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Sustainable Operations in India

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Finally, we like to thank our prospective readers of this book for reading and using this book. We hope that the readers will find this book useful while undergoing sustainable operations in manufacturing and understanding the insights from an emerging economy perspective.

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Chapter 1
Introduction: Sustainable Operations in India

Sirish Kumar Gouda, Ayon Chakraborty and M. S. Gajanand

Abstract This introductory chapter will serve the purpose of providing a brief history of sustainable operations in general and sustainable operations in India in particular. We also discuss about the various modules and chapters which are a part of this book.

Keywords Sustainable operations · Triple bottom line · Corporate social responsibility

1.1 Overview

With the increasing scarcity of resources across the world and growing emphasis on environment, equity, and other social causes, sustainability has become an essential aspect in all major fields such as engineering, healthcare, tourism, and business management. Over the last few years, firms have begun to place increased emphasis on green and community-oriented practices because of the pressure from various stakeholders, including the government, the public, and the shareholders. Also, an increasing interdependence of firms in the global arena and the globalized nature of today's supply chains has made sustainable development an important field of study both in the emerging and the developed markets.

In the year 1987, Brundtland Commission of United Nations[1] defined sustainable development as "*the development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*" The need for research in the area of sustainability is therefore born out of common interests in environmental and social needs of the society and competitive advantage of firms.

[1]http://www.un-documents.net/our-common-future.pdf.

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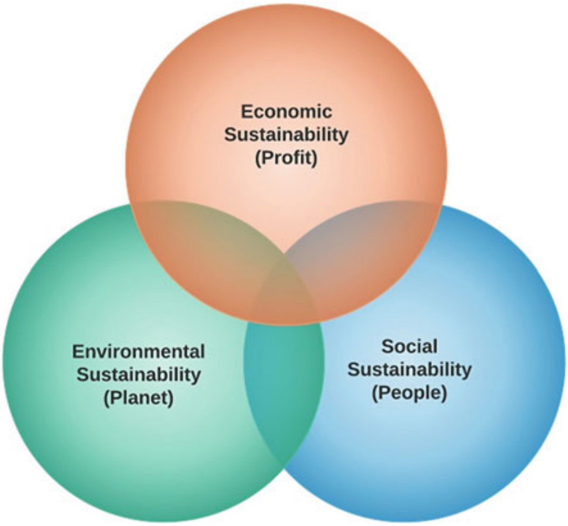

Fig. 1.1 Triple bottom line. Adapted from Carter, Kale, and Grimm (2000)

In a seminal work, Elkington (1998) proposed that firms will be sustainable when they give equal attention to what he calls the triple bottom line*: people, profit, and the planet*. Sustainability is at the heart of all these three elements as illustrated in Fig. 1.1. Firms should be able to have a healthy balance sheet in order to remain in business and at the same time be able to cater to the needs of the society and environment while providing employment and services to the deserving. Organizations and the people who constitute it should respect the environment in which they live and follow practices that have the least negative impact on their surroundings. Sustainable operations management therefore constitutes all those activities and decisions pertaining to the sourcing, production, and distribution of goods and services of firm with an emphasis on the economic, environmental, and social impact of such actions. Kleindorfer, Singhal, and Wassenhove (2005) defined sustainable operations management as "*set of skills and concepts that allow a company to structure and manage its business processes to obtain competitive returns on its capital assets without sacrificing the legitimate needs of internal and external stakeholders and with due regard for the impact of its operations on people and the environment*" (p. 489).

Historically, environmental and social sustainability practices were viewed by firms as an obligation primarily to meet the governmental regulations and other constraints imposed on them. Over the years, however, firms have moved from an "external constraint perspective" to a "component perspective" (Angell & Klassen, 1999), i.e., they have started to integrate various environmental and social sustainability management practices into their operations strategy as they began to realize the untapped potential from these practices in achieving sustained competitive advantage (Porter & der Linde, 1995). These sustainability practices are now aligned with structural and infrastructural operational decisions of the firm so as to derive benefits either in the form of cost reduction through reduced

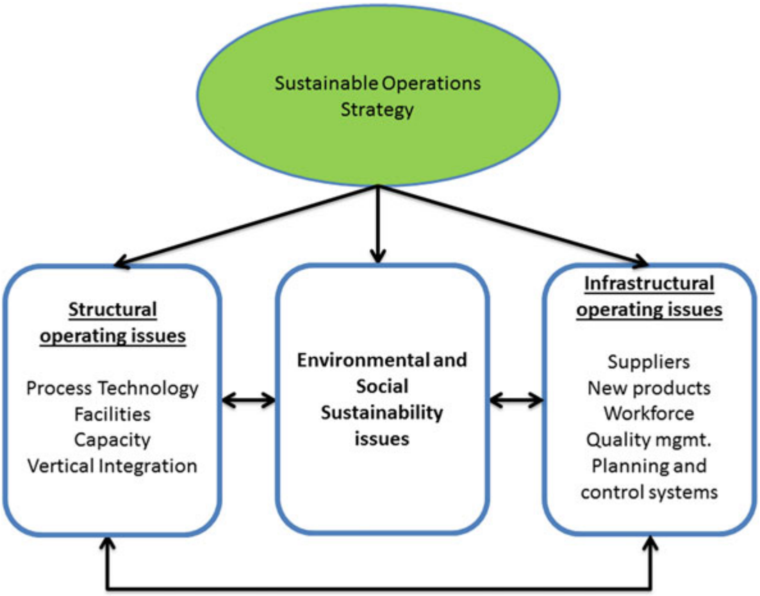

Fig. 1.2 Sustainable operations strategy

inefficiencies or from increased brand value and reputation. Adapted from Angell and Klassen (1999), Fig. 1.2 explains the sustainable operations strategy implemented by many firms across the world.

As a result, firms across the world today are investing in various environmental and social sustainability initiatives for reasons beyond mere compliance. Based on a recent survey by McKisney[2], the various reasons that firms invest in sustainability initiatives include increasing operational efficiency, cost reduction, corporate reputation, operational risk reduction, reaching new markets, employee retention and motivation, and increasing sales (volume and value). On the other hand, from an academic research point of view, the topics researched in the field of sustainable operations management fall under three main areas, viz., Green product and process development, Lean and Green Operations, and Remanufacturing and closed-loop supply chains (Kleindorfer et al., 2005). From the above, it not only appears that perceptions of practitioners and researcher interests in sustainable operations are aligned but also seems that sustainability makes business sense.

[2]https://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/the-business-of-sustainability-mckinsey-global-survey-results.

1.2 A Brief History of Sustainable Operations

In late eighteenth century, an English scholar, Thomas Malthus, commented on the catastrophic effects of world's population growth. He says,

"*The power of population is so superior to the power of the earth to produce subsistence for man that premature death must in some shape or other visit the human race. The vices of mankind are active and able ministers of depopulation… Should success be still incomplete, gigantic inevitable famine stalks in the rear, and with one mighty blow levels the population with the food of the world.*" (Malthus, 1798, p. 44). Even though the world has not seen the level of growth of population that Malthus had predicted, the resource crunch is evidently felt across the world. To meet the exponentially growing demand for products and services, firms have taken to mass production and resource consumption leading to severe negative ecological and social externalities.

While there were historians and environmentalists over the years who raised their voices about the increasing environmental and social degradation, it took the world to come to terms with the impending danger only in the second half of the twentieth century. In the year 1970, in US, Environmental Protection Agency (EPA)[3] was formed as an umbrella body to facilitate research, formulate, and implement standards and regulations and monitor the adherence of firms to these regulations. Following this, a small group of activists from Canada created an NGO called *Greenpeace*, protesting about the underground nuclear testing by USA. These historical events have a great significance as they started the environmental movement in the western world which was later adopted in various parts of the world.

Environmental protection first came into light in India during Mrs. Indira Gandhi's first term as a prime minister of India. She was instrumental in creating awareness about environmental protection and also responsible for the creation of Ministry of Environment and Forests in 1985[4]. In one of her books she writes,

"*For instance, unless we are in a position to provide employment and purchasing power for the daily necessities of the tribal people and those who live in or around our jungles, we cannot prevent them from combing the forests for food and livelihood, from poaching and from despoiling the vegetation. When they themselves feel deprived, how can we urge preservation of animals? How can we speak to those who live in villages and in slums about keeping the oceans, the rivers and the air* clean *when their own lives are contaminated at the source?*" (Gandhi, 1992, p. 15). The excerpt above illustrates the emphasis on both environmental and social sustainability for the betterment of the society.

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[3]https://www.epa.gov/history.

[4]In 2014, in the wake of the impending threat of climate change, this ministry's name was changed to Ministry of Environment, Forest and Climate Change.

However, it was the Bhopal gas tragedy in 1984[5] that made environment a serious agenda point for government to take action on and this led to the creation of Environmental Protection Act 1986. Several regulations protecting the environment such as the Water Act 1974, Air (Prevention and Control of Pollution) Act 1981, Batteries (Management and Handling) Rules, 2001, Bharat Stage regulations for automobile emissions have been proposed and implemented under the aegis and leadership of this ministry. Indian government also actively participated in various international climate change summits in the past several years and has proactively voiced its concerns and has taken steps to formulate regulations promoting environmental and social sustainability.

Over the last few years, firms have also focused specifically on Corporate Social Responsibility (CSR) and have internalized it into their business strategy. Major firms in India such as Infosys, Wipro, Tata Motors, and Reliance have been taking up various environmental and social practices and publishing yearly CSR reports. To improve this behavior by top Indian firms, the Government of India introduced CSR Rules under the Companies Act, 2013 which mandates firms (private or public limited) to invest a minimum of 2% of its average net profit for the next 3 years.[6] While there are still gaps in the enforcement of this rule, the corpus of CSR funds has increased tremendously over the years leading to firms investing in the social and environmental betterment of the society at large.

While research and media reports on sustainable operations indicate dominance by firms in the west, emerging economies such as India and China are not far behind. Multinational firms such as DuPont, Bosch, and PepsiCo have also tailored their sustainability strategies to implement various initiatives in India. For example, textile industry (especially the dyeing process) is one of the industries with a large carbon footprint with heavy water usage. DuPont has worked closely with various firms in the industry to develop a bio-scouring enzyme[7] that reduces the overall water consumption drastically. While Bosch India is involved in a lot of environmental protection projects, they have also initiated various social sustainability projects such as the BRIDGE.[8] This project focuses on school dropouts and provides them with short-term vocational training increasing their readiness for industrial jobs. This also helps the firms as they are constantly in the need of skilled labor for their plants. Such phenomenon is not specific to multinational firms with a base outside India. Indian firms such as Tata Motors, Hindalco, TAFE, etc. have also invested heavily on promoting environmental and social sustainability

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[5]Bhopal Gas tragedy, considered as one of the world's largest and deadliest industrial disasters, took the lives of thousands of people as a result of a gas leak in Union Carbide India Limited plant in Bhopal.

[6]This rule is limited to firms which have a turnover of Rs. 1000 crore, or net profit of 5 crore or a net worth of 500 crore during any financial year.

[7]http://www.dupont.co.in/corporate-functions/our-approach/global-challenges/shunya/articles/eco-scour-solutions-india.html.

[8]http://www.boschindia.com/en/in/sustainability_innovation_5/csr/projects/bosch_india_csr_bridge_1.html.

practices. For instance, Hindalco places a lot of emphasis on recycling of aluminum and copper as it reduces the environmental impact by energy reduction. Their copper smelting plant at Dahej, Gujarat undertakes copper scrap recycling and recovery from scrap collected from customers as well as the market.[9] TANDA[10] is a tribal upliftment program initiated by Tata Motors and Tata Institute of Social Sciences (TISS) which helps de-notified tribal population to become self-reliant by creating self-help groups and making them aware of the various rights.

These are a few examples that indicate that the firms are investing to promote sustainable practices. The various chapters in this book discuss about these practices and policy matters in detail and provide directions for future research in this rich and exciting area.

1.3 Organization of the Book

This edited volume is made up of 10 chapters including this Introduction chapter. Each of the chapters is an independent research paper in the field of sustainable operations with a focus on India. We have classified the various chapters into parts based on the broad theme on which they focus.

The first part (Chaps. 2, 3, and 4) is on Sustainable Manufacturing Management practices prevalent in India. Chapter 2 in Part I discusses about the drivers of sustainable practices in manufacturing firms. With the help of a case study of a prominent cement manufacturing firm in India, they show that organizational practices and culture play a major role in driving firms come up with innovative and economical solutions for implementing sustainability initiatives to meet regulatory standards. Along the similar lines, Chap. 3 classifies drivers of various green initiatives taken by firms into four categories that could be internally or externally driven. With examples from secondary sources in India and China, this study compares and contrasts the various environmental sustainability practices firms invest in these two countries. Chapter 4 discusses about the intellectual property policies in the manufacturing sector in India with a special focus on sustainability practices. This chapter delineates the various strategies firms can implement with respect to IP policies and rights to achieve sustainable manufacturing in the wake of various international treaties such as the Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement.

The second part is on Sustainable Process Management (Chaps. 5 and 6). Chapter 5 discusses about the important aspect of sustainable maintenance. Following the first module on sustainable manufacturing, this chapter discusses various elements of sustainable maintenance and proposes frameworks which can guide firms in various industries. Chapter 6 proposes connections between lean management and sustainability in a food processing SME. The authors use

[9] http://www.hindalco.com/sustainability/sustainable-operations.

[10] http://www.tiss.edu/view/11/projects/tanda/.

Interpretive Structural Modeling (ISM) approach to develop the structural model and MICMAC analysis to categorize the various factors.

The third part includes chapters on Sustainable Supply Chain Management (Chaps. 7, 8, 9, and 10). Chapter 7 discusses about importance of intermodal freight transportation in reducing the overall carbon footprint of shipping companies. The authors of this chapter use levelized cost analysis method to find the optimal road and rail usage with the help of data on the route between two Indian cities (Delhi and Mumbai). Chapter 8 provides an overview of the logistics sector in India and discusses the various growth factors and challenges this sector is facing. It also discusses about how policy decisions impact this sector and outline the various investment opportunities for both the regulatory bodies and firms in the industry. Chapter 9 discusses the influence of fuel consumed by the vehicles on the environment and the various factors that contribute to fuel consumption. It presents a mathematical model to evaluate alternative routes between nodes for routing a fleet of heterogeneous vehicles with the objective of minimizing the fuel consumption. Chapter 10 addresses the pertinent issue of closed-loop supply chain of lead acid batteries in India. The government of India proposed the Battery Management and Handling Rules (BMHR) in 2001 (with a minor revision in 2010) to promote a scientific and safe recovery of lead from used lead–acid batteries.

As discussed earlier, sustainability is a pressing issue for firms across the world. Firms in emerging economies such as India have started to invest in various sustainable initiatives either because of increased regulatory and stakeholder pressure and/or because of internal motivation to reduce costs or meet consumer demand for sustainable products and processes. This book is our effort to bring to the readers sustainable operational practices by Indian firms and policies related to them proposed by regulatory authorities. We hope this work inspires other researchers in the area of research and report further about sustainable operations in India.

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Part I
Sustainable Manufacturing Management

Chapter 2
Identifying Drivers of Sustainability Initiatives in Manufacturing Organizations—An Exploratory Study from the Indian Cement Industry

S. Kumaravel and Ayon Chakraborty

Abstract In the current business scenario, firms need to increasingly focus on environmental sustainability issues, as a result of stricter regulatory enforcements that lay emphasis on cleaner production, and also due to growing pressures from the stakeholders. This paper aims at understanding the organizational factors that contribute towards the successful implementation of sustainability initiatives in a process industry setup. A qualitative case study from a major cement manufacturing firm located in India helps us to identify the key drivers in the context of sustainability. The case findings reveal that organizational culture and practices followed lead to the emergence of innovative and economically viable solutions, which help in achieving the sustainability targets. These exploratory results obtained can be further analysed in the backdrop of other industries.

Keywords Operations strategy · Sustainable operations · Green manufacturing

2.1 Introduction

The concept of 'sustainability' in the business world involves inclusion of sustainable development goals, namely social equity, economic efficiency and environmental performance, into a company's operational practices (Labuschagne, Brent, & Van Erck, 2005). Organizations which compete globally are increasingly required to commit to and report on the overall sustainability performances of their operational initiatives. As it involves mutliple objectives of social, economic and environmental sustainability, some of them may be conflicting (Zhou, Cheng, & Hua, 2000). In the light of increasing importance to sustainability in business operations, there have been many streams of emerging research that include

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developing metrics and frameworks for measurement of sustainability across firms (Seuring & Muller, 2008; Krajnc & Glavic, 2005; Clift, 2003) and analytical optimization models to incorporate sustainability goals (Al-Sharrah, Elkamel, & Almanssoor, 2010).

This paper focuses on how organizational factors contribute towards the implementation of sustainability initiatives taken in a process industry setup, through a qualitative case study. The next section provides a brief literature review that explores the state of present research and the questions we try to address. Subsequently, we present an overview of the research methodology adopted for our study of a major cement manufacturing firm in India. Finally, we report our findings and the implications of this study to industry and academia.

2.2 Theoretical Background

Though the initial research on sustainability focused only on the technological aspects of the manufacturing process, for finding newer methods of economical and cleaner production, in the last two decades, there has been a growing academic interest in the sustainability theme amongst organizational theorists too (Wong, Lai, Shang, Lu, & Leung, 2012). The emergence of topics, such as green logistics (Lai & Wong, 2012; Murphy & Poist, 2000), sustainable operations (Gimenez, Sierra, & Rodon, 2012; Kemp et al. 1998; Kleindorfer, Singhal, & Wassenhove, 2005), and green supply chain management (Srivastava, 2007), stands testimony to this fact. The work of Sarkis, Zhu, and Lai (2011) provides a mapping of green supply chain management literature to nine broad organizational theories.

Hansen, Grosse-Dunker, and Reichwald (2009) provide a framework called the Sustainability Innovation Cube (SIC) by trying to link sustainability initiatives to innovation management. In their view, sustainability puts a normative demand on innovation to become more environmentally and socially benign and, at the same, provides a new source of innovations and competitive advantage.

