implementation literature represents those studies which have documented the implementation experience of different strategies to attain greenness. Conceptual studies and literature reviews which discuss the implementation aspects of GBS have also been considered. **Table 1** presents the detailed review on GBS implementation that has been carried out. Studies under different industrial setting have been performed across various manufacturing sectors such as paper, textile, bio fuels, petroleum, automobile, printing, clothing, chemicals, electronics etc. Studies within GBS implementation literature have also discussed the green performance measures (e.g. Szekely and Knirsch, 2005; Zhu et al., 2005; Li et al., 2006; Gunasekaran and Spalanzani, 2012). As the objective of our review was to identify the green practices discussed in GBS implementation literature, we specifically focussed on the green practices and documented them separately in **Table 2**.

Table 1: Review of studies focussing on GBS implementation

Author	**Country**	**Sector ***	**Industry**	**Empirical/ Conceptual**	**Broad Research methodology**	**Qualitative / Quantitative**	**Scale used**
Sharma and	Canada	M	Canadian	Empirical	Multiple	Quantitative	-

Henriques (2005)			forestry industry		Case, Archival data, and Survey		
Szekely and Knirsch (2005)	Germany	M&S	Wide range	Empirical	Multiple case and Archival	Qualitative	-
Zhu et al. (2005)	China	M	Wide range	Empirical	Survey	Quantitative	5-point Likert scale
Vachon and Klassen (2006)	North America	M	Package printing industry	Empirical	Survey	Quantitative	7 point scale
Svensson (2007)	International	M	Clothing industry	Conceptual	Archival Data	Qualitative	
Walker et al. (2008)	UK	M&S	Public and private sector organizations	Empirical	Multiple Case	Qualitative	Nil
Seuring and Müller (2008)	-	-	-	Conceptual	-	Qualitative	-
Lee (2008)	Hong Kong	-	-	Empirical	Survey	Quantitative	-
Zhu et al. (2008a)	Chinese	M	Power generating, chemical/petroleum, electrical/electronic and automobile	Empirical	Survey	Quantitative	5-point Likert scale
Keating et al. (2008)	Australia	S	Westpac Banking Corporation	Empirical	Single Case	Qualitative	
Zhu et al. (2008b)	China	M	Wide range	Empirical	Survey	Quantitative	5-point Likert scale
Carter and Rogers (2008)	-	-	-	Conceptual	-	Qualitative	-
Pagell and Wu (2009)	International	M&S	Wide range	Empirical	Multiple Case	Qualitative	-
Epstein et al. (2010)	-	M	Nike	Empirical	Single Case	Qualitative	-
Hall and Matos (2010)	Brazil	M	Biofuels production	Empirical	Multiple Case	Qualitative	-
Chen et al. (2012)	Taiwan	M	Electronics industry	Empirical	Single Case	Quantitative	5-Point likert and Saaty's 1-9 fundamental scale
Liu et al. (2012)	International	M	Wide range	Empirical	Multiple Case	Qualitative	-
Schneider and Wallenburg (2012)	-	-	-	Conceptual	-	Qualitative	-
Smith and Ball (2012)	UK	M	High technology industrial equipment	Empirical	Single Case	Qualitative	-
Nouira et al. (2014)	Nil	M	Textile sector	Empirical	Single Case	Quantitative	Nil
Govindan et al. (2014)	India	M	Wide Range	Empirical	Survey	Quantitative	Saaty's 1-9 fundamental scale
Dangelico (2015)	US	M+S	Wide Range	Conceptual	Secondary Database	Quantitative	-

Leonidou et al. (2017)	Cyprus	M	Wide Range	Empirical	Survey	Quantitative	7-point Likert scale
Liu et al. (2018)	China	M	Automobile	Empirical	Survey	Quantitative	5-point Likert scale
Roscoe et al. (2019)	China	M	Wide Range	Empirical	Survey	Quantitative	7-point Likert scale

* M-Manufacturing, S-Service

Table 2: Green practices observed in GBS implementation literature

Author (Year)	Green Practices
Sharma and Henriques (2005)	Pollution control, Eco-efficiency, Recirculation, Eco-design, and Ecosystem stewardship
Szekely and Knirsch (2005)	Documented CSR Reports of 20 major German Companies and segregated them into Social, Economic and Environmental Metrics with specific reference to Dow Jones Sustainability Index and Global Reporting Initiative Sustainability Reporting Guidelines
Zhu et al. (2005)	Documented GSCM Pressures (Supply chain, Cost related, Marketing, and Regulations) and GSCM Practices (Internal environmental management, Eco-design, and Investment recovery)
Vachon and Klassen (2006)	Environmental collaboration, Environmental monitoring, logistical integration as well as technological integration with suppliers and customers to improve environmental results.
Svensson (2007)	Corporate social responsibility, sustainable supply network management, supply chain environmental management, green purchasing strategies, environmental purchasing, green marketing, environmental marketing, environmental product differentiation, reverse logistics, sustainability labeling schemes, life-cycle assessment, and ISO 14000-certifications, product returns, source reduction, recycling, material substitution, reuse of materials, waste disposal, refurbishing, repair, and remanufacturing.
Walker et al. (2008)	**Practices:** Recycling, reuse, input material purification, low-density packaging design; environmental data gathering about vendors, products or processes; waste elimination efforts such as biodegrading, non-toxic incineration; **Internal drivers:** Organization's values, Value champions, Costs reduction; **External drivers:** Access to environmental information, Regulatory compliance, Environmental risk minimization, Monitor environmental performance, Pressure/encouragement by customers; **Internal barriers:** Costs, Local nature of project, Lack of resources; **External barriers:** Exposing poor environmental performance, Lack of information, Confidentiality, Fragmented industry, Small number of suppliers (poor competition), Scale of supply chain, Lack of industry-wide consistent environmental criteria, Procurement legislation, Clinical preference, Inertia by project stakeholders;
Seuring and Müller (2008)	Listed factors under Pressures and incentives for sustainability in supply chains, Sustainable supply chain management and Barriers for sustainable supply chain management.
Lee (2008)	Green spinning, Green selling, Green harvesting, Entrepreneur marketing, and Compliance marketing
Zhu et al. (2008a)	Listed factors under Internal environmental management, Green purchasing, Customer cooperation, and Investment recovery.
Keating et al. (2008)	Increase financial, people, and environmental value, Public reporting, meeting labor standards, Work/life balance, Eco-performance, Stakeholder engagement, Use business case to generate internal support and to secure resource commitments from senior management, Develop governance tools that appropriately reflect CSR requirements for suppliers based on their strategic importance, Develop different assessment tools to measure the performance and compliance of suppliers, Provide quality feedback to stakeholders on the CSR performance of suppliers relative to expectations and the performance of their peers, and Undertake regular reviews of SSCM policies and practices
Zhu et al. (2008b)	Organizational learning and management support, Support for GSCM from mid-level managers, Cross-functional cooperation for environmental improvements, Environmental compliance and auditing programs, ISO 14001 certification, Environmental design, Cooperation with suppliers for environmental objectives, Environmental audit for suppliers' internal management, Suppliers' ISO 14000 certification, Cooperation with customer for eco-design, cleaner production, & green packaging, Sale of scrap and used materials, Chinese customers environmental awareness, Establishing company's green image,

Carter and Rogers (2008)	Systematically address the long-term (sustainability) issues/risks early, Transparency, Organization's sustainability initiatives and its corporate strategy closely interwoven, and supportive company cultures and mindsets
Pagell and Wu (2009)	Listed criteria's under five bundles: Commonalities, cognitions, and orientations, Ensuring supplier continuity, Re-conceptualize the chain, supply chain management practices, and Measurement
Epstein et al. (2010)	Factors most important in its sustainability positioning are: Leadership, Organizational design, Market strength, Market positioning, and Culture
Hall and Matos (2010)	Sourcing of raw materials from impoverished communities to reduce environmental impacts and social exclusion in biofuels production
Chen et al. (2012)	Green management perspectives - Proactive innovation, Active integration, Receptive learning, and Reactive response, Green Design, Green purchasing, Green manufacturing, and Green marketing and service
Liu et al. (2012)	Strategies for GBS: Product-based integration, Promotion-based integration, Planning-based integration, Process-based integration, People-based integration, and Project-based integration. Also documented internal and external drivers and obstacles.
Govindan et al. (2014)	Barriers: Outsourcing, lack of technology, lack of knowledge, lack of financial support, lack of involvement and support
Dangelico (2015) Jabbour et al. (2017)	The presence of employee green teams positive influence environmental performance and environmental reputation in the market.
Leonidou et al. (2017)	Organizational Resources positively contributes to GBS, Organizational Resources positively contributes to Organizational capabilities, Organizational capabilities positively contributes to GBS, GBS leads to competitive advantage and hence higher market and financial performance
Liu et al. (2018)	In Chinese context, internal integration and external integration between stakeholders lead to higher green design and hence higher economic and environmental performance. However, in western manufacturing firms, no evidence exists for the role of integration towards green design. However, if green design is achieved, it definitely leads to higher economic and environmental performance.
Roscoe et al. (2019)	Green human resource management practices lead to positive enablers of green organizational culture and hence higher environmental performance.

Next to GBS implementation literature, we reviewed the studies conducting GBS assessment. GBS assessments studies have attempted to either explain the relationship between firm performance and GBS or have developed a methodology to assess the greenness level of a firm implementing GBS. **Table 3** presents an overview of all the studies on GBS assessment. Majority of the studies were empirical in nature following quantitative models across various industries ranging from automobile, paper, apparel, electronics, telecommunication, chemical, computer, sugar, cement etc. It is also observed that index for measuring performance was only developed by Sundarakani et al. (2010) and Figge and Hahn (2012), but they did not capture the interactions between the green practices. **Table 4** documents in detail the research question addressed, green practices adopted and the green performance measures used in the respective GBS assessment studies. Most of the GBS assessment literatures have focussed on developing evaluation procedures for selecting a supplier who is more inclined towards the GBS initiatives of the focal company (Noci 1997; Humphreys et al. 2003; Lee et al. 2009; Kumar et al. 2014).

The structured review process by segregating the vast literature on GBS into two parts helped to understand the gaps in existing implementation and assessment procedures. Hervani et al. (2005) indicates that "even though environmental indicators are plentiful, there is difficulty existing still in determining which of them to use, when to measure them, and especially how to measure them". Gunasekaran and Spalanzani (2012) based on their review proposed that future research can be conducted to develop models, performance measures, metrics, and procedures for optimizing sustainable business development. Chen et al. (2012) was one of the first few studies in this genre which used Saaty's fundamental scale to gather and aggregate expert opinions concerning how dominant one element is with respect to another with the objective of rank-ordering priorities. The study proposed a network that described business functions and its associated activities with "greenness". Walker et al. (2008) explored the factors that drive or hinder organizations to implement green supply chain management activities. The authors found that organizations are more influenced to external driving factors such as regulatory compliance or motivation from customers rather than internal drivers such as organization values towards greening. Mangla et al. (2018) found that improper green operating procedures is one of the main reason behind failure of green supply chain performance. However, none of the studies has focussed on assessing the systemic nature of the practices by incorporating the interactions existing between these green practices and the associated stakeholders.