A more recent literature review by Adams, Jeanrenaud, Bessant, Denyer, and Overy (2015) shows that research on Sustainability Oriented Innovation (SOI) is widely distributed, of variable quality, immature and skewed. Based on their study, they have developed a model that could classify SOI into three approaches: (1) Operational Optimization, (2) Organizational Transformation and (3) Systems Building.

However, the extant literature does not investigate the mechanism of how organizational factors, such as organizational culture, leadership pattern, team performance influence the implementation of innovative solutions for attaining the firm's sustainability goals. In this paper, we attempt to elucidate these organizational drivers that complement the emergence of sustainable solutions, through a qualitative case study, thereby providing an exploratory insight for future work.

2.2.1 The Cement Manufacturing Process[1]

The primary raw material for manufacturing cement is limestone (calcium carbonate—$CaCO_3$). Hence, most cement manufacturing plants are located in the vicinity of limestone deposits. The quarried material is reduced in size, by processing through a series of crushers. Normally, primary size reduction is accomplished by crusher, followed by secondary size reduction with a roller or hammer mill. In the next step, the raw materials are further reduced in size by grinding to produce ‘raw meal’.

The subsequent step involves the production of an intermediate called clinker, from the raw meal in large kilns. These kiln systems evaporate the inherent moisture in the raw meal by heating through the multistage suspension preheaters (called cyclone). Then, the process of calcination takes place, i.e. removal of carbon dioxide (CO_2) from $CaCO_3$, resulting in calcium oxide (CaO). Further, a series of chemical reactions convert the calcium oxides to silicates, at a very high temperature of about 2700 °F in the rotating furnace. This pyro-processing stage is the heart of the cement-making process. While many different fuels can be used for firing the kiln, coal is the primary fuel used since the 1970s. At the lower end of the kiln, the raw materials emerge as red-hot particles called clinker.

Clinker production is the most energy-intensive stage in cement production, accounting for over 60% of total industry energy use, and virtually all of the fuel use.

Once the clinker is formed in the rotary kiln, it is cooled rapidly. This fast quenching process is important to ensure the hardening properties and high strength of cement. After cooling, the nodules of clinker are ground with additives (such as gypsum, fly ash) to produce the required variant of cement. This process is called cement grinding. The two major variants used for construction purpose are Ordinary Portland Cement (OPC) and Portland Pozzolana Cement (PPC). These differ in their compositions and have varying applicability. The final stage involves packing and shipping of cement bags.

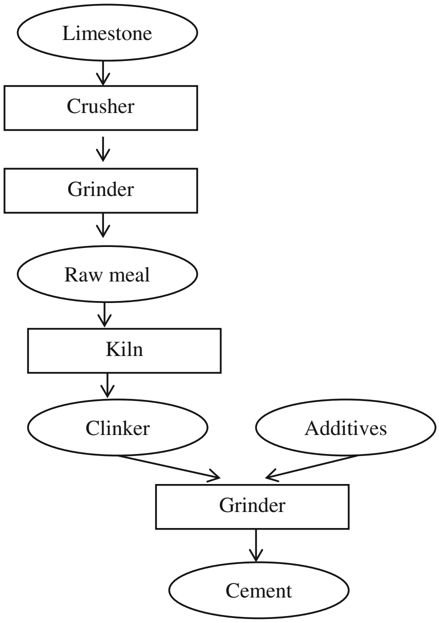
A simple schematic depicting the manufacturing process is shown in Fig. 2.1.

2.3 Research Methodology

Amongst the process industries, the cement manufacturing industry is classified as one of the 17 most polluting industries by the Central Pollution Control Board (CPCB) in India. Also, the cement industry is found to be the most energy-intensive of all manufacturing industries, as per the Manufacturing Energy Consumption

[1]Adapted from: https://www.energystar.gov/sites/default/files/tools/ENERGY%20STAR%20Guide%20for%20the%20Cement%20Industry%2027_08_2013_Rev%20js%20reformat%2011192014.pdf, Accessed on 30 May 2016.

Fig. 2.1 Cement manufacturing process schematic



Survey (MECS, 2010). Hence, our focus lay on understanding how an organization operating in such a polluting and power-thirsty industrial sector is able to achieve its sustainability targets.

Based on published data sources, we found that a firm has won the Energy Efficiency Award for the cement sector, instituted by the Bureau of Energy Efficiency, from the President of India. Henceforth, it shall be referred to as KBL Cements. The actual identity of the firm is concealed here, on request of non-disclosure in public domain, for competitive reasons. We found that KBL Cements is a pioneer in the cement manufacturing sector, with a great legacy. Our objective was to understand the underlying mechanism and organizational drivers, by which KBL was able to attain its sustainability target in terms of energy efficiency.

We adopted the interviewing technique to collect data for this study. Groves and Kahn (1979) describe an interview as a purposeful discussion between two or more people that can help gather valid and reliable data relevant to research objectives. Based on the initial discussion with the manufacturing unit head, we understood that there is an energy management task force, which is an eight-membered cross-functional team which specifically works towards energy efficiency initiatives. Table 2.1 shows the composition of the team, the designation and interview duration.

We took personal in-depth interviews, on the company premises, using a semi-structured questionnaire, with six out of eight members in the team. When we completed the sixth interview, we had almost reached a theoretical saturation of

Table 2.1 Interview respondent profiles

Team member	Designation	Department	Interview duration (min)
TM1 (Lead)	Assistant General Manager	Mechanical	68
TM2	Senior Manager	Production	31
TM3	Senior Manager	Electrical	39
TM4	Assistant Manager	Mechanical	38
TM5	Senior Engineer	Electrical	40
TM6	Engineer	Process	72
*TM7	Senior Manager	Instrumentation	–
*TM8	Senior Manager	Power plant	–

*The last two team members were not interviewed, as we attained theoretical saturation of data

data. The objective of the interview was to understand the individual's engagement with the energy management initiatives of KBL, the functioning of task force, their communication, mode of decision-making, problems faced in terms of sustainability and if any effective and innovative solutions emerged.

All interviews were audio recorded and transcribed. Summaries of the transcripts were produced and were verified by both, the interviewer and an additional researcher. This enabled multiple source triangulation (Denzin, 1978). To corroborate our findings, we also used the secondary data sources, such as documented minutes of meetings and audited annual financial reports.

2.4 Findings

2.4.1 Organization Background

The Dalmia Group of companies is a large industrial and diversified group with a chronicle of over seven decades in India. It was founded by Jai Dayal Dalmia in the year 1935. It is headquartered in New Delhi with cement, sugar, travel agency, magnesite, refractory, and electronic operations spread across the country. The group has an annual turnover of over USD 1 billion (*INR 7000 crores, assuming a conversion rate of 1 USD = 66 INR)*. A brief history of the company's significant milestones is presented in Table 2.2.

The Dalmia Bharat Group was incorporated as a public limited company in February 2006.[2] It comprises the following businesses:

- Dalmia Cement Bharat Limited (DCBL), which started operating in 1939, in the state of Tamil Nadu;

[2]http://economictimes.indiatimes.com/dalmia-bharat-ltd/infocompanyhistory/companyid-14789.cms, Accessed on 30 May 2016.

Table 2.2 Significant milestones of Dalmia group

Year	Events
1939	Dalmia Cement Unit was started. Installed 250 tonnes per day kiln to manufacture cement by semi-dry process. Machinery was then supplied by M/s Polysius, Germany, KRUPP
1949	Installed a 500 tonnes per day wet process kiln supplied by M/s F. L. S. Smidth, Denmark
1958	Magnesite operations commenced
1959	Expansion was undertaken with the installation of another 500 tonnes per day wet process Folax Kiln supplied by M/s F. L. S. Smidth, Denmark
1970	Govan travels acquired
1976	Developed specialty cement for railway sleepers
1981	First to install raw meal roller mill
1984	Developed specialty cement for oil wells
1986	Introduced polybags for cement packing
1989	The only company in South India getting assistance from World Bank (DANIDA, Denmark) to set up its Regional Training Centre
1992	Computerized quarry scheduling
1994	Entry into sugar business
2005	Brownfield expansion of cement capacity from 1.5 to 3.5 MT
2008–09	Integrated 3 sugar plants with total capacity of 22,500 TCD (tonnes of cane per day)
2009–10	Ariyalur unit, in Tamil Nadu commissioned (2.5 MT)
2010	Commissioned refractory plant at Katni Commissioned 27 MW captive thermal power plant at Ariyalur, Tamil Nadu
2012	Enters Northeast India, Acquired Calcom Cement and Adhunik Cement Total capacity of the group—21.8 MTPA including Belgaum Plant. Dalmia Bharat Cement as a top quartile producer in India Became one of the three cement companies in India to adopt the Cement Sustainability Initiative Charter

Source Company website (https://www.dalmiabharat.com) Accessed on 30 May 2016

- Dalmia Bharat Sugar and Industries Limited, which commenced operations in 1994, in Uttar Pradesh;
- Dalmia Refractories, with units in the states of Gujarat and Madhya Pradesh; and
- Dalmia Power, established to meet the power requirements of the Group's cement and sugar plants.

DCBL is a leading player in the Indian cement manufacturing space with a production capacity of 24 million tonnes, with 11 cement manufacturing plants across East and South India, as shown in Fig. 2.2.

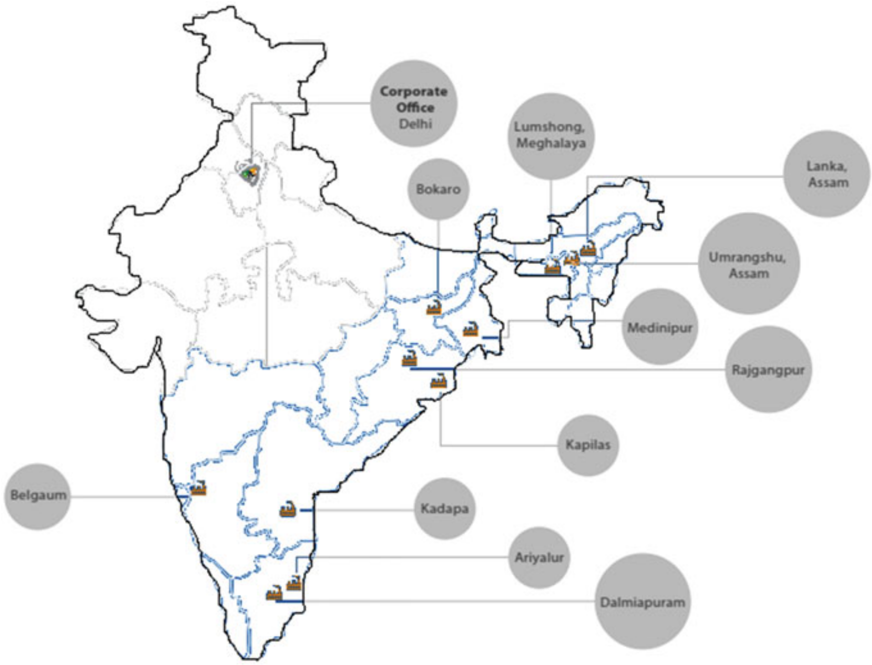


Fig. 2.2 Map showing plant locations of DCBL. *Source* Company annual report 2014–15

2.4.2 *Energy* Management Taskforce

DCBL has always nurtured a work culture that fosters the employees to work towards continuous improvement in energy conservation. The management welcomes suggestions from employees of all cadres, right from the shop floor employee. A person can convey the improvement suggestion through his supervisor or through the suggestion box at the Central Control Room (CCR) building.

A monthly award is given for the best improvement project undertaken. Once in every 6 months, a brainstorming session is held for employees to pool in their ideas for improvement. Ideas and suggestions of all kinds, irrespective of their feasibility, are most welcome in these open-house brainstorming sessions.

To further aid process improvement and energy conservation, Krishna Kumar, the unit head of the Ariyalur plant, constituted an exclusive team called the energy management taskforce in 2012.

This team comprises members from different departments of the manufacturing plant. The composition of the team is shown in Exhibit 4.

The team met once a month to discuss the updates from the last month and they set themselves the targets for energy reduction for the subsequent month. Based on the initial analysis of the transcripts, we found that an innovative solution has emerged through this task force. The idea was to minimize the power consumed by the fan, by implementing a duct modification. It has significantly brought down the energy costs for production.

In the team meetings, the status of the backlogs of the previous month is reviewed and the targets for the current month are set. The team is always open to suggestions from all.

In 2012, the Ariyalur unit bagged the "Green Award" instituted by the State Government of Tamil Nadu. The concerted efforts of the team paved way for this unit to the win accolades in the national arena too. One such recognition is the National Energy Conservation Award for the cement sector, instituted by the Ministry of Power, Government of India. The President of India presented the prestigious award to Krishna Kumar, the unit head.

We could find certain themes emerging from all the interviews:

1. ***Presence of communication channels***: The senior leadership has fostered a culture of openness and practiced employee engagement in sourcing ideas for improving energy efficiency in the plant operations. This is evident from the fact that all the interviewees recollected the incentive schemes (such as special recognition and team awards) to motivate employees. They mentioned the presence of a suggestion box where any employee, even the one working on the shop floor, could communicate her suggestion. This is consistent with the findings of Fairbank and Williams (2001).
2. ***Empowerment***: From the interviews, we found that the energy management task force had the decision-making authority and the power to implement new practices and modifications to the existing process, which do not require any major capital expenditure. The team was self-propelled and required senior management intervention only when huge financial investment was needed. Thus, the empowerment of the team has fostered the spirit of creativity (Burpitt & Bigoness, 1997).
3. ***Strengths of cross-functional team***: Being a cross-functional team with members having varying experience and level of expertise (with different designations, as shown in Table 2.1), the knowledge sharing and trust have been instrumental in the successful functioning of the team. Literature suggests a similar outcome in the use of cross-functional teams, as seen in the context of New Product Development (Love & Roper, 2009).
4. ***Openness of team meetings***: The interviewees mentioned that they were free to voice their views, even when it could lead to a conflict in the team. This constructive conflict in a cross-functional team leads to the emergence of an innovative solution, within the given constraint (Lovelace, Shapiro, & Weingart, 2001).

This case provides an empirical support to the claim of Nidumolu, Prahalad, and Rangaswami (2009) that sustainability targets provide the push for companies to go for innovative solutions.

2.5 Implications and Future Work

From a theoretical perspective, this research study shows that organizational practices lead to emergence of sustainable solution under the normative pressures of sustainability. To a practitioner, this exploratory work highlights the importance of key enablers within an organization that would drive the emergence of innovative solutions in the firm's journey towards sustainability.

The findings of this study affirm the stance presented by Nidumolu et al. (2009) that sustainability targets set forth by regulatory agencies need not be seen as only constraints that would erode a firm's competitiveness in the market but can be viewed as opportunities for innovation. However, we need to observe these factors in the context of other process industries to verify our findings. Multiple cases with cross-case analyses would help us confirm the results obtained through this study. Moreover, it would help us present a broader perspective and develop a conceptual model to understand the drivers of Sustainability Oriented Innovations (SOI), which would be of academic interest to management scholars and of corporate interest to firms, which are keen on driving innovation towards sustainability.

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Chapter 3
What Drives Firms Towards Green Initiatives?—An Emerging Economy Perspective

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Abstract Sustainability is fast emerging as the new paradigm of conducting business. With increasing focus on the environmental impact of firms' operations, there is a need to understand the factors that drive green initiatives of firms. In this work, we aim to understand those factors by studying environmentally friendly initiatives of firms. Our observations, primarily based on the emerging economies of India and China, serve to provide an insight into fast-growing economies which also often face scrutiny for poor environmental performance. We observe and analyse common factors that determine firms' green initiatives. The work aims to derive insights into environmentally friendly practices of firms in emerging economies and also provides directions for further research in green operations.

Keywords Green operations · Environmental regulations · India · China

3.1 Introduction

The United Nations Climate Change discussions have led countries world over to pledge sustainability initiatives towards goals of better and healthier living and environment. The policy initiatives undertaken by Governments world over have significant ramifications for firms as they start to reconsider their existing product and process designs. But the change is not easy. For example, among the two fastest

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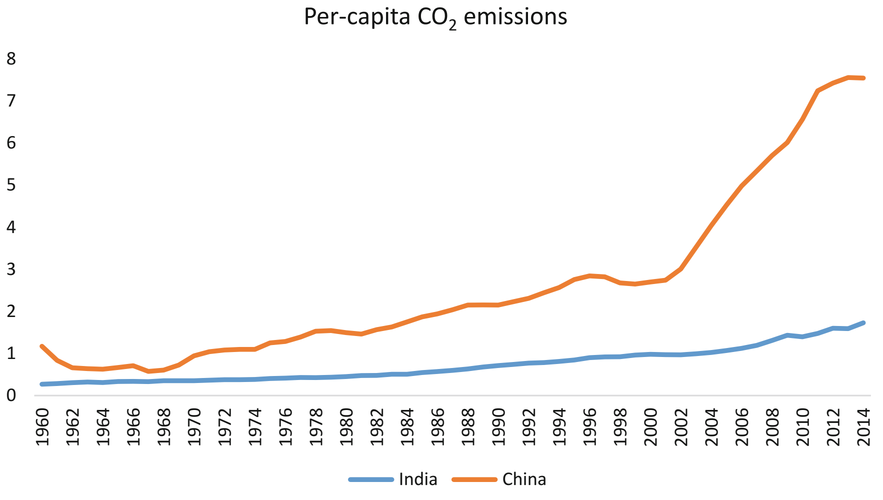

Fig. 3.1 Per-capita CO_2 Emissions (India and China)

growing economies of the world, namely, India and China, it is observed that their ranks in environmental performance index have been below par. India ranks 141 out of 180 countries while China ranks 109 in the annual environmental performance index developed by Yale University.[1] Also, the per-capita CO_2 emissions in India and China are on a rise (See Fig. 3.1).[2] Yet, firms in these countries are gradually undertaking pioneering efforts to redesign their products and processes to become more environmentally sustainable. For example, while giant beverage manufacturer, Coca-Cola, has often faced resistance from local communities and state authorities in the southern state of Kerala, in India (Chang, 2010), due to its operations which affected groundwater table and contamination levels, its competitor, PepsiCo, has undertaken significant strides in maintaining a positive water balance in regions and communities that it operates in.[3]

Another large conglomerate in India, ITC[4] has undertaken several initiatives towards soil and water conservation by investing in watershed development programmes in the communities that it functions in. The firm has also increased its renewable energy portfolio by fuelling 47% of its total energy needs from carbon-neutral sources like wind, solar and biomass (ITC, 2016). In China, Shanghai Sharp electronics co. and Coca-Cola Shanghai Shenmei Beverage & Food Co. (China Greentech Initiative, 2014) have come together to save water by installing a grey

[1]http://epi.yale.edu/.