Table 3: Review of studies focussing on GBS assessment literature

Author (Year)	Country	Sector	Industry	Empirical/ Conceptual	Qualitative / Quantitative	Scale used	Assessment Methodology Adopted	Index (Y: Yes, N: No)
Noci (1997)	-	M	Automotive manufacturer	Empirical	Quantitative	Scores ranging from 1 to 3	Analytic Hierarchy Process (AHP)	N
Handfield et al. (2002)	US	M	Automotive, paper and apparel	Empirical	Quantitative	Saaty's 1-9 scale	Delphi and AHP	N
Humphreys et al. (2003)	-	S	Telecom	Empirical	Quantitative	0—low; 1—average; 2—high	Knowledge-Based System (KBS) and Case-Based Reasoning (CBR)	N
Hervani et al. (2005)	-	-	-	Conceptual	Qualitative	-	Work relies on experiences, case studies and other literature related to performance measurement in environmental supply chains.	N
González-Benito & González-Benito (2005)	Spain	M	Chemical, electronic & electrical, furniture & fixtures.	Empirical	Quantitative	5-point Likert scale	Principal components analysis, correlation, Analysis of Variance (ANOVA) and multiple regression	N
Cholette and Venkat (2009)	US	M	Food and beverage sector	Empirical	Quantitative	-	Used a web-based tool to calculate the energy and carbon emissions associated with each transportation link and storage echelon.	N
Lee et al. (2009)	Taiwan	M	TFT–LCD manufacturer	Empirical	Quantitative	Saaty's 1-9 scale	Delphi technique and Fuzzy AHP	N
Fiksel (2010)	-	-	-	Conceptual	Qualitative	-	Life cycle assessment methodology	N
Sundarakani et al. (2010)	China	M	Automotive supply chain	Empirical	Quantitative	-	Analytical model uses the long-range Lagrangian and the Eulerian transport methods. Analytical and finite difference methods are used to approximate the three-dimensional infinite footprint model.	Y
Yang et al. (2011)	Global	M	Wide Range	Empirical	Quantitative	5-point Likert scale	Confirmatory factor analysis and Structural Equation Modelling (SEM)	N
Chen and Liang (2012)	Taiwan	M	Computer Manufacturers	Empirical	Quantitative		Developed the cost function based on the operation data of computer industry from 1999 to 2005.	N
Hultman et al. (2012)	Brazil and India	M	Sugar and cement sectors	Empirical	Qualitative	5-point Likert scale	Interview with 82 Clean Development Mechanism (CDM) plants	N

Figge and Hahn (2012)	Global	M	Car manufacturers - painting and coating technology	Empirical	Quantitative		Contrasted the green business case with an opportunity cost based app roach for assessing the environmental performance of firms.	Y
Wong et al. (2012)	Taiwan	M	Electronics manufacturers	Empirical	Quantitative	7-point Likert scale	Using natural-resource-based view of how suppliers environmental management capability plays important role in success of green operations	N
Lai & Wong (2012)	China	M	Generic	Empirical	Quantitative	1—"not at all" to 5—"to a great extent"	Confirmatory factor analysis, SEM, and multi-group analysis for moderating effect	N
Kumar et al. (2014)	India	M	Automobile spare parts manufacturer	Empirical	Quantitative	5-point Likert scale	Green Data Envelopment Analysis	N
Balon et al. (2016)	India	M	Automobile	Empirical	Quantitative	7-point Likert scale	Interpretive Structural Modeling	N
Tramarico et al. (2017)	Brazil	M	Chemical	Empirical	Quantitative	Scores ranging from Excellent to Poor (1-5)	AHP	N
Mangla et al (2018)	India	M	Plastic	Empirical	Quantitative	-	Fuzzy Failure Mode Effect Analysis (FMEA) Analysis	N
Mohammed et al. (2019)	UK	M+S	Packed Meat	Empirical	Quantitative	-	Hybrid MCDM-fuzzy multi-objective programming	N

Table 4: Green practices and performance measures in GBS assessment literature

Author (Year)	**Research Question Addressed**	**Green Practices (GP) & Green Performance Measures (GPM)**
Noci (1997)	Designed a conceptual approach that identifies measures for assessing a supplier's environmental performance and suggests a supplier selection procedure	**GP** *Green competencies:* Availability of clean technologies, Type of materials used in the supplied component, Capacity to respond in time; *Current environmental efficiency:* Waste water, air emissions, solid waste, energy consumption; *Suppliers "green" image:* Share of 'green' customers, type of relationships between the examined supplier and its stakeholders, level of a customer's purchase retention; *Net Life Cycle Cost:* Cost of the supplied component, Cost for component disposal, Depreciation for investments aimed at improving the supplier's environmental performance; **GPM** Life cycle cost, waste water, air emissions, solid waste, energy consumption, the share of 'green' customers, type of relationships between the examined supplier and its stakeholders, level of a customer's purchase retention.
Handfield et	Developed decision support model to	**GPM**

Author (Year)	Research Question Addressed	Green Practices (GP) & Green Performance Measures (GPM)
al. (2002)	understand the trade-offs between environmental dimensions	*Product attributes:* internal recycling activities within the supplier's organization, level of toxic and hazardous materials being consumed or emitted by the organization; *Waste management:* gross annual solid waste tonnage that goes to landfill, disposition of hazardous materials; *Labelling/certification*: extent to which the supplier's processes have been certified by third parties (government or non-government), supplier participates in voluntary eco-labelling systems; *Packaging/reverse logistics:* remanufacturing/reuse, returnable or reduced packaging, and reverse logistics systems; *Compliance with Government Regulations:* citations and/or fines levied on the supplier, air and water permits are up to date; *Environmental programs at the supplier's facilities:* Training programs, internal reporting structures, public disclosure statements, internal mission statements relating to the environment, and supplier evaluation systems.
Humphreys et al. (2003)	Developed a Knowledge-Based System (KBS) integrating environmental factors into the supplier selection process.	**GP** Management competencies, Green image, Design for environment, Environmental management systems, and Environmental competencies. **GPM** Environmental costs for pollutant effect and Environmental costs for improvement.
Hervani et al. (2005)	Discussed the issues related to environmental (green) supply chain management performance measurement	**GP** Activity-based costing, design for environment analysis, balanced scorecard, and Life Cycle Analysis (LCA) tools. **GPM** Stack or point air emissions, Discharges to receiving streams and water bodies, underground injection on-site, releases to land on-site, discharges to publicly owned treatment works, other off-site transfers, on-site and off-site energy recovery, on-site and off-site recycling, on-site or off-site treatment, magnitude and nature of penalties for non-compliance, costs associated with environmental compliance, environmental liabilities under applicable laws and regulations, major awards received, total energy use, total electricity use, total fuel use, other energy use, total materials use other than fuel, and total water use.
González-Benito & González-Benito (2005)	Analyses the relationship between environmental pro-activeness and business performance	**GP** Divided environmental management practices into Planning and organizational, Operational (Product related), Operational (Process related) and communicational.
Cholette and Venkat (2009)	Studies how California wines may be routed to U.S. consumers near and far	**GPM** *Product and capacity:* Product weight, Product volume, Overall supply chain configuration, Distances between nodes, Level of temperature control, Transport mode, Utilization rate, Backhaul rate, Dwell times, Location and type of power used, Level of temperature control, Utilization rate. *Transport*: Energy usage per km, Mode-CO_2 emissions profile per km; Parameters - Carrying capacity by volume, Carrying capacity by weight. *Storage:* Energy usage per day; Parameters - Emissions profile per day, Energy usage for each node and link, CO_2 emissions by node and link.

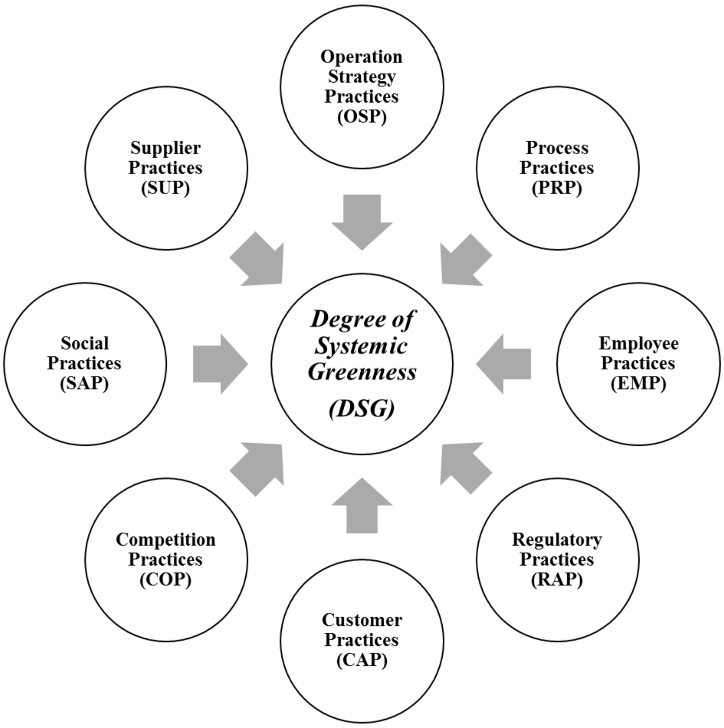
Author (Year)	Research Question Addressed	Green Practices (GP) & Green Performance Measures (GPM)
Lee et al. (2009)	Developed a model to select the factors for evaluating green suppliers, and to evaluate the performance of suppliers	**GP** Quality, Technology capability, Total product life cycle cost, Green image, Pollution control, Environment management, Green product, and Green competencies.
Fiksel (2010)	Described LCA technique to quantify the environmental performance and sustainability of a supply chain from raw material acquisition to end-of-life material recovery	**GPM** Inventory assessment, Impact assessment, Lifecycle footprint methods, Streamlined life-cycle analysis, Energy analysis, and Integrated lifecycle thinking.
Sundarakani et al. (2010)	Examines the carbon footprint across supply chains	**GP** Mitigate carbon emissions through product and supply chain design, Add carbon emission rates to supplier selection criteria, green supply and purchasing policies. Maintain acceptable carbon regulation at the manufacturing level, Leverage innovation in logistics services to reduce carbon emissions, Green packaging and distribution strategies, Reduce, reuse and recycle at the consumption stage, Create awareness among consumers. **GPM** Emission rate, rate of change of chemical transformation and emission of the node, total energy consumption of all sources, etc.
Yang et al. (2011)	Explored relationships between lean manufacturing practices, environmental management, business performance outcomes	**GP** Life-Cycle Analysis, Design for Environment, Environmental certification, recycling, waste management **GPM** ISO 14001 standards
Chen and Liang (2012)	Explored internal cost variation in adopting green supply chains, and calculated sales revenue difference with and without green supply chains, further estimating the so-called "green producer's surplus	**GPM** Total cost, Revenue, Administrative price, Capital price, Material price, Transportation price, and Inventory price
Hultman et al. (2012)	Studied how individual managers understood the potential benefits and risks in CDM investments and outline the diversity of approaches used for the assessment of potential risks and benefits before committing CDM projects	**GP** *Perceived risks*: Non-approval after investment, Rule changes, Reputation, Loss of money, Technical/non-performance, Lack of knowledge; *Benefits*: carbon credits, Image management, Reduce greenhouse gasses, reduce residue, Relationships with consultants, seeing other successful CDM projects, enhancing the factory reputation domestically and internationally.
Figge and Hahn (2012)	Study the suitability of the green business case	**GPM** Environmental value, Amount of environmental resources used by the company, Return of the company compared to the benchmark.
Wong et al.	Examined the boundary spanning role of	**GP**