[2]Data Source: World Bank.

[3]http://pepsicoindia.co.in/purpose/Environmental-Sustainability/positive-water-balance.aspx.

[4]ITC is one of India's leading fast-moving consumer goods company (http://www.itcportal.com/about-itc/profile/history-and-evolution.aspx).

water pipeline from the Coke plant to the Sharp plant (Carberry & Hancock, 2014). The pipeline provides waste grey water from Coke plant to the Sharp plant, thus substituting the need for regular freshwater leading to significant savings. In a different sector, KPMG China has continuously reduced its carbon footprint through various process initiatives which minimize environmental damage. These initiatives include reduced travel, more video conferencing, reduced paper usage, energy efficient lighting, green building infrastructures, etc. Traditional sectors like automotive and industrial firms have also undertaken several green initiatives in India as well as China.

However, several firms still today shy away from undertaking green supply chain initiatives. Managers often are sceptical of the benefits of investing in environmental-friendly initiatives since the long-term results are often not visible or quantifiable. Several firms often pick the low hanging fruits of greening while questioning the long-term investment requirements and the resulting benefits from them. In such a context, this study aims to look at various factors that drive green initiatives of firms. We identify and analyse certain common factors that drive firms towards green initiatives. Outlining these factors, we believe, will provide a better understanding of green initiatives and an insight into firms looking to conduct sustainable business in emerging markets. Our study spans across firms in China and India, and focuses on their operations in these economies. The green initiatives, as we observe, are being driven by the following factors:

A. Environmental regulations driven greening,
B. Consumer demand driven greening,
C. Price premium potential driven greening and
D. Cost reduction driven greening.

Among the above four factors, the first two factors represent the external factors influencing firms to invest in green initiatives, while the other two factors represent internal motivations of firms which directly impact their profits.

3.2 Factors Affecting Green Initiatives by Firms

In this section, we discuss each of the above-listed factors in detail with relevant examples from Indian and Chinese firms and markets.

3.2.1 Environmental Regulations Driven Greening

Our study reveals that in several cases, where firms often do not undertake voluntary initiatives to go green, policymakers play an important role in influencing green initiatives. It is well established that over the last two decades, China has emerged as a major global manufacturing hub (Zheng, Jia Wern, & You, 2005). Exports from China have grown by over 900% over the last 15 years.[5] While China has significantly benefited from global outsourcing of manufacturing activities, it has also faced serious consequences of associated pollution. As a result, today, China faces various pollution-related challenges such as poor air quality and respiratory illness, poor water quality and high water consumption costs. In order to address these challenges and to support various national and international environmentally concerned groups, the Government of China in the last two decades has proposed various environmental regulations. For example, in 2002, the Chinese Government implemented the '*Law of the People's Republic of China on Promotion of Cleaner Production*'. This law encourages reduction and prevention of pollution-generating products, and promotes the use of efficient modes of production, and overall sustainable development of economy and society.[6] This law apart from incentivizing cutting-edge research in cleaner production also penalizes heavily those firms which tend to violate the various articles provisioned. Similarly, Chinese government has come up with regulations such as the *Law of the People's Republic of China on Renewable Energies* (Adopted in 2005, Revised 2009 which promotes the development and use of renewable energy) and *the Regulation on the Administration of Ozone Depleting Substances* (Adopted in 2010; which monitors firms producing and trading ozone depleting substances).

For the automobile sector, Ministry of Environmental Protection (MEP), China has mandated all vehicles to meet Chinese V standards (equivalent to Euro 5 standards) by 2018 and all light-duty vehicles to meet Chinese VI standards (equivalent to Euro 6 standards) by 2020. These legislations have pushed firms in the auto and auto-component industries to work on improving the standards of fuel injection systems, catalytic converters and the engine core (Reuters, 2016). To further add, the Chinese Government has promoted a circular economy policy since 2002. The central idea of the circular economy is to promote—reduction, reuse and recycle activities which improve resource utilization. In 2008, circular economy promotion law was enacted with the objective to promote better resource utilization and improvement in environment (Li & Lin, 2016).

In addition, China has pledged to reduce coal consumption in energy sector by 60% by 2020 (Yeo, 2016). To bring forth the challenges that firms face under such legislations, our study reveals that China cancelled 104 new coal plant operations in a bid to reduce emissions. Encouraged by efforts of economies globally, China also plans to launch the world's biggest cap-and-trade system (Cheadle, 2016) in a bid to reduce pollution and improve the country's environmental performance. With ongoing pilot projects of cap-and-trade system in five cities and two provinces, China is likely to start nationwide cap-and-trade system by July 2017 (He, 2017). China has also tightened its erstwhile pollution discharge policy and has revised the amount of penalty and charges for non-compliance significantly.

[5]https://data.worldbank.org/indicator/NE.EXP.GNFS.CD?locations=CN.

[6]http://www.npc.gov.cn/englishnpc/Law/2007-12/06/content_1382101.htm.

In India too, recent changes in environmental legislations are gradually enforcing green initiatives. For example, the Ministry of Environment, Forest and Climate Change, has enacted strict wastewater generation and effluent standards cutting across various industry sectors. As a part of its National Manufacturing Policy, India has mandated development of National Investment and Manufacturing Zones (NIMZs) where, among other guidelines, the Government has stipulated firms in NIMZs to procure a certain percentage of electricity mix from renewable sources.[7] In addition, the policy also supports conservation of energy and technological adoptions through suitable incentives to firms.

Under the Companies Act, 2013,[8] the Government of India has also made it mandatory for firms to invest at least two percent of their average profit in the previous three years in Corporate Social Responsibility (CSR) activities. A recent study by Rai and Bansal (2014) indicates that firms from various industries have invested at an average more than 20% of their CSR spends on environmental sustainability. These activities not only include greening of the processes of the firms but also involve environmental sustainability efforts in the external society.

It is estimated that India would produce close to 2 million tonnes of e-waste by 2018 (CPCB, 2011). With growing concerns on landfills and e-waste generated in India, Government of India has also set policy guidelines for e-waste regulation. In alignment with the European Waste Electrical and Electronic Equipment (WEEE) Directive, India also requires producers of electrical and electronic equipment manufacturers to be responsible for the life cycle of products and engage in take-back, recycling and disposal.

India currently follows Bharat Stage (BS) IV (equivalent to Euro 4 standards) norms for its automobile emissions. However, keeping in consideration the increasing levels of pollution in cities due to automobile emissions, the government has proposed skipping BS-V norms (which were earlier planned to be implemented by 2021) and directly adopting BS-VI norms (equivalent to Euro 6 standards) by April 2020 (Salhotra, 2016). This has severe implications on the auto and auto-component manufacturers not only in India but also firms which supply to assemblers in India. Analysts also claim that this move will provide impetus to the introduction of newer hybrid and electric vehicles in India which automatically adhere to stringent emission norms proposed by the government.

With various new policies and laws to fight the growing environmental problems, both India and China are making attempts to fare better than their past environmental performance. Studies have shown that regulations once they come into force change the competitive landscape for firms. It is evident that while some firms whose operations and supply chains cater to the regulations enjoy significant competitive advantage, others face the risk of penalty or taxation. We studied the operations and supply chain innovations of firms in the two economies to cater to

[7] http://pib.nic.in/newsite/printrelease.aspx?relid=137814.

[8] Only firms with a net worth of Rs 500 crore or more, or an annual turnover of Rs 1000 crore or more, or a net profit of Rs 5 crore or more are mandated under this law.

the environmental legislations and found that to cope up with such legislations, while few firms have strengthened their own research and development capabilities, others have formed joint ventures or invested in third-party research organizations to develop and implement cleaner technologies. For example, the project ULCOS (Ultra Low Carbon Emissions) is a consortium of several steel manufacturing companies in Europe in which Indian steelmaker Tata Steel is also involved that aims to reduce carbon emissions in steel manufacturing by at least 50%.[9] In another example, Asian Paints[10] in India recycles its effluents and the treated water is either used back in production processes or invested in horticulture development. Asian Paints has also experimented with achieving zero effluent discharge in its production facilities through reverse osmosis techniques. In order to adhere to the E-waste Management and Handling Rules framed in 2011 by Government of India, several electrical and electronic equipment manufacturers in India like Samsung, Acer, Dell and Toshiba, have established several collection centres throughout cities in India and in certain cases have tied up with third-party recyclers as well.

3.2.2 Consumer Demand Driven Green Initiatives

Today, global manufacturers face changing preferences of consumers towards less polluting, green products. A survey done by Nielsen in 2015 indicated that Millennials and Baby-boomers across the world have sustainability as a priority when they go shopping (Nielsen, 2015). This serves as an important opportunity for firms to capture the green-sensitive consumer markets while benefiting in return. Several firms realize the brand value that green products carry and this is turning into an important value proposition for competition.

Both China and India have an increasing number of green-conscious consumers who demand products and services which are better from environmental perspective, for example, fuel-efficient cars, energy efficient appliances and organic produce. A survey commissioned by DuPont in 2014 indicated that consumers in India and China have very high awareness and confidence on green products.[11]

To cite a few examples, Changan automobile, one of the big four automakers of China (Business Standard, 2016), is a state-owned company that has charted out a performance goal to be achieved by 2025 by designing and developing both plug-in hybrid vehicles (PHEV) and electric vehicles (EV) for the consumer market in China. Key goals of Changan are about product greening where the vehicle would consume lesser per unit fuel while in use. In 2015, Changan had also launched

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[9]https://www.tatasteelconstruction.com/en_GB/OurBrands/Colorcoat/Confidex-Sustain%C2%AE/Tata-Steel-commitment-to-reducing-emissions.

[10]Asian Paints Ltd is India's largest paint company and Asia's third largest paint company (http://www.business-standard.com/company/asian-paints-34/information/company-history).

[11]http://www.dupont.co.in/corporate-functions/media/press-releases/Green-living-india-press-release.html.

Eado EV which claimed to save 85% on costs when compared with gasoline run cars.[12] Automakers in India too are increasingly under pressure to design and deliver environmentally friendly vehicles. For a cost-conscious Indian consumer, fuel efficiency of vehicles remains a key product attribute to consider during vehicle purchase. As a consequence, vehicle manufacturers in India often go an extra mile through advertisements to pitch their fuel-efficient vehicles in a highly competitive market. Vehicle makers like Maruti Suzuki and Tata Motors in India are constantly innovating in new vehicle designs to cater to the environmental-friendly and cost-conscious consumer segments in India (Ghosh, Gouda, & Shah, 2015).

Interestingly, our research also revealed that unforeseen effects of pollution also lead to significant rise in demand for environmental-friendly products. Two distinct phenomena can be observed in this respect, namely, proactive and reactive demand of consumers. Proactive demand is where consumers are green conscious and demand greener products which reduce environmental harm. Reactive aspects of green consumer behaviour, on the other hand, can be observed through increased purchase of products which not only mitigate the environmental harm that already exists but also make them feel safe. Organic food purchases are on the rise in China, and Hall (2016) says that this is not primarily because of concern for environment. The managing director of a market research firm in China says that '*Consumers want organic products but they don't necessarily believe [what they are offered is] organic…What they hope an organic label means is at least better quality, better safety, better control of the production process*' which indicates the reactive nature of purchases (Hall, 2016). Purchase of products such as masks for air filtering, water, and air purifiers by consumers are examples of such behaviour. The demand for these products has increased drastically in countries like India and China as there seems to develop a growing concern among consumers about living in highly polluted environments. While proactive consumers drive green initiatives of firms, reactive consumers also contribute to green initiatives, although their effectiveness is questionable. Nevertheless, the existence of environmental conscious consumers tends to provide a source of competitive advantage for firms involved in the production and sale of green products.

Several retail and consumer packaged goods (CPG) companies in economies like China and India are designing and developing low-cost and innovative products to cater to environmental conscious consumers. In order to provide safe drinking water to millions of households in India, Tata Chemicals in India launched, in 2009, portable water purifier named 'Tata Swach'. Requiring no separate energy to run the product, the introduction of an innovative water purifier was based on principles of solving emerging complex problems of clean drinking water availability in the country while attempting to attract an environmental-friendly consumer base which is also cost conscious.[13] Several other competitors like Hindustan Unilever (HUL) have also

[12]http://www.globalchangan.com/changan/sustainable.html.

[13]http://www.tatachemicals.com/Asia/Products/Consumer-products/Water-purifiers/Tata-Swach-non-electric-water-purifier.

attempted to target this consumer segment by launching zero energy consuming water purifier named ‘Pureit’. HUL has also targeted environmentally conscious consumers as a part of its ‘Sustainable Living Plan’. It has set three ambitious goals namely, ‘*(a) Improving Health and Well-being: By 2020, HUL aims to help more than a billion people take action to improve their health and well-being, (b) Reducing Environmental Impact: By 2030 HUL’s goal is to halve the environmental footprint of making and use of products and (c) Enhancing Livelihoods: By 2020, HUL aims to enhance the livelihoods of millions of people as their business grows*’.[14] As a part of this, HUL has introduced several innovative products which consume fewer resources during their usage. ‘Comfort One Rinse Fabric Conditioner’, introduced by the company targets to save water consumption during post-wash activities. Similarly, after wash laundry product, ‘Magic’ intends to reduce water usage during the rinsing of clothes. In addition, shampoo and hair conditioners which reduce water consumption during usage are also being worked on by the firm. HUL’s strategy to introduce environmental-friendly products in the Indian market while leveraging its well-established distribution network is aimed to extract a significant competitive advantage with a change in consumer behaviour towards environmental-friendly products.

3.2.3 Price Premium Potential Through Greening

Contrary to common understanding, research has shown that there are consumer pockets in India and China that are increasingly focussed on products built through ethical and sustainable sourcing, clean manufacturing practices and health friendly. The 2014 Greendex survey revealed that 71% Chinese and 68% Indians agreed that it is worth paying more for energy saving products (Whan, 2015). This provides an opportunity for firms to extract price premium for environmentally friendly products. Today, such products range from organic food and apparels to paints, furniture and electronic gadgets.

It is estimated that the organic food industry in India will grow to a potential value of USD 1.36 billion by 2020, increasing at a rate of 25% (The Times of India, 2015). Several initiatives have been taken by firms focussed on such niche markets. Ecofarms (India) Ltd., for example, started with a group of farmers in 1995 practising organic farming. Over time, the practices have spread to several districts of Maharashtra and Orissa in the country. Today, the company has around 20,000 growers who raise 40 different crops in 60,000 hectares of land. From humble beginnings, the company has tied up with major retailers such as Big Bazaar, Reliance, Aditya Birla (More) and others for reaching out to consumers in India.[15] In another example, Fab India (an Indian craft based retail chain) has set up

[14]https://www.hul.co.in/sustainable-living/india-sustainability-initiatives/.

[15]http://www.ecofarmsindia.in/about_us.htm.

upstream community of artisans, handloom workers and craftsmen to procure most of Fab India's product categories. This supply chain innovation has turned Fab India into a profitable business over the years and a well-known brand reaching out to the organic apparel loving urban consumers in India (Thomas, 2012). Future group in India also launched a similar initiative in selling ethnic products under the brand name 'Mother Earth'. Like Fab India, Mother Earth's merchandize is largely procured from self-help groups, NGOs and communities of artisans in the country. *Bhu:sattva* is another example of organic and eco-friendly apparel manufacturer that uses ethical methods, organic material and fair trade practices to produce and sell apparels in the country. The success of the brand has also led it to internationalize its sales to other countries such as US, Canada and Australia.[16]

In 2014, China became the world's 4th largest market of organic products (Heinze, 2016). Rising disposable income and environmental and health concerns in China have led to unprecedented growth and consumption of environmentally friendly products and food produce in the country. In a recent study by Nielsen, it was found out that more than 50% of consumers in China were willing to pay a premium for products that were made with organic or environmentally friendly materials (Nielsen, 2017). In the food industry in particular, incidents of tainted milk powder and chemical infested agricultural produce have led to significant increase in demand for high quality, safe and organically produced food products which can fetch higher price premium for firms (Duggan, 2015).

A similar phenomenon can be observed with respect to battery electric vehicles (BEV) in China. While government regulations aid the demand, customers also prefer electric vehicles over other options. This has driven major global auto firms like Tesla, Volvo and Ford apart from local auto firms like BYD to ramp up their production (Economic Times, 2017). China accounts for the highest number of electric vehicles in the world (close to 30%) (Rusli & Kirk, 2017), and the demand for these vehicles will only push this higher. Using data from China and US in 2012 and 2013, Helveston et al. (2015) find that American consumers have a lower willingness to pay for electric vehicles than Chinese consumers confirming our hypotheses for electric vehicles in China.

3.2.4 Cost Reduction Through Greening

Greening also provides an opportunity to eliminate waste and reduce costs for firms. 3M was one of the first firms which identified such benefits. In the year 1975, 3M came up with a concept ' *pollution prevention pays (3P)*' which exemplified the benefits of greening initiatives for firms. Over the years, many firms across the world have invested in pollution prevention, waste reduction and other greening initiatives to reduce various costs associated with these activities. This is

[16]http://www.bhusattva.com/biography.html.

also in line with the principles of lean production techniques aimed at waste reduction which in turn helps in cost reduction for firms. Smaller firms in the value chain (like small component manufacturers for various machines) have also invested in these initiatives as they are either mandated by regulation or larger firms or educated by these firms or industry associations helping them improve their bottom line.