Author (Year)	Research Question Addressed	Green Practices (GP) & Green Performance Measures (GPM)
(2012)	Green Operations and investigate the influence of environmental management capability of suppliers on firm performance and pollution reduction	*Product stewardship:* Design of products for easy disassembly, using recyclable/reusable environmental friendly packaging materials; *Process stewardship:* Production processes designed to consume fewer resources, Usage of environmental technologies/ carbon emission control/ cleaner transportation methods, and reverse logistic systems; *Pollution reduction:* Reducing carbon emission, solid waste, water wastage; *Environmental management capability of supplier:* ISO 14000 certification based on guidelines, Second-tier supplier environmental evaluations, Ecological proof, and Suppliers cooperation to reduce environmental impact
Lai & Wong (2012)	Discusses how to manage logistics with environmental considerations.	**GP** Procedure-based practices, Evaluation-based practices, Partner-based practices, and General environmental management practices.
Kumar et al. (2014)	Proposes a methodology for green supplier selection	**GPM** Shelf Life (months); Lead Time (days); Carbon Footprint (Metric Tons CO2)
Balon et al. (2016)	Identified barriers in green supply chain management using interpretive structural modelling	**GP & GPM** Training and skill development programme, level of supply chain integration, commitment from top management towards green practices, presence of integrated information system, adoption of reverse logistics practices, flexibility to change and adoption to innovation
Tramarico et al. (2017)	Effectiveness of green supply chain management training	**GP** Green supply chain management training results in 87% of the organizational benefits, 77% individual benefits. Here, organizational benefits include best practices in green supply chain management and understanding of basic conception and processes. Individual benefits include ability to acquire knowledge and skill towards green supply chain management.
Mangla et al (2018)	Assessed the risks associated with green supply chain for benchmarking the performance	**GP** Improper green operating procedures and green issues while closing the loop of green supply chain are the main reasons behind the failure of green supply chain performance. Other initiatives such as environmental collaboration with suppliers, presence of supplier environmental audits, understanding and training among workers regarding green procedures and practices, top management commitment in adopting green practices, ease of adoption of new technology contributing to green practices are some of the practices which promote greenness in the entire supply chain.
Mohammed et al. (2019)	Develops a green and resilient supply chain network design in determining the optimal number of facilities through fuzzy multi objective programming model.	**GPM** The importance and relevance of facility location in contributing towards an optimal green supply chain network design with trade-off features among economic, green and resilient objectives.

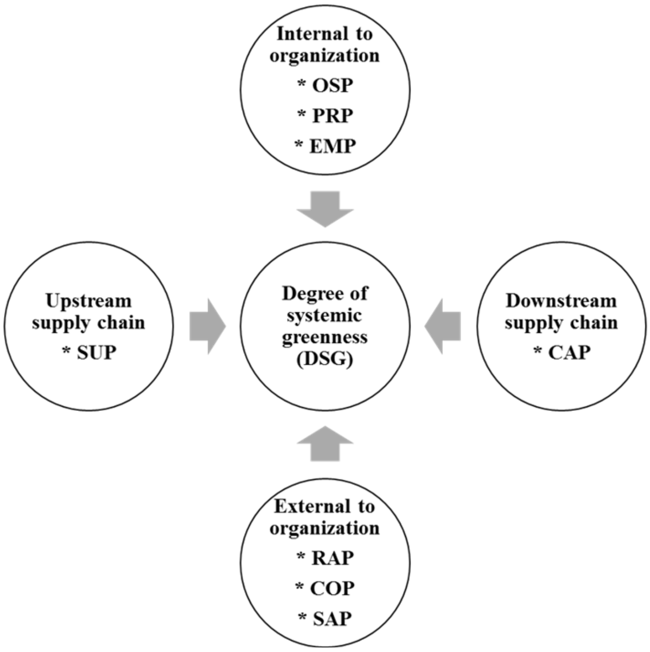
The graph theoretic method proposed in this study captures the interaction of green practices and thus assesses the systemic greenness. Choice of tyre manufacturing industry in this study is novel and perfectly matches the requirements to implement GBS. This is because most of the existing studies are in the auto-component sectors, chemical, textile or electronics industry. There are less number of studies that focus on tyre manufacturing industry, which is highly process driven. Further, it uses lot of "virgin rubber", chemicals such as Sulphur, etc. and therefore the manufacturing process has high environmental impact. Hence, we chose to focus on tyre manufacturing case to highlight how it can help in improving greenness in all the associated processes. Our research, therefore, makes an important contribution to the domain of GBS and sustainability.

3. Stakeholder-Based Framework of Green Practices

Based on the green practices identified from the literature review, we develop a stakeholder-based framework of green practices. We gathered a long-list of green practices from literature and subjected it to content analysis for clustering them within the stakeholder dimensions based on their relevance and contribution. We adopted a qualitative content analysis for our study (Schreier, 2012) as it is the most commonly used technique in qualitative research studies (Graneheim and Lundman, 2004). Also, in the domain of operations and supply chain management, the qualitative content analysis has been widely used in the literature (Brandenburg et al., 2014; Seuring and Gold, 2012). In this research, the unit of content analysis were the articles dealing with green practices which were reviewed in the previous section. Authors reviewed the literature and then categorized different green practices under each category. Based on the content analysis of the literature, eight green practice categories representing different stakeholder dimensions emerged out of the analysis - operation strategy practices (OSP) (Banasik et al., 2019), process practices (PRP) (Campos-Guzmán et al., 2019), employee practices (EMP) (Gölgeci et al., 2019), regulatory practices (RAP) (Kanashiro and Rivera, 2019), customer practices (CAP) (Aslani and Heydari, 2019), competition practices (COP) (Paksoy et al., 2019), social practices (SAP) (Crane et al., 2019), and supplier practices (SUP) (Badorf et al., 2019) (as represented in **Figure 1(a)**). Stakeholders can be also grouped as shown in **Figure 1(b)** based on their relative position to focal organization (internal/external) and its supply chain (upstream/downstream) (Kleindorfer et al., 2005). We ensured for the inter-coder reliability while building the stakeholder-based framework of green practices presented in **Table 5**.



(a)



(b)

Figure 1: (a) Pictorial representation of stakeholder-based framework of green practices (b) Categorization of stakeholders

Table 5: Stakeholder-based framework of green practices

Stakeholder dimension	Green practices
Operation Strategy Practices (OSP) **(B^1)**	1. Design for environment (DFE) - **B_1^1** 2. Environmental certification (ENC) – **B_2^1** 3. Leadership commitment towards green (LCG) – **B_3^1** 4. Green accounting methods (GAM) – **B_4^1** 5. Integration into corporate policy (ICP) – **B_5^1** 6. Environmental and social measures as KPIs (ESM) – **B_6^1** 7. Measurement and reward systems linked to sustainability (MRS) – **B_7^1**
Process Practices (PRP) **(B^2)**	1. Life-Cycle Analysis (LCA) - **B_1^2** 2. Lean and systems thinking adoption (LTA) – **B_2^2** 3. Process improvement consultants (PIC) – **B_3^2** 4. Reduce, reuse, recycle, refurbishing and, remanufacturing (R&R) – **B_4^2** 5. Green procurement, packaging, and labeling (PPL) – **B_5^2**
Employee Practices (EMP) **(B^3)**	1. Titled positions in sustainability/environmental management (TPS) - **B_1^3** 2. Train, empower and involve employees through feedback (TEI) – **B_2^3** 3. Importance to safety and health of employees (SHE) – **B_3^3** 4. Cross-functional employee cooperation (CFE) – **B_4^3** 5. Minimal hesitation/fear to convert to new systems (HCN) – **B_5^3**
Regulatory Practices (RAP) **(B^4)**	1. Industry-specific regulation compliance (ISR) - **B_1^4** 2. Availing government incentives (AGI) – **B_2^4** 3. Proactive action pre-regulation (PAP) – **B_3^4** 4. Regulatory compliance (at firm level) (RGC) – **B_4^4** 5. Public reporting (PUR) – **B_5^4**
Customer Practices (CAP) **(B^5)**	1. Customer co-operation and collaboration (CCC) - **B_1^5** 2. Creating awareness among customers (CAC) – **B_2^5** 3. Green distribution (GDN) – **B_3^5** 4. Accumulate credibility for the deliverables (ACD) – **B_4^5** 5. Importance to customers health and security (ICH) – **B_5^5**

Competition Practices (COP) **(B^6)**	1.	Increasing percentage of CDM projects registered (PCP) - $\mathbf{B_1^6}$
	2.	Benchmark with a best in class organization (BBC) – $\mathbf{B_2^6}$
	3.	Budget for long-term competency development (BLC) – $\mathbf{B_3^6}$
	4.	Sensing and reaching green customers first (SRG) – $\mathbf{B_4^6}$
	5.	Effective risk management (ERM) – $\mathbf{B_5^6}$
Social Practices (SAP) **(B^7)**	1.	Involve societies around and engage with NGO's for GBS (ISE) - $\mathbf{B_1^7}$
	2.	Reduction in percentage of public interest litigations registered at industry level (PPR) – $\mathbf{B_2^7}$
	3.	Extended product responsibility and offering product recovery services (EPR) – $\mathbf{B_3^7}$
	4.	Social fairness and sustainable resource management (SFM) – $\mathbf{B_4^7}$
	5.	Effective corporate social responsibility (CSR) – $\mathbf{B_5^7}$
	6.	Efficient waste disposal (EWD) – $\mathbf{B_6^7}$
Supplier Practices (SUP) **(B^8)**	1.	Values-based supplier selection for GBS (VSS) – $\mathbf{B_1^8}$
	2.	Encourage supplier innovation and green practices (ESI) – $\mathbf{B_2^8}$
	3.	Supplier integration, training and involvement for GBS (SIT) – $\mathbf{B_3^8}$
	4.	Information exchange and conducting joint planning for GBS (IEX) – $\mathbf{B_4^8}$
	5.	Regular environmental assessment before and after selection (REA) – $\mathbf{B_5^8}$
	6.	Common goals and aligned incentives for greenness (CGI) – $\mathbf{B_6^8}$

Operation strategy practices (OSP) dimension comprises of green practices at the top level of operation strategy, which affects the extent of greenness attained by the organization. Operation strategy practices involve the top management decision making (top-down flow). Process practices (PRP) dimension consists of green practices implemented at the process level of the organization. Process owners initiate the environmental friendly practices associated with different processes (bottom-up flow). Employee practices (EMP) dimension comprises of human resources related initiatives by the organization to attain the greenness level targeted. These three practices - OSP, PRP, and EMP - are within the organization level and mostly involve only the resources of the transforming organization.