It was found that several firms in our study realize the potential that design and development of environmentally friendly products and processes hold. For many firms, efficient processes are synonymous with environmentally sound practices. As discussed above, reduction in consumption of fuels, energy savings and reduction in waste aids development of environmentally friendly products and practices. To cite few examples, Dongfeng motor corporation is a state-owned and one of the big four automakers of China.[17] The firm runs various green initiatives such as Green R&D, Green Procurement, Green manufacturing and Green logistics. One of the several initiatives undertaken by the firm include, Dongfeng launching a programme to reduce its suppliers' environmental load by reducing energy consumption at their facilities. The firm has also created a platform to track pollutant emissions of its suppliers through an online system. Other green manufacturing initiatives at Dongfeng include various process improvements and waste elimination efforts as well as use of alternative materials. For example, use of water-based paints instead of oil coatings has reportedly reduced emissions by nearly 50% (DongFeng Motor Corporate, 2015). Moreover, the firm has achieved zero discharge of waste water through physical, chemical and biochemical treatment of wastewater. In addition to aforementioned initiatives, DongFeng also recycles and remanufactures automotive products to reduce its carbon footprint while simultaneously improving its revenues [for example, its remanufacturing revenue was 22.78 million yuan in 2015, (DongFeng Motor Corporate, 2015)].

To cite another example, Bao Steel is China's state-owned steel company which was the fifth largest steel producer in world and second largest in China for the year 2015.[18] The green initiatives of Bao Steel are at three levels, namely, green products, green manufacturing and green supply chain. Under green products, Bao steel produces oriented steel and high-strength steel plates which require lesser resources when used by consumers. As part of its green manufacturing initiative, Bao Steel aims at improving resource utilization. For example, the firm saved energy equivalent of 0.3 million tonnes of coal by installing a 70 MWp solar power station which is expected to conserve conventional sources of energy (BaoSteel, 2015).

Several firms in India too have consciously moved beyond the existing set of processes and products, to adopt changes which are environmentally friendly while

[17]Dongfeng is China's third largest automaker (http://news.xinhuanet.com/english2010/china/2010-02/22/c_13182876.htm).

[18]Bao Steel is world's fifth largest steel producer (https://www.worldsteel.org/en/dam/jcr:1288cdbc-e48c-4467-9a1e-33b18257a16c/2015+Top+Steel+Producers+extended+list.pdf).

leading to reduced costs. Leading CPG firm in India, P&G has introduced several innovations which are both cost-effective and environmentally friendly. For example, the popular detergents Ariel and Tide have been redesigned so as to consume less raw material and packaging material, thus saving costs. P&G's Baddi plant in Himachal Pradesh has successfully converted 380 tonnes of shampoo production waste into car washing agent and transformed 575 tonnes of scrap material into useful daily needs (P&G, 2016). The plant has successfully achieved 40% carbon footprint reduction as a result of these innovations. Mahindra Rise (Indian multinational automobile manufacturing conglomerate) has undertaken several green initiatives leading to cost savings and enhanced brand reputation. Among one of the initiatives, Mahindra Rise uses dryer to convert paint sludge to paint powder which can be used for interior parts of vehicle (Mahindra, 2016). The practice is not only environmentally friendly but also saved 3.03 million rupees in disposal cost saving. PepsiCo India has invested in a rice husk boiler in its plant in Kolkata to help satisfy 75% of the plant's energy needs. The initiative has potentially saved Pepsico USD 0.8 million per year and also helped reduce greenhouse gas emission by 4500 metric tonnes per year (PepsiCo, 2011).

3.3 Conclusion: The Way Forward

Environmental-friendly initiatives by firms in emerging economies of China and India are growing. However, much needs to be done for focussed growth of green initiatives. It is observed that in several firms, managers often have day-to-day operations and supply chain issues to resolve. As a result, the focus on green initiatives often takes a back seat. Further, managers are often unsure about the benefits of greening, raising doubts on the resulting benefits from undertaking such initiatives. However, as our discussion shows, green initiatives have several potential benefits and innovative firms are undertaking significant strides in going green. While we have derived separate insights on each factor driving green initiatives, note that in practice, a combination of factors outlined above lead firms to undertake green initiatives. Firms which realize the potential benefits of greening and have already begun to undertake environmental-friendly initiatives will have a significant competitive advantage as policies and markets change. A case in point being the Paris Agreement, accepted and ratified by several countries in the world, who pledge to work towards capacity building and creation of new technologies to promote sustainable development in a climate-friendly manner.[19] Such commitments by global economies have far-reaching consequences for firms. Faced with fast-evolving policies and markets, companies can find their cost structures significantly increased or face the risk of high environmental penalty in the years to come. Thus, innovative firms investing in green technologies and altering their

[19]http://unfccc.int/focus/technology/items/7000.php.

processes and products to be more environmental-friendly stand to gain an advantage. In addition, our study suggests that firms which identify and target consumer segments which are environmentally friendly will develop niche market segments in otherwise highly competitive markets of India and China with thin margins. CPG companies and manufacturing firms in particular, with their extensive well-developed distribution chains also have an opportunity to reach out to the large Bottom of Pyramid markets in India and China. With ethically sourced, environmentally friendly product offerings which can also help reduce costs during both manufacturing and consumer usage, the strategy of many firms in India and China can lead to sustainable competitive advantage. With globalization, operations and supply chains of firms will undergo closer scrutiny of Governments, NGOs, consumers and media. From the sourcing stage to final distribution, firms would be held accountable for their operations and impact on environment and communities. In this changing landscape, firms which are moving ahead in undertaking green initiatives stand to benefit.

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Chapter 4
Intellectual Property Policy Strategies for Sustainable Manufacturing in India

K. V. Nithyananda

Abstract Sustainability has become the buzzword in recent times. While manufacturing leads to considerable advantages like contributing to the GDP, providing goods and services for consumer, and generating employment opportunities, it is also contributing to the detriment of the environment and the natural resources, which run counter to the philosophy of sustainability. In order to achieve sustainability in manufacturing, substantial investments have to be made towards innovation, which can be protected under the intellectual property regime. But the IP rights prevent others from copying the technology, which is antithesis to the concept of sustainable manufacturing. Companies need to be aware of the IP policy of India, which facilitates the protection of environment and the natural resources. Also, India as a country needs to relook at the IP strategies available to ensure that it has sufficient access to technology, which can help in the proliferation of sustainable manufacturing technologies. This chapter provides for two levels of strategies, both relating to IP rights, which can be adopted by India, in order to achieve sustainable manufacturing in the country. The first level is the IP policy strategies that can be adopted by India, in light of the international treaties like TRIPS, the WTO system, as well as other treaties, conventions and protocols. The second level is the IP strategies that can be adopted by the non-governmental sector including the private commercial sector as well as the academic sector (both public funded as well as private funded). While the former analyses the TRIPS agreement and tries to understand how the objectives stipulated therein have been captured by the Indian IP legislations, the latter looked at strategies like investing towards R&D, licensing of technology, patent pools and copyright collectives, open source and open innovations, and also government initiatives that could ensure the implementation of sustainable manufacturing technology in India.

Keywords IP strategy · Sustainable manufacturing · Business strategy

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4.1 Introduction

During recent times, there have been a lot of discussions on sustainability on various fronts, in the field of marketing, finance, strategy, environmental studies, non-governmental activities and even in the field of legal studies. These discussions are becoming more relevant by the day, as every citizen of every country is facing the impact of environmental degradation, leading to climate change, global warming, natural calamities and human and health calamities. There have been various studies, confluences and forums organized to study the impact of environmental degradation.

Many of these studies point out that human greed is the fundamental reason for the environmental degradation, and the addiction to the economic growth (Meadows, Meadows, Randers, & Behrens, 1972) is forcing the world to adhere to certain indicators (Arrow et al., 1995), which force humans to extract more natural resources than actually needed. In fact, we are extracting natural resources faster than what nature can replenish. This is leading to the products being produced with less or no chance of repairing (causing high carbon footprint on the planet), discarding unusable products, which in turn is leading to environmental pollution and poisoning our natural resources (Vitousek, Mooney, Luchenco, & Milillo, 1997).

This trend of environmental damage and degradation could be curtailed and controlled by adopting sustainable manufacturing practices. Under this, the manufacturing process becomes more environmental friendly by using renewable energy, by reducing wastage of natural resources which are again recycled, by consuming a healthy portion of recycled material as inputs for manufacturing, and ensuring that the products can be easily repaired and fixed. It also ensures that the packaging, the supply chain and logistics, the advertising and marketing efforts, and the sale and after-sale processes are also built in a sustainable manner which is friendly towards the environment (Bonvoisin, Stark, & Seilger, 2017).

In order for the sustainable manufacturing to sustain as a concept, there has to be considerable innovation carried out in all the fields of manufacturing, marketing and customer relations. With innovation comes the challenges of intellectual property rights, which prevent others from following/replicating the technology belonging to the innovator. Such prevention would ensure that the technology required for the practice of sustainable manufacturing by everyone in the country does not get proliferated. This becomes a challenge in implementing sustainable manufacturing techniques across the country. This chapter provides a framework of intellectual property strategies that could be implemented as part of the policy strategies by the government of India for the success of sustainable manufacturing in the country.

4.2 Concept of Sustainable Manufacturing

As mentioned earlier sustainable manufacturing is a process of manufacturing, which is environmentally friendly. It is defined as 'creation of discrete manufactured products that in fulfilling their functionality over their entire life cycle cause a manageable amount of impacts on the environment, (nature and society), while delivering economic and societal value' (Bonvoisin et al., 2017). While considering manufacturing products that are environmentally friendly, one has to pay attention to the following four factors (Bonvoisin et al., 2017):

- Manufacturing technologies in the form of processes and equipment that are used as part of the manufacturing activities. This could include sustainable process of manufacture, which uses renewable energy in energy-efficient buildings, environmentally friendly maintenance of equipment and buildings, optimal resource consumption, etc.
- Product lifecycles in the form of what products should be produced and how. This typically includes asking questions like what material to be used that would facilitate repairing rather than discarding, intelligent products and following simplified product sustainability assessment.
- Value creation networks in the form of processes followed by the organization to ensure the product reaches customers in a sustainable manner. This includes sustainable packaging, sustainable supply chain and logistics processes, and sustainable industrial ecology.
- Global manufacturing impact in the form of the company's contribution to the global sustainability efforts, to ensure that there is a proper proliferation of sustainable technology. This includes education and competence development, developing standards relevant for sustainable manufacturing, licensing relevant intellectual property rights to others encouraging them to adopt sustainable manufacturing.

Each of these factors helps organizations in creating intellectual property rights focusing on sustainable manufacturing, which would be the scope of this study.

4.2.1 Relevance of Sustainable Manufacturing

Though the concept of sustainable development has been in vogue for quite some time (Brundtland et al., 1987), and it has received considerable attention only in recent days. Though the focus on achieving sustainability in terms of sustainable industrial production, recycling, using renewable energy, energy efficiency, sustainable cities, all leading sustainable ecosystems and preserving natural resources were all being discussed since then, the need for focusing on sustainable manufacturing is more relevant now than ever.

The natural equilibrium is getting disturbed at an alarming rate; emissions of chemicals like carbon, phosphor, nitrogen into the atmosphere have surpassed the natural absorption capacity of the nature; the natural flows of rivers are disturbed; the rivers are polluted with industrial effluents; the garbage is being dumped into oceans; we are drawing more from the nature than the rate at which it can replenish those resources (Bonvoisin et al., 2017). All these are leading to distorted social conditions in different parts of the world. This has also led to inequality in terms of resource consumption and utilization by different countries and different classes of people within those countries. In order to preserve such inequalities, laws and treaties are being framed to impose unnecessary costs on developing countries like India by imposing unnecessary taxes on carbon production, which in effect is distorting the competitiveness of nations. Such activities are also leading to unprecedented natural disasters, disturbing the natural equilibrium, unseen and unheard of diseases, which in a way is the nature's way of setting things right.

Such unprecedented exploitation of nature started, it is said, as part of industrialization. Manufacturing, which is considered to be the foundation of the economic activities leading to higher Gross Domestic Product (GDP), is the crucial element of the modern development. Also, manufacturing is not only causing a lot of wastage, in terms of natural resources, human resources and financial resources, but also polluting the natural environment through its processes and remnants. If we are to preserve the earth for our future generations and make their lives comfortable, then we have a moral obligation to monitor our existing economic activities, especially in terms of adopting sustainable manufacturing practices as well as sustainable consumption process.

The United Nations General Assembly adopted the United Nations Sustainable Development Goals (UNSDG) on 25th September 2015, wherein it listed 17 goals to be achieved by nations by the year 2030. The 12th goal on that list is 'Ensuring sustainable consumption and production patterns', which has eight sub-goals. Each of these goals talks about adopting sustainable manufacturing practices, reducing emissions, producing more products with less resources, adopting renewable energy, integrating sustainability into the reporting system and efficient management through education, all leading to harmony with nature (Stark & Lindow, 2017).

The UNSDG was approved with an intention to preserve the plan by preserving the land, oceans and the waterways for the future generations. Through this, it was envisioned to create 'a world in which every country enjoys sustained, inclusive, and sustainable economic growth and decent work for all' (United Nations, 2015). For all these objectives, a focus on sustainable manufacturing becomes very relevant and crucial at this juncture.

4.2.2 Integrating Business Strategy and Sustainability

In order to achieve sustainable manufacturing practices in India, the Government should help companies integrate the SDG sub-goals relevant for sustainable manufacturing and consumption within their business strategy. Such integration could take place if the government is able to develop parameters to measure the success of business organizations by linking economic objectives of the organization with the ecological and social objectives relevant for the society.

Beyond that, at the organizational level, businesses should adopt the following three specific strategies (Oertwig et al., 2017):

- **Eco-effectivity strategies** where the business pursues the objective of reducing environmental pollution by adopting strategies like using renewable energy sources, recirculation of products, by-products and materials into product life-cycles or natural systems, as well as limiting environmental pollution;
- **Eco-efficiency strategies** where the business increases resource productivity through minimization of resources deployed while increasing the outputs, using lightweight structure, recyclable materials, and using material with lower pollution potential; and
- **Socio-efficiency strategies** wherein the value created by businesses are compared with the social burden and social costs, in terms of unemployment, per capita income, cost of outputs, etc.

These strategies are not ad hoc in nature. They have to be consistently implemented by business organizations, in order to have sustained impact on the environment and the society. To ensure consistent implementation of these strategies, business organizations should make structural changes in their organizational process and plans, and their organizational structures, policies, as well as in their very approach to business. Such fundamental and structural changes can be achieved only through consistent and deliberate focus on innovation on all fronts of the organizational activities. These innovations could lead to considerable intellectual property rights for the organization, which needs to be effectively managed, both within the company as well as within the nation in order for a country like India to achieve the SDG set by the UN.

Traditionally the term strategy was borrowed from the field of military warfare and was used to deal with strategic planning, but later on moving to strategic management. What started initially as achieving efficiency in productivity, which later morphed into achieving cost-efficiency, quickly turned into competitiveness, and then into differentiation (For more details on this discussion, see Oertwig et al., 2017, at pp. 177–79). Any product differentiation can be achieved only through consistent and deliberate effort towards research and development with an intention of improving the product to satisfy the customers' needs. The results of such research and developmental activities would lead to innovation, which could then be protected under various intellectual property rights.

These intellectual property rights, once secured by the business organization, would generally be managed with an intention of preventing others from replicating it, or alternatively, to benefit commercially by letting others use it under an agreement in return for a valuable consideration. But when the intention is sustainability, specifically focusing on sustainable manufacturing for the overall development of a country, the intellectual property rights need not be used exclusively by the innovator alone. They can be managed collectively for the overall benefit to the society, with the benefits accruing to the innovator as well.

The following sections discuss the intellectual property policy strategies that can be adopted for the proliferation of sustainable manufacturing in India. Section 4.3 provides a quick overview of the different intellectual property rights that can be acquired by a business organization, and how such intellectual property rights could adversely affect achieving the sustainable manufacturing goals. It also highlights why a country like India should erect necessary safeguards to manage the intellectual property rights effectively and collectively in order to achieve the SDG. Section 4.4 would provide an overview of the policy framework available to countries like India that could be used to carve out necessary general exceptions to the intellectual property rights, as provided by the WTO system as well as by the TRIPS agreement. Carving out such general exceptions to the intellectual property rights becomes very critical to achieving the sustainable manufacturing goals for everyone. This section also discusses how India has used the provisions relating to general exceptions available within the international regime to effectively carve out exceptions within its intellectual property laws with an intention to achieve the sustainable manufacturing objectives (though they were created with an intention to achieve SDG). Section 4.5 would quickly summarize the various intellectual property strategies that could be adopted in India, both at a policy level as well as at the individual business organization level, which could ensure the proliferation of sustainable manufacturing in the country. Section 4.6 summarizes this chapter.

4.3 Overview of Intellectual Property Rights

Within the literature on intellectual property rights, many intellectual property rights (IP rights) are recognized which includes patents, trademarks, copyrights, designs, trade secrets, geographical indications, farmer's rights, traditional knowledge, layout of integrated circuits, etc. But for our discussion on the topic of IP rights relevant for sustainable manufacturing, an overview of only patents, trademarks, copyrights, designs and trade secrets are relevant, while others might not be that relevant. Hence, only these IP rights would be discussed in this section.

4.3.1 Patents

Patents are monopoly rights granted by the government for a limited time (generally for a maximum of 20 years from the date of application, post the TRIPS agreement of the WTO system) to an inventor or his assignee (which typically includes the employer of the inventor or the funding agency of the inventor), in return for a full disclosure of the invention. A patent is granted for only those inventions, which are patentable by nature (most of the countries have a list of inventions which are not patentable), and fulfil the three requirements of novelty, nonobviousness and utility. In order to fulfil the requirement of novelty, the invention, prior to the filing of the application by the inventor, should be considered new and should not be published anywhere in the world, and it should not be worked or known publicly in the country where protection is sought. Nonobviousness, on the other hand, requires that a person having ordinary skill in the art of the invention should feel that the inventor has taken an inventive step beyond what the general literature in the field provides. Utility could be a general utility (where the invention can be applied generally in many fields) or specific utility (where the invention can be applied only in the specified field of operation). The patent rights are territorial in nature. In India, patent rights are granted under the provisions of the Patent Act of 1970, as amended up to 2005.

An inventor is required to make full disclosure of his invention in order to secure the patent right. This is to ensure that the society benefits from the inventors' research work in the long run. People other than the inventor/assignee can use the invented technology only after the expiry of the stipulated period of monopoly rights (which currently is pegged at 20 years from the date of filing the application). This period of monopoly right is granted to ensure that the investments incurred by the inventor towards the invention is recouped by the inventor/assignee, which in turn acts as an economic incentive offered by the society for disclosing the invention and enriching the knowledge of the society in the process.

As patents are granted to inventions in various fields of technology, it becomes the most important IP right relevant to our discussion on sustainable manufacturing. As this IP right is capable of blocking the usage of the technology by others, managing the IP right of patents becomes the most important part of the policy strategy available to the government as well as the companies interested in sustainable manufacturing. Different strategies are available to manage the patents rights for the welfare of the society and the country at large, which would be discussed later in this chapter.

4.3.2 Trademarks

While patents protect inventions in various fields of technology, trademark protects the logo and any other marks capable of distinguishing the goods and services of a particular manufacturer. It does not protect the technology, but it protects the representation of the logo or any other marks belonging to a producer, which are used to depict the product. Such marks could take any form, including names, words, numerals, signature, alphabets, packaging, shape of the goods, smell, colours or combinations thereof, sound and any combination of any of these items. The only requirement for registering such marks as trademark is to ensure that such marks are distinct in nature and does not resemble the marks of others in the field of use. Though this is said, it becomes extremely difficult to establish distinctiveness, due to the fact that marks could fit anywhere on the continuum of distinctiveness starting from being fanciful, arbitrary, suggestive, descriptive, geographical names, family names, to generic names.

Unlike patents, registering a trademark is not mandatory. As long as the producer is using a distinct mark on his products and services, he would be accorded with the protection for such mark under the common law system. But under that system, if the producer wants to bring in legal action against an infringer of a trademark, then establishing his right over the mark and its usage becomes extremely difficult. To prevent such difficulty, it is advisable to register the trademark with the Registrar of Trademarks in India. Once approved, a trademark gets registered initially for a period of 10 years from the date of application. But technically protection on the trademark can be extended eternally by renewing it with the trademark office as long as it is used commercially in products, services and even marketing literature. Like patents, trademarks are also territorial in nature. In India, trademarks can be registered under the provisions of Trademark Act of 1999.

Trademark enables distinguishing the goods and services of one producer from that of the other. If a particular producer has spent time, effort and money to create a product/service with good quality, then trademark ensures that the competitors of the producer are not allowed to enjoy an unfair advantage by using the pioneer's mark on their (counterfeit) product or service. For the consumers and users of the product/service, it also helps reduce the search cost.

Though trademark rights are not very critical in the discussion on sustainable manufacturing, its understanding becomes very critical especially given the fact that under the licensing terms (which is one of the strategies that a company could adopt for achieving sustainable manufacturing) using the trademarks in the appropriate manner becomes extremely critical. Non-usage of trademarks in a specified manner could lead to the cancellation of the licensing agreement, which might affect the sustainable manufacturing efforts. In addition to this, large business corporations have the tendency to sue anybody who uses their trademarks without their authorization, even the media or civil society organizations. Media and civil society organizations play an important role in exposing the unauthorized use of products relating to sustainable manufacturing and their trademarks through the process of counterfeiting. In order to enable sustainable manufacturing, strategies relating to free and unencumbered usage of trademarks with no risks of litigations become a critical part of the IP strategies relevant to this study.

4.3.3 Copyrights

While trademarks protect the graphical representation of a mark, copyright, on the other hand, protects any creative work. It generally protects literary works, artistic works, dramatic works, musical works, cinematographic works, sound recordings, broadcasting rights and the performer's rights. Copyright is not a single right granted to the author/creator, it is a bundle of rights covering both economic rights as well as moral rights, where the former can be transferred to others for commercial consideration while the latter cannot be separated from the author, no matter what.

Just like trademarks, registration is not mandatory for copyrights. The rights accrue to the author immediately upon creation of the copyrightable work by the author under the common law system. But in order to enforce the copyright against infringers, the courts insist on registration as an evidentiary support. Copyrights are registered with the Registrar of Copyrights under the provisions of the Indian Copyright Act of 1957 as amended up to 2013. Among all the IP rights copyrights provides the longest first instalment protection. Copyrights can be enforced against the infringers by the author or his legal heirs during the entire life of the author and 60 years after the death of the author, in case the work is attributable to natural persons. But in case of the works registered by non-natural persons, then the term of the copyright would be 60 years from the date of the creation of the work.

Copyright does not protect the idea or a concept, but it protects the creative expression of that idea. For instance, the theme of Ramayana, an epic story popular in Asia is about the protagonist Ram being banished to the forest by his father, where the antagonist Ravan captures his wife, Sita. Ram later gathers an army predominantly of monkeys, goes after Ravan, defeats him in the war and brings back Sita safely to his place. Though this idea is unique and is said to have been stated about 2000 years ago, this idea has been expressed in various forms like books, comics, drama, TV shows, movies, cartoon movies, children stories, etc. by companies based all over the world all without infringing the original copyright, as well as without infringing on each other's copyrights. This was made possible because of the idea-expression dichotomy considered within the copyright laws. Copyright laws aim to promote and nurture creativity within the society, by granting monopoly rights to the creator for a limited period during the life of the creator as well as limited monopoly of 60 years after his death.

In terms of sustainable manufacturing, copyright serves three functions. The first is that knowledge gets transferred from one individual to the other (during modern times) in the form of written text (unlike during olden days where it was transmitted orally from one person to the other through what was traditionally called as the Shravana system of education), which are protected under copyrights. Transfer of knowledge (or alternatively creation of new knowledge) would be considered as the foundation of economic growth, technological development, as well as the development of the society and the civilization. If the knowledge relating to any field is curtailed through copyrights, then a developing society cannot grow. This becomes all the more pertinent when combined with the second function of the copyrights for this research. Most of the research papers published on sustainable manufacturing would be protected under the copyright laws under the common law system, irrespective of whether they are registered or not. So if somebody wants to adopt the practices described in that article, then the permission of the author would be required. We need to understand how to manage this IP right within the legal framework, while also achieving the SDGs. Third, the producer of sustainable manufacturing techniques would be using the copyright laws to protect his product packaging, the advertisements and other marketing literature including the website where it is described. If others want to use similar packaging, or advertising and other marketing literature, then they have to seek permission of the producer; otherwise, unauthorized usage would be considered as copyright infringement, which in India can be treated as a criminal offence.

4.3.4 Designs

While patents protect the inventions in the field of technology, trademarks protect the distinctiveness of marks, and copyrights protect creative outputs, designs protect only the visual appearance of the finished products. It protects the features of shape, visual configuration, patterns, ornamentation, composition of lines or composition of colours, or a combination of any of these elements. But these elements have to be applied to any article (either in two dimensions or three dimensions or both) using an industrial process (either manual or mechanical or chemical or a combination of these processes). These design elements, once integrated into any article, must be able to produce a visually appealing and a visually unique article. Like patents, designs are to be necessarily registered under the provisions of The Design Act of 2000. Once registered, the designer is protected initially for a period of 10 years, after which it can be renewed only once for a period of 5 additional years.

Design protection is accorded on products (and not services) to encourage creativity of producers to produce visually appealing products, for the overall beautification of the society. However, it is to be remembered that the design protection is granted only for visually appealing design creations. If the design element has some utility, then it must be registered under the patent laws and not under the design laws.

For a discussion of sustainable manufacturing, designs become one of the very important IP rights. For instance, the design of the blades of the wind turbine used to generate electricity from the wind energy could be an important element in determining the quantum of electricity generated by the wind turbine. But without claiming the protection for the utility aspect of the design of the blades under the patent laws, the producer could protect them under the design laws, as it would be visually appealing as well. In such cases, the design rights, especially for the shape of the product as well as the shape of the spare parts, have to be licensed from such producer, in order to be used by others.

4.3.5 Trade Secrets and Confidential Information

As the name suggests, this class of IP rights protect only those information or processes or recipes or formula or data or arrangements that are maintained confidentially within an organization. While above-mentioned IP rights require registration under the specified IP laws, most of which insist on disclosure of the process, logo, copyrighted work, or the design drawings, trade secrets and confidential information (TS&CI) need not be registered with any statutory authority, and there is no legislation governing its registration and infringement in India. An organization can retain TS&CI on certain things (like the recipe for the Coca-Cola beverage)/information (like the source code of a software programme or the customer list) as long as they are maintained as a secret within the organization.

Typically, any information can be maintained as a trade secret. But such information must be sufficiently developed and must be capable of industrial application and for commercial purpose. The basis of seeking protection for the TS&CI is belief. The creator of such information must actively believe that the information has significant commercial value, he must also have a reasonable belief that his competitors/rivals do not possess such information and he must also believe that competitors/rivals would be able to commercially benefit if they get hold of the information. Such beliefs held by the creator of the information must be reasonable as determined by the usage and practices of the industry in question. Once this is determined, the creator must also demonstrate that he has taken reasonable effort to safeguard the information by creating necessary barriers preventing others from accessing such information, and with an intention of maintaining it as confidential information.

Unlike other IP rights, there is no expiry date for the protection of TS&CI. One can consider any information as TS&CI as long as it is not known publicly. But from the moment the information becomes public, the protection of the information under the TS&CI gets lost. Generally, the creator shares TS&CI, under a Non-Disclosure Agreement (NDA) combined with Non-Compete Agreement (NCA). If somebody either discloses the TS/CI after having signed the NDA and NCA, then the person is guilty of breach of contract and would be sued in the civil court for breach of contract. Also, if somebody accesses the TS&CI without authorization and uses it, then such person can be prosecuted for theft of a property under the provisions of the Indian Penal Code.

For the discussion on sustainable manufacturing, one can relate to the fact that the knowledge (which can be communicated) would be protected either as a patent or a design. But all the other information or knowledge which cannot be communicated to general public would be retained as TS&CI. Typically, know-how of assembling machines, or of manufacturing, or of skill sets deriving out of experience of an individual is generally retained as TS&CI. They would be shared only through a licensing agreement, which includes the NDA and NCA clauses therein.

4.3.6 IP Rights in India

IP rights have been recognized and registered in India as early as the 1900s. The patent act was enacted and amended multiple times even before the Indian independence. The trademark and merchandise act was also enacted before independence. Before independence, the IP rights were predominantly registered to protect the economic interests of the colonizers and the foreign citizens. After independence, however, India adopted a more rational approach towards registered the IP rights and became more open in terms of recognizing and registering it for Indian citizens on a non-discriminatory basis. It either scrapped the pre-independence legislations (like in the case of patent act) or amended them to suit the modern requirements.

Intellectual property rights, though a domestic prerogative of the sovereign state of India, is influenced by many international treaties to which India is a signatory. One such treaty, which significantly influences the operation of IP rights, is the Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement, which is a part of the World Trade Organization (WTO) system. India became a signatory to the World Trade Organization (WTO) system in 1996. This TRIPS agreement provides for the context, the scope and the mode of operationalizing the various IP rights, with a view to harmonize the IP laws across countries partnering in international trade. TRIPS agreement, like all the agreements under the WTO was mandatory for implementation and India agreed to fulfil the obligations under it. However, India being a developing country was given a 10 years' time to fully comply with the stipulations of the TRIPS agreement.

Based on the commitments made to the WTO delegation, India amended its various intellectual property legislations, to make it compliant with the TRIPS agreement. The last amendment (before implementation of the TRIPS agreement) was completed just before the deadline of 1st January 2005, to the patent act. Through these amendments, Indian IP legislations are not only made compliant with the TRIPS agreement, they have been enacted to fulfil the social obligations considering the social, demographic, environmental and the economic conditions prevalent in India.

4.4 Sustainable Manufacturing and the International IP Regime

As mentioned earlier, IP rights bestow exclusive privileges upon the rights holder, for a limited period of time during which they can exclude others from using and exploiting the rights bestowed upon them. From an economic sense, this exclusivity makes sense as it helps the creator of such IP rights an opportunity to recoup the investments, in terms of time, effort and money, made towards creating such IP rights. But it is to be remembered that knowledge is not built individually and autonomously; it is built with the help of already existing knowledge in the society. As Isaac Newton once famously said in 1675, 'if I have seen further, it is by standing on the shoulders of the giants', innovation would become possible only if one masters all the literature on the subject created by earlier authors and creators and then internalizing it, and thinking about it from different circumstances prevalent at that point of time using the intelligence and knowledge inherently available with that individual. This would lead us to the conclusion that if the society is deprived access to knowledge, then such a society would be unable to advance in terms of technology, art and culture, and also as a civilization. Also, innovation should contribute positive benefits to the society. If it harms the society in any manner, then the government, who bestows such privileges can withdraw, curtail, modify or cancel such privileges. But such powers have to be granted to the government domestically through legislations, and internationally through treaties to which such government is a signatory.

The TRIPS agreement, which became the primary international treaty governing the IP rights after the WTO, by no means replaced all the existing international treaties and international systems governing the IPR. It makes numerous references to many conventions, treaties and protocols, which were in effect before the WTO, to effectively implement certain provisions relating to IP rights. For instance, it includes the Paris Convention for the Protection of Industrial Property (which primarily deals with patent protection), the Berne Convention for the Protection of Literary and Artistic Works (which deals with copyright protection) and the Madrid Agreement on the Repression of False or Deceptive Indication of Source on Goods (which deal with trademarks) (Stoll, 2009). These conventions, treaties or protocols have been included either as a reference or as an inclusion into the TRIPS agreement (Busche, 2009).

The TRIPS agreement and its administration, as part of the international trading system, provided certain exceptions, either created by itself for the first time or referenced earlier conventions, treaties, or protocols, which were then included and integrated within the TRIPS agreement. Signatories to the TRIPS agreement could use such exceptions to construct provisions within the laws governing individual IP rights to curtail the privileges granted to the IP right holders. Such curtailment could be for socially relevant purposes like human rights (in terms of promotion of right to education, health, life, food, freedom of expression and work), or to promote competition in the country, or to protect the environment (like promoting efficient use of natural resources, restoration and conservation of ecosystems and dissemination of technologies in these aspects). The restrictions that can be imposed varies from the sovereign government cancelling, or withdrawing the privileges so granted, to allowing others to use the IP rights with or without relevant license fees.

The TRIPS agreement provides such exceptions under what are called the 'General Exception Clauses', for various IP rights. For copyrights, the general exceptions are provided under two different articles: Article 9 of TRIPS and Article 13 of TRIPS. Article 9 of the TRIPS states, 'Members shall comply with Articles 1 through 21 of the Berne Convention of 1971 and the Appendix thereto. However, Members shall not have rights or obligations under this Agreement in respect of the rights conferred under Article 6bis of that Convention or of the rights derived therefrom'. Through Article 9, TRIPS has effectively indicated that the provisions of the Berne Convention would apply in matters relating to copyrights.

For patents, the general exceptions are covered under Article 30 of the TRIPS, for designs under Article 17, and for trademarks under Article 26.2 of the TRIPS agreement (Rodrigues, 2012). The provision therein enables the sovereign state to assess and establish provisions within their respective national legislations, and based on its understanding of these aspects, erect relevant safeguards to protect the local fabric and local ethos, which it considers important. This section analyses the general exception clauses provided within the TRIPS agreement and other relevant treaties, conventions and protocols, for patents, copyrights, trademarks and designs and how it has been implemented by India under its various IP-related legislations.

4.4.1 Treaty Interpretation Under the VCLT

Before delving into the specific exclusions, it becomes pertinent to understand a little bit about the principles of treaty interpretation, as governed by the public international law. Though the WTO is a comprehensive regime dealing with matters concerning liberalization of the international trade containing within itself even an exclusive dispute settlement body to deal with interstate trade disputes, it cannot function without adhering to the general principles of the public international law. Even the Dispute Settlement Body of the WTO (DSB) in its *US—Gasoline case* stated that the rules covered within the WTO agreement are not to be read in clinical isolation from public international law (United States—Standards for Reformulated and Conventional Gasoline (U.S. Gasoline Case), 1996).

In order to incorporate the principles of public international law to the provisions of the WTO and in turn the TRIPS agreement, the members came to an understanding, which was documented as the Understanding on Rules and Procedures Governing the Settlement of Disputes at the WTO (which is commonly known as the WTO Dispute Settlement Understanding or the DSU). Article 3(2) of the DSU states '*The Members recognize that it serves to preserve the rights and obligations of Members under the covered agreements, and to clarify the existing provisions of those agreements in accordance with customary rules of interpretation of public international law*'. The principle/rule highlighted by the US Gasoline case has already been recorded within the DSU of the WTO.

When the DSU indicated that the customary rules of interpretation have to be followed, it was referring to Articles 31 and 32 of the Vienna Convention on the Law of Treaties (VCLT), which deal with the principles of interpreting international treaties, especially those rules that were derived from trade customs.[1] Though India

[1]VCLT was concluded on 23th May 1969 and was kept open for signature from that day. It came into effect on 27th January 1980.

is not a signatory to the VCLT, Indian judiciary has been recognizing the principles of VCLT in various disputes with international scope.[2]

Article 31 of the VCLT deals with the general rule of interpretation, while Article 32 of the VCLT deals with supplementary means of interpretation, both of which are applicable to international treaties like the WTO. These two articles of the VCLT are reproduced below for reference:

Article 31: General Rule of Interpretation

1. *A treaty shall be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the treaty in their context and in the light of its object and purpose.*
2. *The context for the purpose of the interpretation of a treaty shall comprise, in addition to the text, including its preamble and annexes:*
   (a) *Any agreement relating to the treaty which was made between all the parties in connection with the conclusion of the treaty;*
   (b) *Any instrument, which was made by one or more parties in connection with the conclusion of the treaty and accepted by the other parties as an instrument related to the treaty.*
3. *There shall be taken into account, together with the context:*
   (a) *Any subsequent agreement between the parties regarding the interpretation of the treaty or the application of its provisions;*
   (b) *Any subsequent practice in the application of the treaty which establishes the agreement of the parties regarding its interpretation; and*
   (c) *Any relevant rules of international law applicable in the relations between the parties.*
4. *A special meaning shall be given to a term if it is established that the parties so intended.*

Article 32: Supplementary Means of Interpretation

Recourse may be had to supplementary means of interpretation, including the preparatory work of the treaty and the circumstances of its conclusion, in order to confirm the meaning resulting from the application of article 31, or to determine the meaning when the interpretation according to article 31:

[2]See, for instance, the cases of Ram Jethmalani vs. Union of India ([(2011) 8 SCC 1]) where it was held that the Vienna Convention codifies many principles of customary international law; AWAS 39423 Ireland vs. Directorate General of Civil Aviation & others ([MANU/DE/0832/2015]), where it was held that the international treaties (including the VCLT) should be interpreted in good faith, in accordance with the ordinary meaning given to the terms of the treaty, in their context and in the light of its stated object and purpose. For more details, see Nagaraj (2015).