Regulatory practices (RAP) dimension consists of green practices that are imposed by the government associations for safeguarding the environment. The enforcement can come from the regulatory bodies existing within the operational environment of the organization or from the agencies at the international level. Customer practices (CAP) dimension comprises of those green practices that are driven from the customer's end. These practices primarily attempt to cater to the green requirements of the products/services expected by the customers.

Competition practices (COP) dimension consists of practices driven by competitor's initiative and also by the interest of the organization to stay ahead of their competitors in sustainability. Social practices (SAP) dimension comprises of initiatives by the organization to involve and contribute to the society in which it operates. Along with considering the usual economic aspects, these practices assist the organization in considering environmental as well as societal aspects. Finally, supplier practices (SUP) dimension comprises of green practices expected from the suppliers to the organization.

For an organization to attain the GBS, it is not sufficient to be green within the organization (internal) but has to remain green over its entire supply chain by incorporating the viewpoints and interactions of different stakeholders (external) (Wolf, 2011). The five dimensions, namely RAP, CAP, COP, SAP, and SUP, are external to the focal organization. The proposed framework also takes into consideration the entire supply chain (upstream and downstream) of the focal organization. To be the market leader in GBS by maintaining the internal capabilities and withstanding the external pressure, the organization has to relook at its internal process as well as control/guide other external entities that affect the achievement of GBS (Zhu et al., 2013). In section 5, while introducing the systemic greenness assessment procedure, we discuss how the interaction between different stakeholders and their associated green practices are captured.

4. Case Study - An Overview of the Tyre Manufacturing Firm

This section is primarily divided into two parts. The first part explains in detail the research design adopted including the rationale behind the case based methodology, the reason behind purposive sampling and in particular the choice of tyre manufacturing unit (unit of analysis), and a brief background of the case organization towards systemic greenness. The second part of the section explains the data collection procedure.

4.1 Research Design

This study tries to answer 'how', 'what' and 'why' form of research questions on assessment of systemic greenness implementation by focusing on contemporary events without controlling for the behavioral events around it. Hence, case study research methodology is found to be appropriate (Yin, 2014). In case study research, the unit of analysis is not randomly sampled, but rather chosen based on how they contribute to the research questions raised (Eisenhardt, 1989; Glaser and Strauss, 1967; Siggelkow, 2007). Best-fit candidate for this study would possess four main characteristics. First, we require an organization that is implementing GBS. Second, the organization should have a standalone green implementation team. Third, different stakeholders within the organization must play a significant role in influencing their operations. Fourth, the organization's failure to implement GBS should have a significant negative impact on the environment and society. Finally, for the purpose of convenience sampling, authors should have ease and accessibility to data.

The validation of the proposed framework by conducting systemic greenness assessment has been carried out in a large tyre manufacturing firm in India. The Indian tyre manufacturing firm chosen satisfied all the four main characteristics to be shortlisted as a best-fit candidate. The firm was established in 1977 and has close to 15% market share of the total Indian tyre manufacturing industry. Case organization is also one of the largest tyre exporters from India with a world-wide customer base in over 75 countries across all the six continents. Firm's exports account for about 20% of the total tyre exports from India. The case organization has been investing significantly from 2010 to achieve GBS. The mission statement for GBS along with the targets set by the organization is captured in **Table 6**.

The unit of analysis chosen for this study is a large manufacturing unit of the case organization. This manufacturing unit is situated in northern India and has both radial and bias tyre manufacturing division with a total annual production capacity of around 60,000 MT (worth of INR 6.0 billion). A total of around 1450 employees, both regular and contractual, are engaged with this manufacturing unit. The manufacturing unit formed a multidisciplinary team to implement GBS and assess its benefits. The team comprised of members from R&D centre, product development centre, technical and quality analyst group, manufacturing group, engineering group, marketing and technical service group, and purchasing group. This team has been attempting to implement the green practices listed in **Table 5**. To give a snapshot, we present the implementation of "life cycle analysis" practice at the manufacturing unit in **Table 7**. Members from GBS team participated in conducting the systemic greenness assessment using the methodology developed in this study.

Table 6: Mission and target set by the case organization for GBS implementation

Topic	**Event**
Mission	Being cognizant to the need of green business growth and dwindling stock of natural capital
Target 1	Reduce specific consumption of energy and water by 2-5% every year over next 10 years
Target 2	Reduce specific generation of waste and reduce the quantum of waste going to land fills by 2-5% every year over next 10 years
Target 3	Increase use of renewable resources including energy in place of non-renewable resources by 2-5% every year over next 10 years
Target 4	Reduce specific green house gas emissions and other process emissions by 2-5% every year over next 10 years and explore opportunities through Clean Development Mechanism (CDM) and other Carbon Exchange Programs
Target 5	Increase use of recyclables and enhance recyclables of resources embedded in the product by 2-5% every year over next 10 years
Target 6	Increase the share of harvested rainwater in the overall annual use of water by 2-5% every year over next 10 years
Target 7	Incorporate life cycle assessment criteria for evaluating new and alternative technologies and products
Target 8	Strive to adopt green purchase policy and incorporate latest clean technologies
Target 9	Take lead in promoting and managing product stewardships program by forging partnerships with businesses and communities
Target 10	Reduce depletion of natural capital, which is directly attributable to company's activities, products, and services by 2-5% every year over next 10 years

Table 7: Implementation of "life cycle analysis" green practice at the manufacturing unit

Short-term objective: Improving initial mileage of the tyre
Target - Passenger Car Radial Tyres: 50,000 KM; Truck Bus Radial Tyres: 1,50,000 KM (Average)

Long-term objective: Improving total life cycle of the tyre (including recyclability)
Target 1- Passenger Car Radial Tyres: 60,000 KM (by improving the mileage); Truck Bus Radial Tyres: 3,00,000 KM (Average; Initial & Retread)
Target 2- Complete buy back of used Tyres by the Manufacturer in association with ATMA.
Target 3 - Develop innovative technology to recycle the used tyres in association with institutes like rubber board

Aspect	Interface considered	Science & Engineering support
1. Design of the product	• Rubber compounding	• Material chemistry
	• Tyre engineering	• Material physics
	• Tyre development	• Mechanical engineering & Advanced tyre mechanics
2. Material used	• Polymer/Polymer	• Material chemistry
	• Polymer/Filler	• Material physics
	• Cord rubber compound	• Thermodynamics
	• Wire rubber compound	• Surface science
3. Manufacturing process adopted	• Man	• System
	• Machine	• Rheology of rubber compound
	• Material	• Diffusion chemistry
	• Method	• Thermodynamics
	• Environment	• Heat transfer
4. Performance of the product	• Vehicle - Tyre - Road	• Vehicle Dynamics
	• Traction/Wear/Noise	• Sound engineering • Simulation engineering • Vibration mechanics
5. Manufacturing process scrap recycling and after life recycling	Tyre is a 100 % recyclable product Tyre recycling unit uses pyrolysis process to recycle a tyre and deliver the following: • 30% Carbon: Crumb powder/ Reclaim rubber obtained is re-used in tyre and other rubber products as a reinforcing material in addition to filler • 45% Oil: Due to high calorific value recently the tyres are used in Clinkers of cement Industry after use in Vehicle ,as a cheaper source of energy • 15% Steel: Reclaimed steel from tyres of high value are used back by steel industries in a specific ratio • 10% Gas: Gaseous by products collected during the process of high calorific value can replace natural gas and reused as fuel in other industries	

The company was actively engaged in green initiatives for the past ten years in various capacities (refer **Table 6** for GBS implementation targets). In 2007, the company had set a target to plant 6000 trees to promote healthy environment as part of their environmental philosophy. The company introduced the green mobility program and the eco-friendly silica technology during the period 2010-2016. The green mobility program aimed at reducing fuel consumption and non-renewable energy use in the manufacturing process. This exercise was complimented with continuous strive to improve reliability, durability and operational efficiency of the tyre. In the process of tyre manufacturing, carbon had been widely used as filler for the reinforcement of the rubber compound. They developed the technology blend carbon with silica so as to reduce the carbon content of the rubber compound, which made the tyres lighter and reduced rolling resistance. On an average, this initiative led to reduction of 5% fuel consumption and hence saving approximately 10 grams of CO_2 per km. Other impactful initiatives include reduction in tyre lubrication consumption, R&D facility for energy efficient production process and water recycling initiatives. The water recycling initiatives saved approximately 500 kilolitres of fresh water each day in the manufacturing process. The GBS team of this manufacturing unit had made progress in implementing different green practices and were interested in assessing their green journey so far to plan the future initiatives. Research study in the tyre manufacturing plant was conducted as events unfolded and both the process and outcome were studied in phases. It helped us in avoiding retrospection bias and the influence exerted by the data collector in the research context (Miles and Huberman, 1994).

4.2. Data Collection

Structured case study methodology discussed by Eisenhardt (1989) and Yin (2003) for data collection and data analysis was followed in this study. Interaction with the green implementation team, direct observations, and company documents were considered to be the sources of data and evidence for their targeted focus, contextual reality and stability advantages (Yin, 2014). Interactions with the members of green implementation team were performed to gather individual insights and interpretations on the company's performance in the green journey. Along with this information, data was collected (will be detailed in section 5) from the green implementation team for carrying out the greenness assessment. These multiple sources of evidence helped in interpretation and triangulation of results to develop converging lines of inquiry, which remains one of the primary evaluation criteria of conducting case study research.

5. Methodology - Assessing Systemic Greenness of the Case Company

Application of graph theoretic approach (GTA) to quantify the degree of systemic greenness (DSG) of a supply chain is being demonstrated using the data from the case organization described above. Important reasons for utilising GTA to conduct systemic greenness assessment are as follows: the technique enables visual analysis of a complex system and makes it simpler to analyse at systemic level, graphs developed help in understanding the whole system with clear-cut identification of sub-system and components, and finally it is capable of quantifying the outcomes by developing a single numerical index. The utility of the DSG index lies in identifying the sub-practices (sub-factors) and the respective practice (factor) from the proposed framework that needs to be improved for further enhancing the greenness of its supply chain. Through this assessment, the extent of implementation of different practices under different higher order categories is also revealed. Scenario analysis is also performed to benchmark the DSG outcome of the assessed unit.