(a) *Leaves the meaning ambiguous or obscure; or*
(b) *Leads to a result, which is manifestly absurd or unreasonable.*

Article 31 provides that while interpreting any treaty, not only the text of the treaty combined with the preamble and annexes to that treaty should be used, but any agreements entered between the party in finalizing that treaty, and any instrument finalized by the parties and agreed to be a part of the treaty, should also be considered. In addition to this, any agreements or practices that have been agreed between the parties for implementation should also be considered to be relevant along with the relevant rules of international law applicable between the parties. Article 32 provides that, if there are ambiguities in terminology at the time of interpretation, then the discussions, preparatory work at the time of initializing the treaty, the circumstances existing at the time of its conclusion can be referred for interpretation.

4.4.2 Interpreting the Objectives of the WTO and the TRIPS Agreements

Based on the principles under Articles 31 and 32 of the VCLT, we could analyse the preamble, objectives, annexes, etc. relating to WTO, to understand why the WTO for brought into existence and what it tries to achieve through its operations. It needs to be remembered that the WTO was established at the conclusion of the Uruguay Round of multilateral trade negotiations, and was finalized through what is known as the Marrakesh Agreement. Article II(2) of the Marrakesh Agreement states that '*The agreements and associated legal instruments included in Annexures 1, 2, and 3 (hereinafter referred to as "Multilateral Trade Agreements") are integral parts of this Agreement, binding on all Members*'. The TRIPS agreement is contained in Annexure 1(c) of the Marrakesh Agreement, and hence, the objectives set for the WTO becomes relevant for our discussion.

The objectives of the WTO are enshrined in its preamble, which is reproduced as below:

'The Parties to this Agreement,

Recognizing that their relations in the field of trade and economic endeavour should be conducted with a view to raising standards of living, ensuring full employment and a large and steadily growing volume of real income and effective demand, and expanding the production of and trade in goods and services, while allowing for the optimal use of the world's resources in accordance with the objective of sustainable development, seeking both to protect and preserve the environment and to enhance the means for doing so in a manner consistent with their respective needs and concerns at different levels of economic development.

Recognizing further that there is a need for positive efforts designed to ensure that developing countries, and especially the least developed among them, secure a *share in the growth of international trade commensurate with the needs of their economic development,*

Being desirous of contributing to these objectives by entering into reciprocal and mutually advantageous arrangements directed to the substantial reduction of tariffs and other barriers to trade and to the eliminations of discriminatory treatment in international trade relations,

Resolved, therefore, to develop an integrated, more viable and durable multilateral trading system encompassing the General Agreement on Tariffs and Trade, the results of past liberalization efforts, and all of the results of the Uruguay Round of Multilateral Trade Negotiations,

Determined to preserve the basic principles and to further the objectives underlying this multilateral trading system,

Agree as follows:'

On a quick analysis of the preamble, the objectives of the WTO can be listed as below:

a. Raising the standards of living of the population of all the members of the organization;
b. Ensuring full employment;
c. Steadily increasing the real income and effective demand for services and goods;
d. Expanding the production of and trade in goods and services;
e. Promoting the use of natural resources in accordance with the objective of sustainable development;
f. Protecting and preserving the environment;
g. Enhancing the means to protect and preserve the environment, in a manner consistent with the needs and interests of the WTO members and in accordance with the different levels of economic development;
h. Promoting 'positive efforts designed to ensure that developing countries, and especially the least developed among them, secure a share in the growth in the international trade commensurate with the needs of their economic development;
i. Substantially reducing tariffs and non-tariff barriers to international trade; and
j. Creating a multilateral secure and predictable trade system.

With respect to sustainable manufacturing, the objectives e, f and g become very relevant, as they try to protect and preserve the environment and natural resources with an intention of attaining sustainable development. Not only that, the WTO is required to ensure such protection standards, as determined by the member states, as long as they are not conflicting with the principles of international trade as governed by the WTO. This means that every individual signatory to the WTO can set their own environmental standards and sustainability standards, as long as they do not conflict with the WTO provisions. Article III (1) of the Marrakesh Agreement also states that '*The WTO shall facilitate the implementation, administration, and operation, and further the objectives of this Agreement and of the Multilateral Trade Agreements*'. So the role of the WTO is to implement the objectives enshrined in its preamble, which in turn includes, not just promoting international trade in goods and services, but also in ensuring that the environment and natural resources of the member countries are safeguarded, with an intention to achieve sustainable development.

Having understood the objectives of the WTO as listed in the preamble to the Marrakesh Agreement, we should try to understand the objectives of the TRIPS agreement. Articles 7 and 8 of the TRIPS agreement along with the preamble to the TRIPS agreement establish the objectives of having the TRIPS agreement. The preamble of the TRIPS agreement is provided below.

'*Members,*

Desiring to reduce distortions and impediments to international trade, and taking into account the need to promote effective and adequate protection of intellectual property rights*, and to ensure that measures and procedures to enforce intellectual property rights do not themselves become barriers to legitimate trade;*

Recognizing, to this end, the need for new rules and disciplines concerning:

(a) *The applicability of the basic principles of GATT 1994 and of relevant international intellectual property agreements or conventions;*
(b) *The provision of adequate standards and principles concerning the availability, scope and use of trade-related intellectual property rights;*
(c) *The provision of effective and appropriate means for the enforcement of trade-related intellectual property rights, taking into account differences in national legal systems;*
(d) *The provision of effective and expeditious procedures for the multilateral prevention and settlement of disputes between* government*s; and*
(e) *Transitional arrangements aiming at the fullest participation in the results of the negotiations.*

Recognizing the need for a multilateral framework of principles, rules and disciplines dealing with international trade in counterfeit goods;

Recognizing that intellectual property rights *are private rights*;

Recognizing the underlying public policy *objectives of national systems for the protection of* intellectual property*, including developmental and technological objectives;*

Recognizing also the special needs of the least-developed country Members in respect of maximum flexibility in the domestic implementation of laws and regulations *in order to enable them to create a sound and viable technological base;*

Emphasizing the importance of reducing tensions by reaching strengthened commitments to resolve disputes on trade-related intellectual property issues through multilateral procedures;

Desiring to establish a mutually supportive relationship between the WTO and the World Intellectual Property *Organization (referred to in this Agreement as "WIPO") as well as other relevant international organizations;*

Hereby agree as follows:'

Article 7 of the TRIPS agreement is titled as Objectives: '*The protection and enforcement of intellectual property* rights *should contribute to the promotion of technological* innovation *and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge and in a manner conducive to social and economic welfare, and to a balance of rights and obligations*'.

Article 8 of the TRIPS Agreement is titled as Principles: '*1. Members may, in formulating or amending their laws and regulations, adopt measures necessary to protect public health and nutrition, and to promote the public interest in sectors of vital importance to their socio-economic and technological development, provided that such measures are consistent with the provisions of this Agreement.*

2. Appropriate measures, provided that they are consistent with the provisions of this Agreement, may be needed to prevent the abuse of intellectual property rights by right holders or the resort to practices which unreasonably restrain trade or adversely affect the international transfer of technology'.

A quick reading of the preamble of the TRIPS agreement along with Articles 7 and 8 would help us understand that some of the important objectives that the TRIPS agreement tries to achieve are as follows:

a. Promote effective and adequate protection of IP rights.
b. Ensure that IP rights do not become barriers to trade.
c. Promote technological development using IP systems, while considering the technological and developmental objectives of the member countries.
d. Contribute to the promotion of technological innovation.
e. Transfer and dissemination of technology.
f. Contribute towards mutual advantage of producers and users of technological knowledge.
g. Lead to social and economic welfare: where it covers the protection of human rights as guaranteed by various international instruments like the International Covenants on Human Rights of 1966.
h. Establish balance of rights and obligations: For the purposes of international treaties, balance of rights are generally understood to mean the alignment of moral and economic rights resulting from any scientific, literary, or artistic production held by the holders of IPRs with: that of the right to 'take part in cultural life', the right to 'enjoy benefits of scientific progress and its applications', and with the right to 'the freedom indispensable for scientific research and creative activity' (Rodrigues, 2012). The socio-economic welfare and IPR is another conflicting area, which should be balanced, by carving specific exceptions to the rights of IPR holders with an intention to protect the socio-economic, which in turn would include socio-environmental concerns of the member nations. Similarly, the interests of the developed nations and that of the developing nations would be the other aspect that needs to be balanced: while developed nations want their IP rights to be protected, developing nations, on the other hand, would like to have the technology transferred to their domain, in order to achieve technological development/advancement. Thus, these

potential conflicts have to be balanced by considering their respective rights and obligations, with an intention of promoting the general well-being of all the parties to the agreement.

i. While formulating the legislations compliant with the TRIPS agreement, the member nations may focus on maintaining the public health and nutrition, and promote policies which advance public interest in terms of socio-economic and technological development, provided that such policies are consistent with the general provisions of the Agreement, as well as the general provisions of the WTO system.
j. Prevent abuse of IP rights by the innovators and the IP right holders.
k. Prevent practices that 'adversely affect the international transfer of technology.

What emerges from these objectives is that while protecting the economic interests of the innovators are fundamentally guaranteed, if such economic rights conflict with the socio-economic, socio-environmental, as well as developmental goals of the member country, then exceptions could be carved out for curtailing such economic rights of the innovators. The freedom and the flexibility available to the members of the WTO system to decide on carving out exceptions and the circumstances under which they could be activated should also be provided either by the WTO system or by the TRIPS agreement, or by any other agreement/treaty which led to the creation of the WTO system (as provided by the Article II (2) of the Marrakesh Agreement). Incidentally, Article XX of the General Agreement on Tariffs and Trade (GATT), which is considered to be the predecessor of the WTO, and which has been specifically included as part of the WTO, provided a General Exceptions Clause, which is as follows:

'*Subject to the requirement that such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade, nothing in this Agreement shall be construed to prevent the adoption or enforcement by any contracting party of measures:*

(a) *Necessary to protect public morals;*
(b) Necessary to protect human, animal or plant life or health;
(c) *[…]*
(d) *Necessary to secure compliance with laws or* regulations *which are not inconsistent with the provisions of this Agreement, including those relating to customs enforcement, the enforcement of monopolies operated under paragraph 4 of Article II and Article XVII, the protection of* patents, *trademarks and copyrights, and the prevention of deceptive practices. […]*' (emphasis added)

Article XX of the GATT provides that the member states can carve out exceptions to the protection of IP rights, in order to protect public morals, and to protect human, animal, or plant life, or health which are considered necessary for the social-economic, and socio-environmental needs of the member state, provided such exceptions are primarily consistent with the provisions of the WTO system as well as the TRIPS agreement. But the critical word is '*necessary*' whose meaning is not only ambiguous, but could also spread within a large spectrum of meanings, and might change according to circumstances. Thus, the WTO DSB took upon itself the task of clarifying the meaning of the word '*necessary*' used in Article XX of the GATT, in the *Korea—Beef case*. It stated, '*As used in Article XX (d), the term "necessary" refers, in our view, to a range of degrees of necessity. At one end of this continuum lies "necessary" understood as "indispensable"; at the other end, is "necessary" taken to mean as "making a contribution to". We consider that a "necessary" measure is, in this continuum, located significantly closer to the pole of "indispensable" than to the opposite pole of simply "making a contribution to*"'. (Korea—Measures Affecting Imports of Fresh, Chilled and Frozen Beef (Korea—Beef Case), 2001).

The WTO DSB has clearly indicated that the measures that need to be protected should be of an indispensable nature, and only in such circumstance can the exception carved out could be justified. If on the contrary, there are competing needs causing a friction within the policy debate, then the State deciding on the policy framework should ensure that all such competing needs are attained to the highest possible extent.

Complying with the provisions of the GATT, as well as the objectives set by the preamble as well as the articles relating to the objectives of WTO and the TRIPS agreement, the TRIPS agreement enables its member states to carve out three types of exceptions to the IP rights: The first is the admissibility exception, the second is the compulsory licensing, and the third is the actions considered as non-infringement. The *admissibility exception* is to be considered and included in the IP legislations based on the socio-economic, socio-environmental and socio-cultural factors prevalent in the country, after due consideration is paid to the technological and development goals set for the country. This exception determines what gets protected within the IP system of the country. For instance, within the patents act, the legislation could determine what kinds of inventions do not get protection under the patent regime of the country, or in the case of trademarks, certain kinds of marks are excluded from being protected as trademarks (which would vary from country to country). The *compulsory licensing exception* is prevalent in almost all the IP legislations. This is a system, where under certain circumstances, the government (which is the granting authority for the IP rights) forces the IP rights holder to license the IP rights to a third party (typically against his will), for failing to meet certain criteria. The government can also fix the license royalty rate, which could be substantially lower than the market rate for the innovation. The *non-infringement exception* is generally effected in the IP legislation where it provides a list of actions (which are otherwise considered as infringing actions) that might not be considered as infringement, as per the provisions of the legislations. This list might be prepared after due consideration of the circumstances and social conditions prevalent within the country. But these exceptions are to be permitted by the TRIPS agreement.

Though the TRIPS agreement does not generally provide for these categories of exceptions within itself, it authorizes them, based on the general provisions of the agreement. Also, it authorizes the use of these exceptions, based on the principles laid down under the five general exception clauses within itself (Articles 9(2) of the Berne Convention, 13, 17, 26(2), and 30 of the TRIPS agreement). These exceptions provide the sum, substance and the function of the general exception clause, which provides the circumstances under which the above-mentioned three categories of exceptions could be activated by a member state. All these three clauses are similar in nature. They provide for a three-step test (which would be discussed later), which should be cumulatively fulfilled by any member state, while carving out exceptions in their domestic legislations. Also, it is to be noted that if the domestic legislation does not meet these requirements, then they would fail in complying with the provisions of the TRIPS agreement and in turn the WTO system, which could then be taken up by the aggrieved member nation as a dispute to the DSB.

Beyond the provisions highlighted above, it should also be noted that any provision adopted by the member state of the WTO system has to fulfil the consistency standard provide within the TRIPS agreement. It means that the provisions so adopted and implemented in their domestic legislations should be consistent across all other members of the WTO. These principles of consistency are the Most-Favoured Nation principle (MFN) (governed under Article 4 of the TRIPS agreement) and the principle of National Treatment (governed under Article 3 of the TRIPS agreement). While the former states that a member state should treat all its international trade partners equally without prejudice, the latter states that a member state should ensure that a foreigner must receive no less favourable treatment than what is conferred on its own national.

Having understood the objectives of the WTO system as well as the TRIPS agreement along with the provisions relating to the creation of exceptions permitted under these two agreements, we then need to understand the principles governing the creation of exceptions specifically for the copyrights, patents, trademarks and the designs, as elaborated by the TRIPS agreement and its related agreements and systems. A separate discussion becomes necessary given the fact that the principles applicable there are significantly different from one another, while still adhering to the general principles elaborated in this subsection. The next subsections would examine these individual IP rights separately.

4.4.3 Exceptions for the Copyrights

As discussed earlier, a society advances by advancing its knowledge, its culture, as well as its technological development. A nation can achieve these three ideals only under the purview of the copyrights legislations. Knowledge, which is created by the authors and the creators, should become easily accessible to everyone without much of difficulty in terms of technical barriers (creating a scenario of non-availability) and financial barriers (creating a scenario of non-accessibility). Copyright legislations provide for the economic and moral rights of the authors and the creators. But it is to be remembered that these rights are not sacrosanct, and the sovereign state enacting legislations for protecting them also have the right to carve out exceptions to these rights, as granted to it by the TRIPS agreement and other treaties, conventions and protocols, as discussed in the previous subsections. This subsection of this chapter discusses the provisions available under various international treaties including the TRIPS agreement to carve out necessary exceptions to the grant of copyrights.

Apart from fulfilling the regular requirements like the most-favoured nation treatment and the principle of national treatment, the copyright legislations enacted by the member states should fulfil the requirements provided within the From the point of copyrights, it is to be remembered that Article 8 of the TRIPS provides for adopting measures '*necessary for the conservation, the development and the diffusion of science and culture*'. Similarly, the International Covenant on Economic, Social, and Cultural Rights (ICESCR),[3] which work towards the granting of economic, social and cultural rights like the right to education, right to adequate standard of living, and right to health, provides in its article 11(1) that the goal of this international covenant is to work towards 'raising standards of living of individuals'. Combining these provisions with the WTO's goal of optimizing the use of world resources (in order to achieve sustainable development) would insist that resources need to be conserved by preventing duplication of research activities and sharing the research in a viable manner. With these guiding principles, the Berne Convention as well as the TRIPS agreement has carved exceptions from the rights accruing to the creators and the artists.

As mentioned earlier, the general exceptions to the copyright are governed by two articles: Article 9(2) of the Berne Convention and Article 13 of the TRIPS agreement. The relevant portion of these articles is produced below:

Article 9 of the Berne Convention—Right of Reproduction:

(1) *[…]*
(2) *It shall be a matter for legislation in the countries of the Union to permit the reproduction of such works in certain special cases, provided that such reproduction does not conflict with a normal exploitation of the work and does not unreasonably prejudice the legitimate interests of the author. […]*

Article 13 of the TRIPS Agreement—Limitations and Exceptions:

Members shall confine limitations or exceptions to exclusive rights to certain special cases, which do not conflict with a normal exploitation of the work and do not unreasonably prejudice the legitimate interests of the right holder.