Over the recent years, GTA has been widely used in various fields. Grover et al. (2004) developed a mathematical model for evaluation of factors responsible in TQM environment, Singh and Agrawal (2008) integrated a comprehensive manufacturing system to attain system-wide optimization, Anand et al., (2013) assessed organization readiness for implementing lean thinking, Aravind Raj et al. (2013) computed the dependencies among the individual agile attributes and subsequently modelled the entire agile system, Attri et al. (2014) found the intensity of the barriers of implementation of total productive maintenance, and Mishra (2014) developed an integrated system model of world-class maintenance system using graph theory and matrix algebra to quantify the gap between existing maintenance systems priorities and their perceptions of organizations performance. At the interface of GTA and GrSCM, Muduli and Barve (2013) identified the behavioral factors present in GrSCM environment of Indian mining industries and found their effect on its implementation through GTA and matrix approach. Muduli et al. (2013) focussed on the mining industry by identifying factors and sub-factors hindering GrSCM implementation and used GTA to quantify the adverse impact of these barriers on GrSCM implementation.

Considering the wide applications as well as ability to provide a systemic assessment, GTA was considered highly appropriate. To capture the complexities of the interactions between the sub-factors of the system, "digraphs" showing the directional relationships are constructed between sub-practices and also for the higher order practices. A 5-point Likert scale has been used to obtain the degree of interaction (**Appendix 1**) and Saaty (1-9) scale (Saaty, 1980) has been used for capturing the degree of inheritance (**Appendix 2**) between the practices and sub-practices.

The mathematical model developed using GTA accounts for (a) the contribution of higher order practices (i.e. the inheritance), and (b) the extent of dependence among other higher order practices (i.e., their interactions). The measurement of the degree of implementation is referred to as “inheritances” and degree of relationship or interdependencies of sub-practices is referred to as “interactions”. All these aspects are derived from the digraphs and captured in a matrix. The inheritance values are filled in the diagonal elements of the matrix and the interaction values are filled in the off-diagonal elements of the matrix. With this data on the degree of inheritance and interaction for higher order practices and sub-practices, the systemic greenness of the unit of analysis is calculated (more details on the mathematical aspects of GTA are available in Grover et al. (2004) and Grover et al. (2006)).

This study adopts the GTA Procedure followed by Anand and Kodali (2010), but for a different utility (i.e. for assessing systemic greenness). Algorithm comprises of five stages namely, development of digraphs (a five-step approach), matrix representation of digraphs for deriving Variable Permanent Matrix (VPM), quantification of B_i's and b_{xy}'s of the matrix constructed, evaluation of the VPM-B matrix, and finally the calculation of DSG for best-case and worst-case scenarios. A detailed demonstration of the procedure adopted in this study is presented below.

5.1. Stage 1 - Development of Digraphs

Step 1: Specify clearly in detail the problem that needs to be addressed. In this study, the problem is to assess the DSG attained by an organization which is attempting to reduce its carbon content through the implementation of various GBS initiatives.

Step 2: Identify the practices and sub-practices that influence the problem faced. Represent the higher order practices category as B^i's, where 'i' varies from 1 to 'n' and 'n' is the total number of higher order practices, which is eight in this study (as shown in **Table 5**).

Step 3: Represent the sub-practices within each higher order practice 'i' as B_j^i's where 'j' varies from 1 to 'm' and 'm' is the total number of sub-practices within a higher order practice. **Table 5** indicates sub-practices in the current study with notations.

Step 4: After identifying the practices and sub-practices, understand the logical interactions between them using a digraph. Nodes of the digraph capture the inheritance of higher order practices as B^i and inheritance of sub-practices within a higher order practice as B_j^i. The edges of digraph represent the interactions between the higher order practices as b_{xy} and between the sub-practices within a higher order practice as b_{xy}^i. Based on the literature, unidirectional, bidirectional or no interactions were considered for both higher order practices and sub-practices. **Figure 2** shows the digraph capturing the inheritances and interaction between various higher order practices (B^1 to B^8).

Step 5: Similarly, digraphs were constructed for sub-practices under each higher order practice (as shown from **Figures 3 (a-h)**.

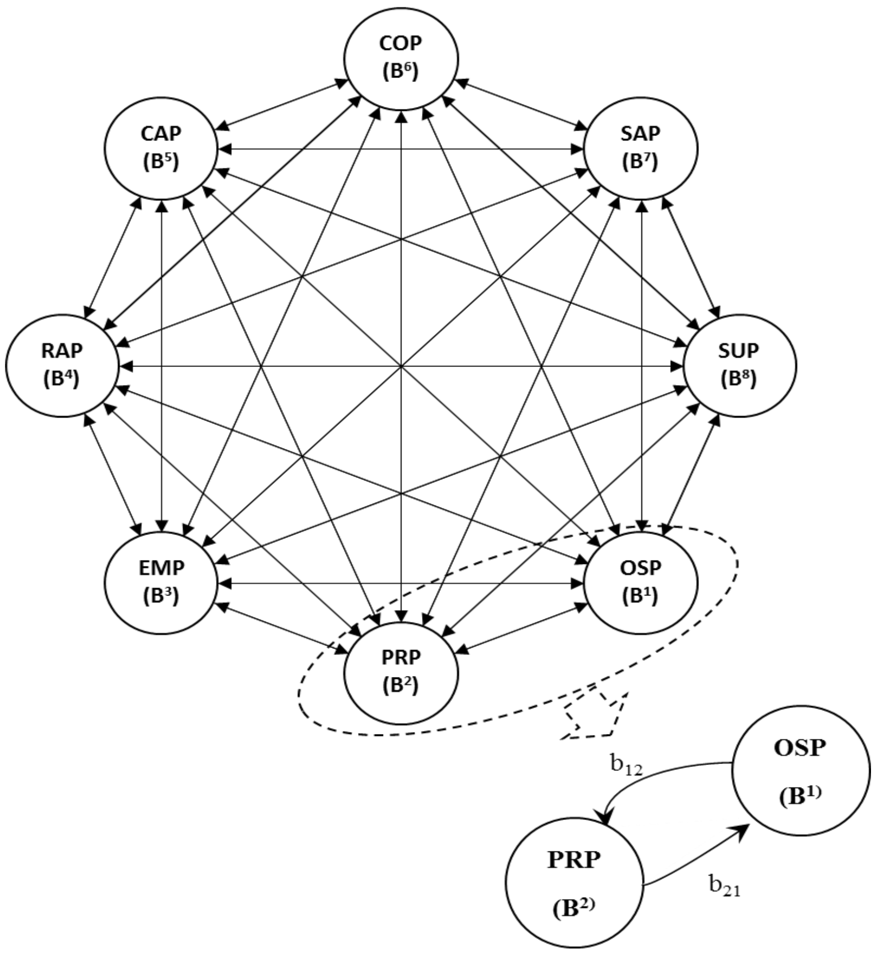


Figure 2: Digraph capturing the inheritance and interdependencies between the higher order practices *(B^i's).*

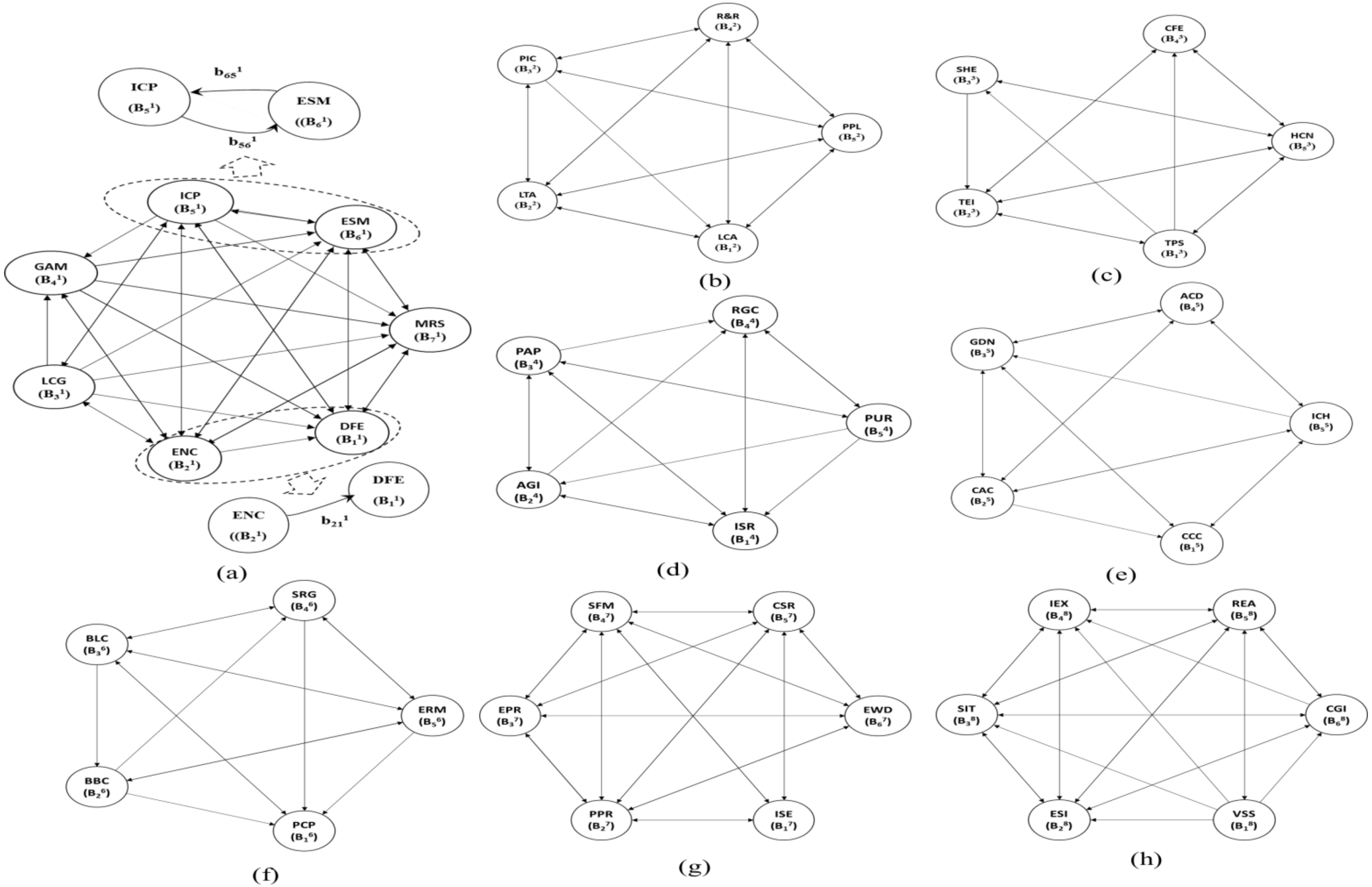


Figure 3: Digraph capturing the inheritance and interaction between the sub-practices within the higher order practice (a) Operational Strategy Practices (OSP); (b) Process Practices (PRP); (c) Employee Practices (EMP); (d) Regulatory Associated Practices (RAP); (e) Customer Associated Practices (CAP); (f) Competition Associated Practices (COP); (g) Stakeholder Associated Practices (SAP); (h) Supplier Associated Practices (SUP).