Both these provisions are almost similar in structure and interpretation. This is because the provisions of the Berne Convention, which was finalized in 1886, inspired Article 13 of the TRIPS. It provides that the member states can enact legislations limiting the scope of copyright and allowing persons other than the

[3]This was adopted by the United Nations General Assembly on the 16th December 1966 and came into effect on 3rd January 1976. India is a signatory to this Covenant and has also ratified it.

creators and artists to reproduce the copyrighted work, if such provisions do not impede the normal economic rights of the authors and creators to exploit the works. As mentioned earlier, these two provisions have three steps which have to be cumulatively fulfilled by the member state, in order to be able to justify any kind of exception enacted under the IP legislation.

The first step requires that the member states can carve out exceptions to copyrights (either in the form of limitations or exceptions) only in certain special cases. It is understood that these special cases would be governed by Article 8 of the TRIPS agreement as well as the special exemption clauses of the Berne Convention, viz. for education, access to information and knowledge, freedom of expression, preservation and protection of the environment as well as the advancement of sustainable development.

The second step mandates that the exceptions can be carved out, if they are not in conflict with the normal exploitation of the copyrighted work by the owner of the copyright. In this step, understanding the meaning of the phrase normal exploitation of the copyrighted work become very critical to understand the implications of this step. Normal exploitation would generally mean commercial exploitation of the work, but that does not include the scenarios where individual/institutions are unable to pay for such work, or if no market exists for such works, as well as if the copyright holder is capable and competent enough to supply the work in adequate quantities or not. Also, one needs to look at achieving the objectives set forth by the WTO, the TRIPS agreement, the Berne Convention as well other international treaties, etc., which have determined the scope of the copyrights. In such cases, the normal exploitation would require that a market exist, the consumers are capable of paying for such works, adequate quantities of the copyrighted works are made available to the consumers of that work, and that the exploitation should also be advancing the objectives like promoting continuous creation and wider dissemination of new works, while also expanding the society's stock of knowledge with an intention to achieve material, cultural and spiritual progress (Rodrigues, 2012, at pp. 131–133). It should also consider if the copyright holder ensure.

The third step stipulates that such exceptions carved out, should also not unreasonably cause any prejudice to the legitimate interests of the rights holders. Here, when we talk about legitimate interests, it is generally understood to mean commercial interests, which naturally leads one to conclude that moral rights are not included within the ambit of legitimate interests of the rights holders. As mentioned earlier, moral rights cannot be separated from the creator, and hence, separating it as a carve-out from the copyright is not possible. Only the economic rights can be separated from the rights holders (which could include non-creators as well). Hence, as the persons holding legitimate economic rights on the copyrighted works, they can seek to recover the investments made towards the creation of the work as well as earn sufficient profits beyond the investments, while also raising sufficient resources to finance new creative activities. Simultaneously, they also have the right to ensure that they have access to the copyrighted works of others for creating future creative works.

4.4.4 Exceptions for the Patents

While the copyrights related to literary and artistic works relevant from the perspective of dissemination of knowledge and culture within a particular country, the patent actually deals with the technology relevant for technological advancement of a country. When innovative people come up with inventions in fields of technology, they are necessarily pushing the boundaries of technological development in that country. These inventions once protected under patents for a limited period of time would ensure that the inventor or his assignee is provided with sufficient opportunity to recover the investments made towards that invention (investments in terms of time, effort and money). Once the patent expires, the knowledge about the invention moves to the public domain thereby enabling others to follow that invention, while also enabling them to make their own modifications to it and internalize it. This way, the patents actually help the technological advancement in the country. But patents being a monopoly right granted by the government could also be inhibiting such technological advancement. In order to promote it, countries need to have powers to carve out necessary exceptions in the patent regime, thereby facilitating the grant of compulsory licenses, withdrawal of patent rights granted earlier, and also be excluding certain technologies from being patented, based on the priorities of that country.

As discussed earlier, the TRIPS agreement, in combination with other international treaties, has provided the guiding principles that can be followed while carving out necessary exceptions in the patent acts. Article 30 of the TRIPS states, '*Members may provide limited exceptions to the exclusive* rights *conferred by a patent, provided that such exceptions do not unreasonably conflict with a normal exploitation of the patent and do not unreasonably prejudice the legitimate interests of the patent owner, taking account of the legitimate interests of third parties*'. Like the exception discussed under copyrights, this exception is also a three-step test, which has to be cumulatively fulfilled by the member states, while justifying the exceptions carved out from patents.

1. First step: '*Members may provide limited exceptions to the exclusive rights conferred by a patent* […]': Under this, '*limited exceptions*' is to be critically analysed and understood. Article 28(1) of the TRIPS (stated below) enables that the patentee has the right to prevent unauthorized manufacturing, using, offering for sale, selling or importing the patented technology within the jurisdiction of the member state. This is the legitimate right of all the patentees. If such legitimate right has to be curtailed, then the exceptions carved out should only be limited. The word limited can mean 'confined to certain limited', which could be interpreted to have limitation on the extent of the rights, or limited in quantity. But in the case of *US—Wool Shirts and Blouses*, the DSB indicated that the phrase 'limited exceptions' should be interpreted it as the former, limitation on the extent of the rights.

2. Second step: '[…] *provided that such exceptions do not unreasonably conflict with a normal exploitation of the patent* […]': The normal modes of exploiting a patent right is provided in Article 28(1) of the TRIPS. It states, '*A patent shall confer on its owner the following exclusive* rights*: (a) where the subject matter of a patent is a product, to prevent third parties not having the owner's consent from the acts of: making, using, offering for sale, selling, or importing for these purposes that product; (b) where the subject matter of a patent is a process, to prevent third parties not having the owner's consent from the act of using the process, and from the acts of: using, offering for sale, selling, or importing for these purposes at least the product obtained directly by that process*'. If the member state has to carve out exceptions to the patent act curtailing the rights of the patent holder, then the State must ensure that it does not significantly jeopardize the rights stipulated under Article 28(1) of the TRIPS agreement. While deciding on the extent to which such legitimate interests have to be protected and while carving out exceptions, principles like identifying the degree of protection of the legitimate objectives pursued by such exceptions; the extent of control exercised by the patent holder on the patented invention and the degree of restriction envisioned by the State; and exploring the alternative modes of protection available which would guarantee the rights provided under Article 28(1) should be followed (Rodrigues, 2012, at p. 103).
3. Third step: '[…] *and do not unreasonably prejudice the legitimate interests of the patent owner, taking account of the legitimate interests of third parties*'. This step is one of the most difficult steps to assess, as it stipulates that two conflicting rights have to be balanced in a reasonable manner. The state while deciding on granting exceptions to the patent right should carry out a comparative assessment of the legitimate interests of the patent holder that might be harmed by such exception and the legitimate interests of the third parties who might gain by such exception and based on the balance of convenience, the decision to curtail the rights of the patent holder have to be taken.

Besides the provisions of Article 30 of the TRIPS, any exception so carved out, is also required to fulfil the general requirements provided under TRIPS, which are listed below:

1. It patent act must comply with the principles of most-favoured nation and the national treatment.
2. It should protect all kinds of inventions that are listed out under TRIPS. This is covered under Article 27(1) of TRIPS, which obligates that the member states protect inventions in all fields of technology, provided such inventions fulfil all the requirements of patentability (like novelty, nonobviousness and utility, the standards of which the individual member states are free to decide). But under the provisions of Article 27(2) and (3), the member states are also free to exclude protection to certain controversial matters like plants and animals; genetic material; biological processes; diagnostic, therapeutic and surgical methods for treatment of humans or animals; inventions that does not meet the

local standards of public order or morality; including to protect the human, animal, or plant life or health or to avoid serious prejudice to the environment (Rodrigues, 2012, at p. 67).

3. It should provide protection to the invention for a minimum of 20 years, or as stipulated under the TRIPS agreement (as provided under Article 33 of the TRIPS).
4. It should following the requirements stipulated for compulsory licensing, including the fields that can be granted compulsory licenses, and the process to be followed thereof before such grant, as provided under Article 31 of the TRIPS. This stipulates that compulsory licensing can be granted by the member states generally to promote the exploitation of the patent, either by the state or by third parties authorized by the State, especially in the case of national emergency or non-commercial public use. Also, if the foreign patentee does not have the localized manufacturing capabilities to produce the patented pharmaceutical product, the also the State can grant compulsory licenses.
5. Article 31(1) of the TRIPS also empowers the states to enact legal provisions to prevent ever-greening of patents (especially in the case of pharmaceutical, biotechnological and chemical patents), wherein it can either prevent such inventions from being patented, or it can grant compulsory licenses of such inventions along with the earlier patent.
6. It should also comply with the principles of non-discrimination based on national origins, the field of technology and the manner of exploitation of the invention.

This subsection provides the summary of all the rules and principles provided by the TRIPS agreement, which can be followed by the member states while carving out the exceptions that limit the rights of the patent holders. Such exceptions, as mentioned earlier, could be in the form of excluding certain inventions from the protection of patents; restrictions the rights of the foreign patentee if he does not manufacture the patented invention locally; restrictions imposed in terms of compulsory licensing; and also classifying certain actions as non-infringement of the patentee's rights. Such exceptions can be justified on the basis of larger benefits to the society in terms of promoting scientific progress; human rights; as well as protecting the lives of human beings, animals and plants; as well as protecting the environments (the last two in order to achieve sustainable development objectives accepted by the country).

4.4.5 Exceptions for the Trademarks

Trademarks protect the distinctive identity of the goods and services belonging to one company from that of others. It can be represented in various forms, which includes marks, logos, art, shapes, sounds, colours, etc. If two companies have the same mark for their products and services (also in the same category), then the consumers would get confused as to the origin of the goods and services, if they are keen about having quality products. In order to prevent such situations, the trademark laws provide for protection against infringement.

Sometimes, companies could copy either the name or the mark belonging to others and use it on products, which are dissimilar to the product of the owner of the mark. Such instances are known as passing off in the trademark law. Trademark law, generally speaking, allows such actions, as the consumers would not be deceived about the origin of the goods and services. But the trademark is a well-known mark then the court would prevent such actions, as it would affect the reputation of such well-known marks.

Similarly, usage of trademarks by civil society organizations, including the media, is another instance where the rights of the trademark owner might adversely affected and might lead to a cause of action for infringement. The TRIPS agreement tries to address these and other issues through the exceptions clause covered under Article 17, which is reproduced below:

Article 17: Exceptions*: Members may provide limited exceptions to the rights conferred by a trademark, such as fair use of descriptive terms, provided that such exceptions take account of the legitimate interests of the owner of the trademark and of third parties.*

As can be observed, the exception clause of Article 17 is similar to that of Article 30 discussed above. Again, this has the same three steps, which again follows a similar line of justification as discussed above under the section on patents. But the rights do not come from Article 27 of the TRIPS, but rather come from Article 16 of the TRIPS. Article 16(1) states what kinds of rights are granted under the trademark laws. It indicates that the member states should grant exclusive distinctive identity, and ensure that the marks do not cause confusion in the minds of the consumers. Article 16(2) requires that the member states follow the procedures provided under the Article 6bis of the Paris Convention of 1967 in interpreting what well-known marks are how they should be treated and judged in litigation. Article 6bis of the Paris Convention is reproduced below for reference:

Article 6bis: Marks—Well-known Marks: *(1) The countries of the Union undertake, ex officio if their legislation so permits, or at the request of an interested party, to refuse or to cancel the registration, and to prohibit the use, of a trademark which constitutes a reproduction, an imitation, or a translation, liable to create confusion, of a mark considered by the competent authority of the country of registration or use to be well known in that country as being already the mark of a person entitled to the benefits of this Convention and used for identical or similar goods. These provisions shall also apply when the essential part of the mark constitutes a reproduction of any such well-known mark or an imitation liable to create confusion therewith. (2) A period of at least five years from the date of registration shall be allowed for requesting the cancellation of such a mark. The countries of the Union may provide for a period within which the prohibition of use must be requested. (3) No time limit shall be fixed for requesting the cancellation or the prohibition of the use of marks registered or used in bad faith.*

This article mandates that, if the owner of a well-known mark makes an application for cancellation of a mark, which is being used on identical or similar goods within a period of 5 years of registration of the mark, then the member states shall accept such application and honour it by cancelling such registration. But before cancellation, the member state or the judiciary has to ensure that the passing off has substantially been justified. Such cancellation of trademarks could amount to revocation of a trademark, which would be a legal exception carved out within the trademark legislation.

Based on these and other provisions of the TRIPS agreement and other international treaties, the principles to be followed by the member states while carving out exceptions to the trademark laws are listed below:

1. The trademark law must comply with the principles of the most-favoured nation and the principle of national treatment (Article 3 and 4 of the TRIPS);
2. It must ensure that the trademarks are protected for a period of not less than 7 years and must enable its renewal indefinite number of times (Article 18);
3. It must not allow compulsory licensing of trademark (Article 21);
4. Trademarks must be registered only if it meets the requirements of Article 15 of the TRIPS agreement (it insists on identifying the distinctiveness of the mark); and
5. It must enable utilization of the mark on the goods and services by the company, and also enable the company to license and assign the trademark to others (Article 21).

4.4.6 Exceptions for the Designs

Designs protect the look and feel of the articles, which are used primarily for commercial purpose. It protects the visual appeal of those articles. Such visual appeal could comprise the shapes, contours, lines, colours, ornamentations, embellishments or any combination of these items. The design act generally prevents others from using such shapes, etc., which are similar or substantially similar to the one registered by the owner of the design.

Article 26 of the TRIPS agreement provides for the protection for such visually appealing elements incorporated on goods used for commercial purpose and the limitations thereof. While Article 26(1) describes the rights of the owner of the design, Article 26(2) provides the exceptions to those rights. Article 27 is reproduced below:

Article 26: Protection

1. *The owner of a protected industrial design shall have the right to prevent third parties not having the owner's consent from making, selling or importing articles bearing or embodying a design which is a copy, or substantially a copy, of the protected design, when such acts are undertaken for commercial purposes.*

2. *Members may provide limited exceptions to the protection of industrial* designs, *provided that such exceptions do not unreasonably conflict with the normal exploitation of protected industrial designs and do not unreasonably prejudice the legitimate interests of the owner of the protected design, taking account of the legitimate interests of third parties.*
3. *The duration of protection available shall amount to at least 10 years.*

As can be seen, Article 26(2) is very similar to the exceptions discussed under the copyrights, patents and trademarks. It provides for a similar three-step test to be followed by the member states at the time of carving out exceptions to the design protection. This clause should again be interpreted in line with the ones described for copyrights, patents, and trademarks. Also, consideration should be given to the objectives of the TRIPS agreement and other international treaties, along with the general principle of the TRIPS agreement relevant for designs. One additional condition stipulated specifically for designs is by Article 25(2) of the TRIPS which states that the designs on textile fabrics should also be protected under designs.

4.5 IP Policy Strategies Adopted by India for Sustainable Manufacturing

In the previous section, we have understood the principles that need to be followed while enacting exceptions to the IP rights, as available in the international treaties like TRIPS, the WTO system, as well as other treaties, conventions and protocols. In this section, we would highlight how India has complied with the principles of general exceptions while enacting its respective IP legislations.

4.5.1 Policy Strategies for Copyrights

The exceptions to copyrights can be carved out by the member states of the TRIPS agreement only on fulfilling all the above-mentioned criteria. On a quick analysis of the Indian Copyright Act of 1957, as amended by Copyright (Amendment) Act of 2012, we can identify that most of the stipulations provided within the WTO and TRIPS have been fulfilled. It has created all three kinds of exceptions as part of this legislation. Under section 13, it defines what are copyrighted works and lists out various categories of creative and artistic work, which can be protected under copyrights. The same section, by reference to Section 40 and 41 of the Act, also specifies that the works of international artists and creators are extended copyright protection in India, thereby ensuring that the requirements of Most-favoured nation and the national treatment conditions of the TRIPS are fulfilled. Under Section 13, certain works are exempt from copyright, which includes international orphan works, unpublished works and certain kinds of literary, dramatic or musical works.

Under Sections 31 to 32B (which includes eight separate sections 31, 31A, 31B, 31C, 31D, 32, 32A and 32B), provisions relating to compulsory licensing of copyrighted works are dealt with. On a quick reading of these sections, we can make out that compulsory licensing can be applied for and granted by the copyright office only on fulfilling the conditions like the copies are not available or are not made available by the rights holder; the copies are not available at reasonable price, for translation and the copies are not made available to disabled persons. In order to be eligible to apply for compulsory licensing, the applicant should have tried to seek normal license from the rights holder and he should not have succeeded. And once the compulsory license is granted, the licensee should agree to pay a reasonable royalty fixed by the copyrights office. Once a compulsory license is granted, he is not allowed to sublicense it, nor make unreasonable and unstipulated exploitation of the copyrighted works.

Similarly, Section 52 of the Act provides for a list of acts not considered as infringement of copyrights (it is one of the longest sections of the Act). It states that copying a copyrighted work for purposes like private personal use, private research, criticism/review of the copyrighted work, using the copyrighted work as part of teaching it to a small group of audience, reproducing the work for judicial purposes, using it as part of the education (in question papers, presentation material, handouts, etc. to small group of students), presenting it as part of a small public gathering, reproducing in newspaper on the topic, making three copies of the book to be used in a non-commercial public library (if such book is not available for sale in India), making a drawing or a painting of an architectural work, and so on. These exceptions ensure that the socio-economic, socio-environmental, as well as cultural and developmental needs of the country are attained to the extent possible.

Through these sections, India IP policy has integrated the provisions of the TRIPS and other related international treaties dealing with copyrights.

4.5.2 Policy Strategies for Patents

The Patents Act of 1970 was the principle legislation governing the patents in India. But on becoming a part of the WTO system in 1996, India took upon itself to amend its patents legislation to make it compliant with the provisions of the TRIPS. It made a series of amendments starting from 1996, 1998, 1999, 2003 and the final one was in 2005, which became effective from 01st January 2005 (which was the deadline for Indian patent legislation to become compliant with the TRIPS agreement). The current Patents Act is the Act of 1970 as amended in 2005 (Act).