5.2. Stage 2 - Matrix Representation of Digraphs for Derivation of Variable Permanent Matrix (VPM)

VPM at the system level is represented in the form of a matrix VPM-B. The actual VPM-B for our problem, derived based on the digraph represented in **Figure 2** is shown in equation (1).

$$VPM-B = \begin{matrix} B^1 & b_{12} & b_{13} & b_{14} & b_{15} & b_{16} & b_{17} & b_{18} \\ b_{21} & B^2 & b_{23} & b_{24} & b_{25} & b_{26} & b_{27} & b_{28} \\ b_{31} & b_{32} & B^3 & b_{34} & b_{35} & b_{36} & b_{37} & b_{38} \\ b_{41} & b_{42} & b_{43} & B^4 & b_{45} & b_{46} & b_{47} & b_{48} \\ b_{51} & b_{52} & b_{53} & b_{54} & B^5 & b_{56} & b_{57} & b_{58} \\ b_{61} & b_{62} & b_{63} & b_{64} & b_{65} & B^6 & b_{67} & b_{68} \\ b_{71} & b_{72} & b_{73} & b_{74} & b_{75} & b_{76} & B^7 & b_{78} \\ b_{81} & b_{82} & b_{83} & b_{84} & b_{85} & b_{86} & b_{87} & B^8 \end{matrix} \quad \text{--- (1)}$$

The nodes in the digraph represented as B^1 to B^8 occupy the diagonal position in the matrix VPM-B, while the remaining off-diagonal positions are filled up based on the interaction between the practices, which is represented by a direct arrow in **Figure 2**. If an arrow is not present between the practices, the value corresponding to that relationship in matrix VPM-B is assigned as '0'. The purpose of VPM-B is to capture the extent of implementation of green practices by incorporating the degree of interactions between different practices and the degree of inheritances represented by B^i's (i.e. each higher order practice contribution) in a mathematical form.

5.3. Stage 3 - Quantification of B^i's and b_{xy}'s of the Matrix for the Given Problem

The permanent equation of matrix VPM-B also named as 'per B' is multinomial and is called as Variable Permanent Function (VPF-B). It is evaluated by standard procedures similar to that of the computation of determinant for the matrix VPM-B but with all signs positive in the formulae. The 'per B' value obtained would represent systemic greenness attained. The procedure to obtain these values for elements of matrix VPM-B is explained below.

Compute the inheritance values B^i's and the interaction values b_{xy}'s to develop the VPM-B matrix. The VPM for each sub-system is represented as VPM-B_{SSi}, where 'i' varies from 1 to 8. If there is no directed arrow from one node to another in the digraph, then a value of '0' is assigned. For instance, VPM-B_{SS2} (for the second higher order practice 'PRP') will be represented as:

$$VPM - B_{SS2} = \begin{matrix} B_1^2 & b_{12}^2 & 0 & b_{14}^2 & b_{15}^2 \\ b_{21}^2 & B_2^2 & b_{23}^2 & b_{24}^2 & b_{25}^2 \\ b_{31}^2 & b_{32}^2 & B_3^2 & b_{34}^2 & b_{35}^2 \\ b_{41}^2 & b_{42}^2 & b_{43}^2 & B_4^2 & b_{45}^2 \\ b_{51}^2 & b_{52}^2 & b_{53}^2 & b_{54}^2 & B_5^2 \end{matrix} . \quad \text{--- (2)}$$

From these matrices, the permanent for each of the sub-systems are calculated. These values were obtained by asking the following questions to the green implementation team of the case organization:

- What is the understanding about different sub-practices classified under respective higher order practice?
- How effectively have they implemented the sub-practices and in turn the higher order practices?
- How one implemented practice or sub-practice influenced other in their GBS transformation?

Answers in the form of ratings were obtained based on the GBS team's experience and knowledge of implementation. Updated VPM-B_{SS2} matrix with all the values filled in for both the inheritance and interaction between the sub-practices is shown in matrix equation 3.

$$VPM{-}B_{SS2} = \begin{matrix} 6 & 4 & 0 & 4 & 4 \\ 4 & 8 & 3 & 4 & 3 \\ 3 & 4 & 7 & 3 & 3 \\ 3 & 4 & 3 & 7 & 4 \\ 4 & 4 & 3 & 3 & 5 \end{matrix} \quad \text{--- (3)}$$

From the derived variable permanent matrices, VPM-B_{SSj} where 'j' varies from 1 to 5, the permanent of the matrices is calculated, which are represented as Per (B_{SSj}). The purpose of this permanent is to quantify the inheritances and interactions of each of the sub-practices within a higher order practice. It can be clearly observed that if large number of practices is considered, the permanent equation tends to become large resulting in computational complexity. A sample permanent value for VPM-B_{SS2} representing the DSG for 'PRP' is shown below:

$$\text{Per } (B_{SS2}) = 130284$$

The obtained values were expressed in logarithmic terms as $\log_{10}$ (130284), which is 5.115. Logarithmic transformation was applied for easy interpretation and comparison as permanent values of systems and sub-systems were widely varying, making the final comparison difficult. In a similar manner, the permanent and their logarithmic values for the remaining subsystem matrices are shown in **Table 8**. These permanents of sub-systems will be filled as diagonal elements in matrix equation 1 to compute the permanent of higher order practices which in turn represents the DSG index for the supply chain of the assessed unit.

Table 8: Permanent values for best-case situation and worst-case situations

System / Sub-system	Current value (Case Organization)	log_{10} (Current value) (Case Organization)	Highly maximum value (Theoretical best-case situation)	log_{10} (Highly maximum value) (Theoretical best-case situation)	Maximum value (Practical best-case situation)	log_{10} (Maximum value) (Practical best-case situation)	Minimum value (Practical worst-case situation)	log_{10} (Minimum value) (Practical worst-case situation)	Highly minimum value (Theoretical worst-case situation)	log_{10} (Highly minimum value) (Theoretical worst-case situation)
Per B_{SS1} (OSP)	23052168	7.363	271000000	8.433	49135977	7.6914	1932841	6.286	1224	3.088
Per B_{SS2} (PRP)	130284	5.115	700824	5.846	270126	5.431	23654	4.374	96	1.982
Per B_{SS3} (EMP)	65295	4.815	345774	5.539	148671	5.172	4591	3.661	34	1.531
Per B_{SS4} (RAP)	47792	4.679	402024	5.604	133792	5.126	3784	3.577	48	1.681
Per B_{SS5} (CAP)	60843	4.784	428374	5.632	180285	5.256	9661	3.985	50	1.699
Per B_{SS6} (COP)	8652	3.937	314924	5.498	97566	4.989	886	2.947	32	1.505
Per B_{SS7} (SAP)	1195056	6.077	14018016	7.147	4274076	6.631	231596	5.365	336	2.526
Per B_{SS8} (SUP)	377272	5.577	9267816	6.967	1730233	6.238	25769	4.411	192	2.283
Per B (DSG)	**$2.22 \text{ X } 10^{42}$**	**42.347**	**$4.63 \text{ X } 10^{50}$**	**50.67**	**$3.43 \text{ X } 10^{46}$**	**46.536**	**$4.06 \text{ x } 10^{34}$**	**34.61**	**$1.99 \text{ x } 10^{16}$**	**16.3**

5.4. Stage 4 - Evaluating the VPM-B Matrix

To evaluate the value of VPM-B at the system level (i.e. matrix equation 1), diagonal and off-diagonal values are needed. Diagonal values are filled with permanents of sub-systems. The values of off-diagonal elements (b_{xy}'s) for matrix 1 can be obtained based on the degree of interactions among the higher order practices (B_i's). As mentioned earlier, the relationship between various practices can be captured based on the past experience and by identifying the level of integration, association, interrelationships, and interdependence among the practices based on direct observation. The values for these off-diagonal matrices can be entered after adequate discussion by the team of evaluators. The complete VPM-B matrix for higher order practices at the assessed unit is as shown below:

$VPM-B=$

Main factor	OSP	PRP	EMP	RAP	CAP	COP	SAP	SUP
OSP	23052168	5	3	5	3	3	4	3
PRP	4	130284	4	4	3	3	4	3
EMP	2	4	65295	2	3	2	3	3
RAP	5	4	3	47792	3	4	3	2
CAP	3	3	3	3	60843	4	3	2
COP	4	3	2	3	3	8652	4	4
SAP	4	4	3	2	3	3	1195056	2
SUP	2	3	2	2	2	3	2	377272

--- (4)

Value of the permanent function for the system level matrix (i.e. matrix equation 4) is calculated. Per (B) value obtained indicates the systemic greenness by incorporating the total contribution of all the practices and sub-practices. In the above case, the Per (B) of matrix equation 4 is **2.22×10^{42},** with corresponding logarithmic value as **42.347**. This represents the DSG index for the assessed unit.

However, if we benchmark this value with other organization's supply chain which is known for its greenness level or an organization's supply chain that have not implemented GBS, it is possible to compare and analyze where the results of the case organization stand in the continuum. The DSG index gains greater information and potential for interpretation while assessing it in comparison to best-case and worst-case scenarios. The next stage discusses the utility of the assessment model by comparing it with the best-case and worst-case scenario evaluations.

5.5. Stage 5 - Scenario Analysis of the DSG Assessment

Permanent of VPM-B (i.e., matrix equation 1) needs to be calculated for different case situations to understand the range within which the values of DSG vary. Practical best-case situation (in comparison to the case considered) can occur only if the organization under assessment has implemented all the sub-practices (sub-factors) that are grouped under various higher order practices (factors) to the fullest extent. The degree of implementation of green practices by an organization with a strong inclination towards environment will have a maximum value of 9 (i.e. the diagonal elements in each sub-system will be 9). At this situation, the DSG will be at its maximum as the inheritance of all the practices is at its best. In this case, the VPM for B_{SS2} will be re-written as shown in equation 5. Similarly, the VPM for other sub-systems are recomputed. These permanent values of B_{SS1} to B_{SS8} are filled in the diagonal elements of matrix equation 4 and DSG is recalculated for the practical best case.

$$VPM{-}B_{SS2} = \begin{matrix} 9 & 4 & 0 & 4 & 4 \\ 4 & 9 & 3 & 4 & 3 \\ 3 & 4 & 9 & 3 & 3 \\ 3 & 4 & 3 & 9 & 4 \\ 4 & 4 & 3 & 3 & 9 \end{matrix} \quad \text{--- (5)}$$

The theoretical best-case situation can be computed by considering both the degree of implementation of sub-practices and degree of relationship between sub-practices at its maximum (as represented in matrix equation 6).

$$VPM - B_{SS2} = \begin{matrix} 9 & 5 & 0 & 5 & 5 \\ 5 & 9 & 5 & 5 & 5 \\ 5 & 5 & 9 & 5 & 5 \\ 5 & 5 & 5 & 9 & 5 \\ 5 & 5 & 5 & 5 & 9 \end{matrix} \quad \text{--- (6)}$$

Similarly, practical worst-case situation can occur if an organization has not transformed itself into green or has failed in successfully implementing the sub-practices during the transformation. Such situations can be found in an organization that has just started the process of implementing GBS. In other words, the DSG will be at its worst, when the inheritance of all its practices is at its worst. In this case, the VPM for B_{SS2} will be re-written as shown in matrix equation 7.

$$VPM{-}B_{SS2} = \begin{matrix} 1 & 4 & 0 & 4 & 4 \\ 4 & 1 & 3 & 4 & 3 \\ 3 & 4 & 1 & 3 & 3 \\ 3 & 4 & 3 & 1 & 4 \\ 4 & 4 & 3 & 3 & 1 \end{matrix} \quad \text{--- (7)}$$

In the theoretical worst-case situation, an organization has not implemented any of the sub-practices and the relationship between sub-practices is also poor. Such a situation may exist in the organization, which is functioning in a traditional paradigm. Under such circumstances, minimum values for both the degree of implementation of sub-practices and degree of relationship between sub-practices will be considered and is represented as matrix equation 8.

$$VPM - B_{SS2} = \begin{matrix} 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{matrix} \quad \text{--- (8)}$$

The permanent values and DSG for all the transformed matrices of four different scenarios along with their log transformations are shown in **Table 8**.

6. Results and Discussion

DSG has been calculated for different scenarios to assist evaluators in assessing the status of DSG attained by an organization in comparison to different scenarios. Case company scored a DSG value of 42.347, whereas practical best-case scenario scored a DSG value of 46.536. Hypothetically, DSG of practical best case situation is assumed to be the systemic greenness attained in an organization which has pioneered implementing GBS. Thus, it can be found that the case organization has scope and potential for further improvement. By understanding the interrelationships/interdependencies discussed, the case organization can choose from the key green practices to improve the overall DSG in future. Implementation of the identified green practices can be achieved through implementation of sub-practices listed within them in the framework shown in **Table 5**. Processes of implementation of the sub-practices to improve DSG are not discussed here as many studies in literature (refer to section 2) have documented the procedure for implementation of different green practices. In addition, the focus of this study is only to develop an assessment methodology for evaluating the systemic greenness and not to discuss the implementation aspects of green practices.

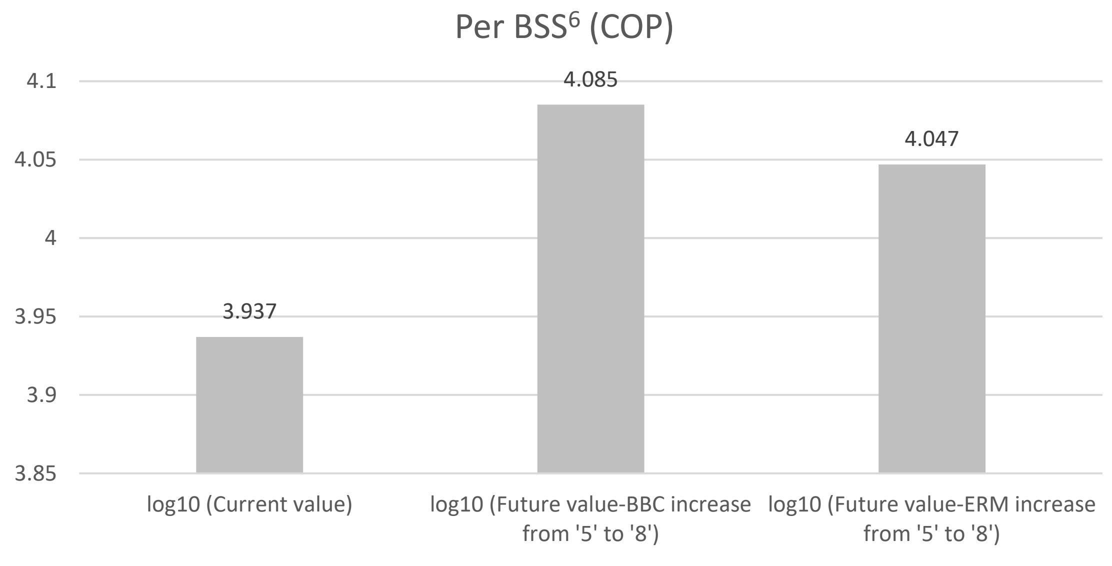
Comparing the DSG with different case scenarios would help the decision maker to quantify the greenness attained so far (difference between the case organization and theoretical worst case) and also the gap that the organization needs to fill in future (difference between the theoretical best case and the case organization) to achieve a more greener supply chain. **Table 9** assesses the GBS transformation journey of the case organization by comparing it with its theoretical best case and worst case scenarios. By comparing with theoretical worst case situation, the extent of implementation of individual higher order green practices is evaluated and ranked as “Past achievement ranking”. “Past achievement ranking” conveys where the organization has performed at its best so far in GBS transformation. By comparing with theoretical best case situation, the extent of implementation that is still feasible for individual higher order green practice in future is computed and based on it a “Future focus ranking” is created. “Future focus ranking” conveys where the organization can perform at its best in future (differences having equal values till second decimal point were given same ranks). This comparison reveals the green practices (and subsequently the sub-factors) in which the future emphasis of the case organization should be to further improve DSG. Focussing on these shortlisted green practices in future would increase the pro-activeness of the organization towards the attainment of green supply chain.

Table 9: GBS transformation assessment of case situation.

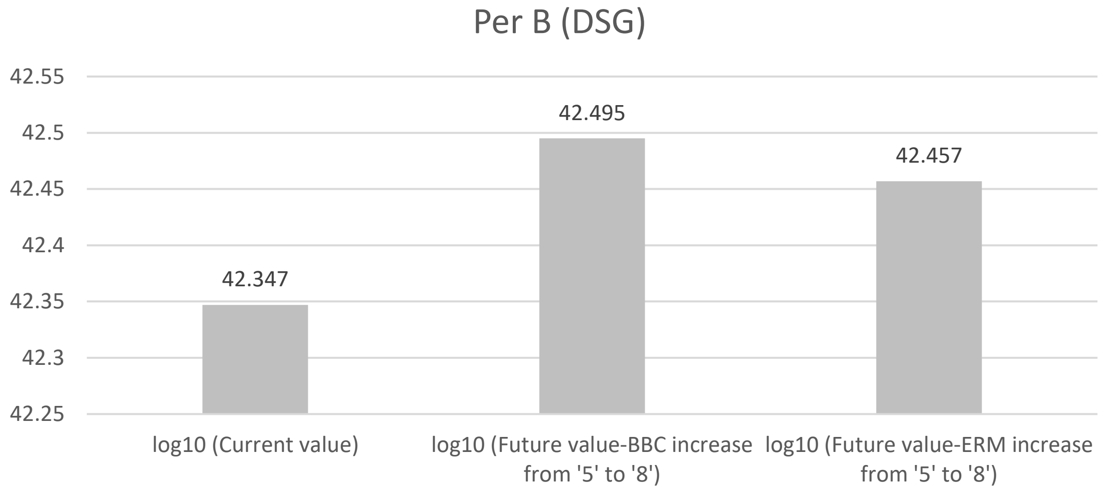
Sub-system	$\log_{10}$ (Case Organization - Theoretical worst case)	Past achievement ranking	$\log_{10}$ (Theoretical best case - Case Organization)	Future focus ranking
OSP	4.275	1	1.07	3
PRP	3.133	5	0.731	7
EMP	3.284	4	0.724	8
RAP	2.998	7	0.925	5
CAP	3.085	6	0.848	6
COP	2.432	8	1.561	1
SAP	3.551	2	1.07	3
SUP	3.294	3	1.39	2

COP which was earlier ranked “8” in past achievement ranking, was ranked “1” in the future focus ranking. Case organization focuses on those past initiatives where they did not perform as per their benchmark. However, poorly performed sub-factors in “Past achievement ranking” were not always given high priority in “Future focus ranking”. For example, RAP moved from “7” in “Past achievement ranking” to “5” in “Future focus ranking” and SUP moved from “3” in “Past achievement ranking” to “2” in “Future focus ranking”. Even though the organization achieved its maximum in ‘SUP’ implementation in past, it can still achieve huge benefits in future by further focusing on it. This is in alignment with the observation in practice where green practices have different proirities based on the impact they can have on the extent of future greenness achievement in an organization.

To demonstrate the ability of DSG to capture the future improvement in implementation, we increase the implementation rating of a sub-practice, say benchmark with a best in class organization (BBC) in COP, from ‘5’ to ‘8’. As expected, permanent value of COP and the overall DSG value increased (captured in **Figure 4**). In addition, to demonstrate the capability of the assessment model to capture the interactions between the green practices, we increase the implementation rating of another green practice (holding the original implementation rating of BBC i.e. ‘5’), say effective risk management (ERM) sub-practice in COP, from ‘5’ to ‘8’. As expected, permanent value of COP and the overall DSG value increased. But, the magnitude of increase in the case of ERM was lesser than in the case of BBC. This difference conveys that BBC has higher interaction with rest of the green practices in the framework than ERM. Therefore, along with inheritance, varying extent of interactions between the green practices in the framework has an impact on the DSG (captured in **Figure 4**).



(a)



(b)

Figure 4: Assessment model capturing the improvement in implementation along with the interactions (a) Permanent of COP (b) DSG.

Logarithmically transformed DSG values computed for different case scenarios were standardized to obtain a 0-1 continuum. Theoretical worst case and best case were transformed to standardized normal values of 0 and 1 in the rating continuum. For instance, the case organization DSG value was standardized as shown below:

$$Standardized\ value\ of\ case\ organization\ example = \frac{42.35 - 16.3}{50.67 - 16.3} = 0.76$$

Standardized values of other scenarios were evaluated using the same procedure. **Table 10** presents the standardized rating scale for DSG at different scenarios. **Table 11** provides a lookup table for categorization of organizations based on their final DSG values. Similar rating scales were established for all the higher order green practices to see where the case organization stands in those practices in the continuum (shown in **Table 12**). From the scale in **Table 12**, it can be inferred that the implementation level of higher order green practices in the case organization have crossed 0.6 out of 1. The normalized DSG value for each of the green practices can be treated as greenness index of the case organization in those practices (e.g.

0.81 is the greenness index for PRP). We present the actual process related practices implemented by the assessed unit in **Appendix 3 (a-d)**, which provides the background for the greenness index score computed.

In addition to the practical relevance of our study, as discussed above, we argue that our paper has important theoretical implications. First, this study is one of the first of its kind to capture systemic greenness by incorporating various stakeholders in the supply chain. Very few studies have divulged into stakeholder perspective while attaining greenness in its operations (e.g. Geng and Dai, 2018; Smith and Minutolo, 2014). Second, this study is one of first few to contribute towards the application of graph theory as a tool towards assessing greenness in an organization. There are two studies that have utilized graph theory towards sustainability (Kong et al., 2010; KEK et al., 2018). Kong et al. (2010) utilize graph theory to enhance urban bio-diversity in China by improving the green landscape of the region. Our paper differs from their research in two key aspects. First, we use a firm level approach while the former takes a region level approach. Second, we conduct a greenness assessment objective keeping in mind different stakeholders in the organization. The former does not assess greenness in the region, rather it intends to improve the overall urban bio-diversity by considering completely different set of factors. KEK et al (2018) compute the overall sustainability score in a manufacturing setup by using triple bottom line dimensions. Our paper differs in both the choice and clustering of criteria along the stakeholder dimensions (refer Table 5). In addition, there are very few articles that explicitly explain the importance of graph theory and its ability to capture the systemic aspect in operations and supply chain management literature (e.g. Rabbani et al., 2018; Mishra et al., 2013). Third, this paper has made significant contribution in advancing the literature of greenness assessment by developing the systemic greenness index through scenario analysis. Almost all the articles (except Figge and

Hahn, 2012) reviewed in the greenness assessment literature is devoid of any assessment index (Mohammad et al., 2019; Mangla et al., 2018). Fourth, we believe that the stakeholder greenness framework proposed is a valuable contribution to the theory of GBS literature (Weng et al., 2015). Finally, our research is an important addition to the literature focussing on tyre manufacturing as we demonstrate an assessment in this setting (Gupta et al., 2018; Jovanović et al., 2016).

Table 10: Standardized rating scale for DSG at different scenarios

Scenario	$\log_{10}$ (permanent value)	Normalized value
Theoretical worst case	16.3	0.0
Practical worst case	34.61	0.53
Case Organization	**42.35**	**0.76**
Practical best case	46.54	0.88
Theoretical best case	50.67	1.0

Table 11: Lookup table for categorization of organizations based on DSG values

Range of standardized DSG value	0 – 0.5 (Theoretical worst – Practical Worst)	0.5 – 0.9 (Practical Worst – Practical best)	0.9-1.0 (Practical best – Theoretical best)
Organization category	Traditional	Transforming	Perfection

Table 12: Standardized rating scale for all the higher order practices at different scenarios

Scenario	$\log_{10}$ (OSP_PV)	OSPNV	$\log_{10}$ (PRP_PV)	PRPNV	$\log_{10}$ (EMP_PV)	EMPNV	$\log_{10}$ (RAP_PV)	RAPNV	$\log_{10}$ (CAP_PV)	CAPNV	$\log_{10}$ (COP_PV)	COPNV	$\log_{10}$ (SAP_PV)	SAPNV	$\log_{10}$ (SUP_PV)	SUPNV
Theoretical worst case	3.088	0	1.98	0	1.53	0	1.68	0	1.70	0	1.51	0	2.53	0	2.28	0
Practical Worst case	6.286	0.59	4.374	0.62	3.662	0.53	3.578	0.48	3.985	0.58	2.947	0.36	5.365	0.61	4.411	0.45
Case Organization	**7.362**	**0.79**	**5.115**	**0.81**	**4.815**	**0.82**	**4.679**	**0.76**	**4.784**	**0.78**	**3.937**	**0.61**	**6.077**	**0.77**	**5.576**	**0.70**
Practical best case	7.691	0.86	5.431	0.89	5.172	0.91	5.126	0.88	5.256	0.90	4.989	0.87	6.631	0.89	6.238	0.84
Theoretical best case	8.433	1	5.85	1	5.54	1	5.60	1	5.63	1	5.50	1	7.15	1	6.97	1

7. Conclusion

Comprehensive list of green practices and performance measures were documented from literature and a holistic framework of green practices has been developed. GTA has been used to perform GBS assessment of a tyre manufacturing unit. Assessment methodology proposed based on GTA takes into account the interactions among various green practices/sub-practices, thus attempting to mimic the actual practice conditions. DSG has been proposed as a metric to compare and improve the greenness of an organizations' supply chain. A scale has been developed to assist the practitioners in categorizing and benchmarking the organization based on their greenness level.

Two research questions raised in the beginning of this study have been answered. To answer the first research question, a generic framework of practices for greenness assessment has been developed by reviewing the relevant literature. To address the second research question, application of GTA for assessing the GBS has been demonstrated by collecting data from tyre manufacturing case study. By incorporating the interrelationships and interdependencies, a systemic greenness index has been developed for the organization assessed. Assessment methodology developed is capable of ranking the eight higher order practices based on their past achievement in implementation and future potential to deliver the benefits. The ranking procedure rolls out a complete plan of action for the case organization to assist in its future GBS transformation strategy. From the results, it is clear that the assessed unit is currently doing well in process related practices and employee practices and the normalized score of the same are above 0.8. With respect to the closeness to the practical best case, the assessed unit has performed well in operations strategy practices. Surprisingly, competition practices are falling behind in normalized scores. The only plausible explanation remains that benefits accrued from competition practices must be low for the given manufacturing unit in the past and therefore negligible priority is given for the same which gets reflected in past achievement ranking of the unit. However, since the difference between current performance in that category and theoretical best case is large, it provides an opportunity for the unit to shift their focus towards the same in their future strategy.

Current study has its own limitations. Assessment technique proposed only assesses the systemic greenness attained by an organization at a particular point in time. Future studies can develop assessment methods to evaluate the systemic greenness over a period of time and study the associated dynamics. The framework proposed in this study is only based on green practices across the supply chain of an organization. In future, assessment methodology can be developed by incorporating objective values of green performance measures also as inputs. Greenness assessment in future research can be extended to capture the relationship between different green practices implementation and corresponding green performance measures improvement. Understanding the dynamics of this relationship will help in efficiently and effectively investing the resources and predicting the GBS outcome.

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Appendix

Appendix 1: 5-point Likert scale to capture the degree of interaction

Assigned value	Quantitative measure of interaction	Explanation
5	Very strong	When the practice (or sub-practice) is very strongly interacting with another practice (or sub-practice)
4	Strong	When the practice (or sub-practice) is strongly interacting with another practice (or sub-practice)
3	Medium	When the practice (or sub-practice) is moderately interacting with another practice (or sub-practice)
2	Weak	When the practice (or sub-practice) is weakly interacting with another practice (or sub-practice)
1	Very weak	When the organization is aware of the sub-practice and it has When the practice (or sub-practice) is very weakly interacting with another practice (or sub-practice)

Appendix 2: Saaty scale to capture the degree of inheritance or implementation *(Adapted from Saaty, 1980)*

Assigned Value	Quantitative measure of inheritance	Explanation
1	Extremely low	When the organization is not aware of the sub-practice, and it has not been implemented
3	Low	When the organization is aware of the sub-practice, but it has not been implemented
5	Average	When the organization is aware of the sub-practice, but it has been only partially implemented
7	High	When the organization is aware of the sub-practice and it has been implemented properly with appropriate documented
9	Extremely high	When the organization is aware of the sub-practice and it has been implemented properly as a result of which excellent results have been achieved
2, 4, 6, 8	Represent the intermediate values	Used, when compromise is needed between the above described assigned values.

Appendix 3a: Recycle and reuse of the process scrap and product parts

S. No.	Description	Recycle and reuse
1	Compound	Use for making floor mats, reclaim rubber, toys, motor parts, oil seal, packing and cycle pedal
2	Defective tyres (cured) scraped and after life	Using for making crumb rubber and rubber sole
3	Trimming	Using for making crumb rubber
4	Green tyre	Using for making slipper and shoes
5	Tubes	Using for making reclaim rubber, rubber item and packing item
6	Bladder	Using for making sole of shoe /replacing of sole
7	Fabric	Making shoe, fish net and repair Shoes
8	Steel wire	For nets/netting

Appendix 3b: Reduction in toxic or hazardous substances in manufacturing process

S. No.	Initiative	Description
1	Reduction in lube and Naptha consumption	• Multi Lube is used in place of Mono Lube to reduce the consumption of lube used for green tyre painting • Usage of automated spray guns to ensure correct quantity consumption without wastage • Cross-functional teams working in projects on reduction of naptha usage in different process areas • Naphtha based paints are replaced with water based paints for GreenTyre painting
2	Mica filled to unfilled lube	• Mica filled lubes to unfilled lubes usage in green tyre painting eliminating Mica content in lubes used
3	Naphthenic oil used as lubricant mixer	• Naphthenic oil used in place of Aromatic – as lubricating oil , in dust seal area of the mixing chamber
4	Reduction in spillage of chemicals	• By using pre-weighed LDPE/EVA bag packing, used as such while mixing

Appendix 3c: Reduction in toxic or hazardous substances in product

S. No.	Initiative	Description
1	Reducing polycyclic content	• Replacement of Aromatic oil (high levels of polycyclic content) with low PCA poly cyclic aromaticity) oil and naphthenic oil in progress
2	Carbon black replacement	• Partial replacement of carbon black with silica by 2 -12 phr in passenger car tyres (PCR) and truck & bus tyres (TBR) formulations • High silica content compounds in current and development compounds being used
3	Eliminating oil usage	• Introducing no oil formulations in TBR compounds, eliminating the oil usage in the rubber compound
4	Recycled rubber usage	• Usage of Recycled or reprocessed rubbers such as Crumb rubber, super fine reclaim, Butyl reclaim and SMR in place of virgin rubber (around 25 % of total consumption of virgin rubber used) • 2% of petroleum based synthetic rubbers is used in total consumption of rubber used

Appendix 3d: Reduction in environmental impact

Product type	Initiative	Description
Passenger car tyres (PCR)	Reducing polycyclic content	• Replacement of Aromatic oil (high levels of polycyclic content) with low PCA poly cyclic aromaticity) oil and naphthenic oil in progress
2	Carbon black replacement	• Partial replacement of carbon black with silica by 2 -12 phr in passenger car tyres (PCR) and truck & bus tyres (TBR) formulations • High silica content compounds in current and development compounds being used
3	Eliminating oil usage	• Introducing no oil formulations in TBR compounds, eliminating the oil usage in the rubber compound
4	Recycled rubber usage	• Usage of Recycled or reprocessed rubbers such as Crumb rubber, super fine reclaim, Butyl reclaim and SMR in place of virgin rubber (around 25 % of total consumption of virgin rubber used) • 2% of petroleum based synthetic rubbers is used in total consumption of rubber used

Assessment of Systemic Greenness: A Case Study of Tyre Manufacturing Unit

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