While making these amendments to the Act, the Indian government ensured that the amendments were in full compliance with the TRIPS agreement as well as all other international treaties that it has signed. Consequently, the provisions that were included in the patents act considered all the above-mentioned aspects and provided for all the three kinds of exceptions: the non-patentable inventions category, the compulsory licensing category, as well as the acts not considered as infringement category.

The provisions relating the non-patentable inventions are covered under Sections 3 and 4 of the Act. Section 3 excludes a lot of inventions from being patented like the inventions relating to plants and animals, human beings and microorganisms; methods of agriculture, horticulture and pisciculture; methods of medicinal, surgical, curative, diagnostic and therapeutic techniques; any invention which is frivolous or which claims anything obvious or contrary to natural laws; inventions whose primary or intended commercial use is contrary to public order or morality, or which causes serious prejudice to human, animal or plant life or health, or to the environment; mere discovery of a scientific principle or the formulation of an abstract theory or discovery of any living thing or nonliving substance occurring in nature, etc. Section 4 excludes inventions relating to arms, ammunitions and nuclear material from being patented in India (as it is reserved as a sovereign prerogative).

Section 3(d) prevents ever-greening of patents, by stating that mere discovery of a new form of known substance, which does not result in enhancement of the known efficacy of the substance (especially in the pharma, chemical and biotechnology fields), thereby preventing frivolous inventions.

Sections 83 to 94 deal with provisions relating to compulsory licensing and local working of the patent. These sections stipulate that the foreign patentee should establish sufficient manufacturing capabilities (either on own or through contract manufacture), without which the government can permit domestic companies to manufacture the patented invention within India. But the grant of compulsory license is neither automatic nor easy. The applicant seeking compulsory license should have contacted the patentee for a regular license and the patentee should have rejected his proposal. A period of 3 years should have expired from the date of the grant of patent, and the applicant should demonstrate that he has the necessary competency and capabilities to start manufacturing the patented inventions immediately after the grant of the compulsory license. Once these conditions (as stipulated by the TRIPS agreement) are fulfilled, then the government (through the office of the Controller of Patents) would grant a license to manufacture the patented invention by the applicant, in return of a reasonable royalty fixed by the Controller.

Similarly, Sections 99 to 102 deals with acquisition of patents by the government for government use. These sections provide that if the government finds that the invention is critical from the perspective of national interest, then it can acquire the patentee from the patentee in return for a sum of money (either lump sum or periodic royalty payments). However, the conditions for such acquisition would be determined by the national interest and the priorities determined by the government therefor. So, if the government feels that the certain patents have to be acquired for government procurement or for public benefit purposes (especially on technologies relevant for sustainable manufacturing), then the government has the powers to acquire such patents from the patentee.

While the provisions of Section 99 to 102 deals with regular acquisition of the patent rights from the patentee for national interests (in which case the patent could still be valid and it could exist, but in the name of the government, which could later be revoked), Sections 64 to 66 deals with revocation of the patent rights of the patentee (in this case the patent right does not exist and it is terminated). If the patent right has been secured by wrongful means (like providing wrong information), in such cases, the government can revoke the patent rights granted to the inventor and get the invention removed from the patent register.

Also, Section 107A provides for a situation where certain actions like making, constructing, using, selling, or importing a patented invention without authorization, for the purposes of research and development, or even to conduct market feasibility or for seeking regulatory approvals, are treated as acts not resulting in infringement of the patent rights.

These provisions enacted as part of the Patents Act (which are fully compliant with the provisions of the WTO and the TRIPS agreement), provide sufficient ammunition to the government and even to private individual who are seeking an exclusion from the patent rights, and are interested in manufacturing or otherwise practice technology relating to sustainable manufacturing.

4.5.3 Policy Strategies for Trademarks

On a quick review of the Indian Trademarks Act of 1999, we can note that the requirement for securing a trademark is indeed distinctiveness in the mark. Also, it ensures that the minimum protection is for 10 years (more than the minimum of 7 years stipulated by the TRIPS agreement), and it does not contain the provisions relating to compulsory licensing. It also allows the trademark owner the right to license and assign the trademark to other under the provisions of Section 37 of the Act. However, on the matter relating to passing off, Section 29(4) of the Act stipulates that if the owner of the mark has reputation, and his mark is being used on goods and services not similar to that of the trademark owner (which is the necessary condition for passing off), then it would amount to infringement of trademark. But it mandates under Section 29(4) (c) that such acts would be considered as infringement only, if the original mark has reputation. This section has been interpreted in many cases of trademark infringement as well. For instance, in the case of Toshiba Corp versus S. K. Sil, the court laid down the standards for ascertaining what a well-known mark is (Kabushiki Kaisha Toshiba Trading (as Toshiba Corp) vs. Mr. S. K. Sil and Another, 2011).

Similarly, the Act also provides protection to the member of the civil society organizations including the media houses under the provisions of Section 30(1). It states that if anybody uses a trademark for the purpose of identifying the goods and services of the trademark owner or to refer to him, and such use is not causing any detriment to the trademark owner or is not taking unfair advantage of the rights of the trademark owner or is not affecting the distinctive nature and the reputation of the trademark owner, then such use is considered to be not an infringement under the Act.

4.5.4 Policy Strategies for Designs

India enacted its Design Act in the year 2000. This legislation (a very short legislation comprising of around 48 sections in total) provides for the legal mechanism for seeking protection for the visually appealing features of products. Section 22 of the Act deals with the piracy of registered design. Section 22(1) (a) deals with infringement of designs with frivolous modifications or changes, in which case, the person would be held liable for paying damages to the registered owner of the design. Similarly, Section 22(1) (c) of the Act deals with registration of a design with a fraudulent intention, knowing fully well that the design actually belongs to somebody else, and even then such actions would be considered as infringement of designs. Under Section 42 of the Act, it also provides for the license, transfer and assignment of designs, just like any other IP right.

4.6 Summary

Section 4.5 deals with the intellectual property policy strategies that were available to the Indian government to make its IP laws compliant with the TRIPS agreement. Having made it compliant with the TRIPS agreement, we can notice that there are many opportunities within the existing IP laws (specifically the legislations dealing with copyrights, patents, trademarks and designs), which would enable the Government of India to ensure that sustainable manufacturing as an objective of national priority is achieved. Government of India could use these legal provisions to effectively to ensure it has sufficient access to technology relating to sustainable manufacturing. This can be ensured through policy measures like compulsory licensing, exclusion of certain categories of products from protection under the IP laws, considering certain actions as not infringement, and also by having provisions of licensing and assignment of those IP rights.

Protecting Mother Earth and the natural resources is the most important priority for every human being. Manufacturing as an economic activity could lead to disrupting the ecological balance. Using intellectual property rights policy, Government of India has created a policy ecosystem, which if utilized properly, can ensure that the manufacturing processes adopted in the country could be sustainable for future generations leading to the safeguarding of the environment, Mother Nature, as well as conserving the natural resources efficiently. These policy guidelines have been captured by the Government of India policy initiatives like the Science, Technology and Innovation Policy of India 2013 (Government of India, 2013, at p. 14) as well as the National IPR Policy of India (Government of India, 2016).

4.7 Other IP Strategies for Sustainable Manufacturing

Having understood the IP policy strategies that can be adopted by the Indian government based on the requirements stipulated by the TRIPS agreement, we now move on to the discussion on the other intellectual property strategies that companies as well as governments can adopt to attain the objective of sustainable manufacturing. In fact, there are a whole bunch of IP strategies that are at the disposal of both the government as well as the private sector, in promoting sustainable manufacturing.

4.7.1 Focus on Research and Development (R&D)

The first and the foremost IP strategy that could be adopted, both by the government sector as well as the private sector in India, would be to develop and have a comprehensive research and innovation strategy for sustainable manufacturing. Having understood the relative importance of sustainable manufacturing for the overall development of the country and more importantly for the overall benefit of the mother earth, both the government sector and the private sector should earmark significant investment towards the research and development in the area. This investment could be targeted towards the key areas of focus, like the manufacturing techniques, energy sufficiency, alternative and renewable energy, sustainable supply chain and logistics technologies, packaging technologies and also sustainable marketing practices.

The private sector could invest this amount, either as part of their internal R&D efforts, or they could donate the money as part of their CSR activities to various academic and research institutions, which could then be directed to carry out research in the area of sustainable manufacturing. Similarly, the government could initiate competition or institute grants for targeting R&D activities in these areas. In addition to this, the government could also institute a mechanism within its educational institution set up (specifically the IITs, the NITs, the IIITs, the IISc, CSIRs, IISERs and other institutes of national repute, which are under the control of either the central or the state governments), and motivate them to carry out research in the area of sustainable manufacturing.

Both the private sector and the public sector investments into the academic and research institutions could be controlled and monitored in terms of milestones (within the research output) or in terms of the number of publications that come out of the research activities or in terms of the number of patents that are generated from it. The investments/grants could be tied to such milestones, which would ensure that not only the research outputs are measurable but also significant IP rights generation takes place as part of the exercise. The government could also attach incentives like appointments, confirmations, promotions, etc. on the IP generation from such research projects.

The funding agency (be it either the public sector or the private sector) should insist that the IP rights generated from such research projects are not just academic in nature. They must ensure that the IP rights so generated are of commercializable quality and are in the nature of production model. This would help not only secure IP rights from the R&D activities but also be able to quickly implement it and facilitate its quick proliferation.

4.7.2 Open Source and Open Innovation

The next strategy could be that the people working in the area of sustainable manufacturing could decide to put all the works done in this area into the open domain. This would ensure two things: one is that it helps everyone to know the extent of knowledge in the area. Second, this would also ensure that there is no duplication of research activities. Rather the research activities could be focused on solving technological problems in the area of sustainable manufacturing, which in turn could help the development of technology in the domain. This could also lead to faster proliferation of the technology. Putting the technology on to the open source could also attract experts in the field, who could contribute to the development of the field. Another advantage of this IP strategy is that there would not be any licensing fees for following the technology, which could be very helpful while entering into an unchartered territory.

The organization focusing on R&D on sustainable manufacturing could decide to publish all the knowledge including research outputs and other data into the public domain, thereby preventing others from ring-fencing the technology using patent rights. This would serve two objectives: one is that the published knowledge would explain the technology, which could be used as a prior art to prevent others from patenting, and second, it could also help quickly distribute the knowledge to a large number of people in a short period of time. But the latter advantage could be achieved only if the publication is done as part of the open source journals, without which the knowledge might again become concentrated in the hands of publishers who would be controlling such knowledge.

Some of them would think that putting the research project on the open domain, as an open source project would not lead to creation of IP rights. This is completely a wrong notion. Open source could create IP rights for the improvements they make under the open source platform, but they can decide not to enforce them when somebody infringes the IP rights. More information could be had at (Sarefjord, 2006).

Similarly, companies adopt the open innovation model for working on sustainable manufacturing. Under this, companies could license-in IP rights and license-out IP rights in order to advance their work on the technology. The research could be licensed either from the public sector or from the private sector, either by the public sector or by the private sector. This would be one of the best IP strategies to work with as it facilitates standing on the shoulders of the giants and looking into the future. But the company or the organization working on the open innovation model should be able to understand the risks and costs associated with model (Chesbrough, 2003). But then, this model provides an excellent opportunity for organizations to advance their research very quickly, which would help advancement of the technology, which in turn could lead to the proliferation of the technology.

4.7.3 Licensing of IP Rights

Under the licensing strategy, the IP rights belonging to the IPR holder are licensed to others, in return for a consideration. The consideration could be either in the form of a royalty payment by the licensee to the IP holder, or in the form of exchanging another IP right (which is called cross-licensing) for the IP right licensed, or it could also be in the form of a royalty-free licensing (without any requirement of royalty payments). The royalty payment could be fixed either at the normal commercial rate (as applicable to normal commercial technologies), or the IP right holder could agree to license the technology at a reduced (or even nominal) royalty to be paid, as the technology would be related to sustainable manufacturing which would be benefitting many people and that it would be implemented for the betterment of the mother earth.

The license could be either an exclusive license or a non-exclusive license. It would be advisable to have non-exclusive license, as it would be enable others to seek licenses and adopt a path-breaking technology in the area of sustainable manufacturing. Also, non-exclusive license would enable many people to start practicing the technology, which would help in achieving the proliferation of the technology relating to sustainable manufacturing.

If on the other hand the IP right holder disagrees to provide a license at a reasonable royalty rate, then the party interested in implementing the technology has an option of applying to the government for a compulsory license of such IP rights (the provisions of compulsory licensing have been discussed in earlier sections). For seeking compulsory licensing, the applicant should fulfil all the requirements stipulated under Section 84 of the Indian Patents Act.

4.7.4 Patent Pools and Copyright Collectives

Patent pool is an arrangement where competing firms combine all their patents on a particular technology (in this case sustainable manufacturing) and decide a common licensing and usage pattern among themselves (Merges, 1996). They also decide not to sue each other in case of infringement of the other's patents. Such an arrangements offers many benefits: first is that it reduces the cost of transaction for all the parties who participate in the patent pool, as they would not be required to negotiate a separate license agreement with different IP right holders; second, they would have access to all the patents relevant for successfully implementing a marketable product in the domain of sustainable manufacturing, which could help achieve social objectives; third, as they do not have the fear of infringement suit, the cost of litigation would be less for each of the participants in the pool; fourth, it eliminates the problems of anti-commons (Merges, 1998), as everyone would have a stake in the patent pool, they would ensure that the resources are carefully managed and not wasted; lastly, it would ensure there is a sense of cooperation among the participants in the patent pool, which would ensure that not only would the technologies be shared but also know-how could be shared (alternatively, the members could assist each other in terms of contract manufacturing, and out-sourcing of services, assembly, etc.).

The patent pools could be created either at the initiative of the private organizations, or the government could help establish such pools. Though there are many instances of the former (as in the case of MPEG2, DVD technology, etc.) (Lampe & Moser, 2009), there are hardly any examples of the latter. This is because, creating a patent pool requires owning at least some IP rights, which are critical for the operation of the field of technology, using which others in the industry can be motivated to participate in the pool. But if the government is keen in promoting sustainable manufacturing, then it can motivate IP right holders to contribute their IP rights to a patent pool, which it helps create. After creation, it should ensure that the IP right holders do not renege on their promise of not suing the users (participants in the patent pool) for infringement.

While patent pools can be created for patent rights, similar pools can also be created for copyrights and they are called as copyright collectives. Under this, the owners of copyrighted works could pool their copyrighted works and they could negotiate the license arrangements, as well as its utilization among themselves as a collective. There have been various instances where copyright collectives have been functioning very efficiently, the most popular one being the American Society of Composers and Performers (ASCAP), which is a pool comprising of all the copyrighted works of the American film and music industry (Aoki & Schiff, 2008).

4.7.5 Standard Setting

This is a process where all the patents relating to a particular technology are evaluated by the standard-setting organization (SSO), and based on such evaluation, would determine that for effective implementation of a particular technology certain patents are essential and would notify them as technology standards for that field (Park, 2010). Once determined, these patents would be called as Standards Essential Patents (SEPs) and the IP holders of these patents have to follow certain standards for charging royalty rates like the FRAND rules (Fair, Reasonable, and Non-Discriminatory). Also, they cannot deny access to anyone who would like to use such patents as part of their production process.

In a sense, standard setting operates similar to the patent pool system, but is far more complicated and far more cumbersome to operationalize. Being similar to patent pools, standard setting helps reduce duplication of R&D investments, and by making the patents essential for the technology standards on FRAND terms it would help access to technology as well. This also helps in easy and quick proliferation of the technology and facilitates interoperability between the components of various manufacturers. Another advantage of the standard-setting process, especially for the patent holder is that once the patent is accepted as an SEP, the demand generated for the product would be enormous, which would more than help the IP right holder to recover the investments made on inventing that technology.

But then, the major problem with the standard-setting process is that of the submarine patents, where an inventor could file for a patent, and not process the application with the patent office. Once the technology is accepted as an industry standard, then he would process and prosecute the patent application quickly (as he would have the priority on the technology through the application) and then hold the others in that field of technology to ransom with a threat of suing them for infringement. But once these kinds of challenges are overcome, the strategy of standard setting could be very effective in managing technologies relating to sustainable manufacturing.

4.7.6 Government Initiates

Apart from the above-mentioned strategies, which could be adopted both by the public sector as well as the private sector, there are certain initiatives that the government could adopt in managing the IP rights relating to sustainable manufacturing better. The government could notify the sustainable manufacturing as a priority sector as part of its Science and Technology Policy. Once it is notified, under the IP policy, as well as within the provisions of the Patent Act, the government could also notify that courts should not encourage litigation in that field of technology, as it is the field of national importance. Second, through its agencies like the University Grants Commission (UGC) and the All India Technical Education Council (AICTE), could notify sustainable manufacturing as the new research focus for the universities, which would ensure that all the universities would dedicate substantial part of their resources towards developing the technology. As part of the same policy, it could also direct that such research focus should be either on generating patents or on publishing the research in academic journals (depending on the strategy and the results that are sought to be achieved).

It could also incentivize research towards sustainable manufacturing through competitions, awards, grants, etc., which could again lead to renewed focus on the area. As part of these strategies, it could direct the researchers to generate technology, which are commercializable and production ready, which can be quickly used to implement the manufacturing capabilities in the field of sustainable manufacturing. It could also facilitate the industry–university partnerships, through which it could channelize funding for research or transfer of technology resulting from the research to the industry, thereby ensuring quick implementation as well as quick proliferation of the technology relating to sustainable manufacturing.

The government could also establish sustainable manufacturing standards, which can be used to benchmark the industry players operating in the field of sustainable manufacturing. It could notify that all the government procurements would be from companies who have adopted sustainable manufacturing technologies, and who meet certain threshold limits set by the benchmark for sustainable manufacturing.

4.8 Concluding Remarks

During recent times, considerable discussion is being carried out on topics relating to sustainability, which necessarily includes protecting the environment and other natural resources for future generations. But chasing economic goals like GDP and per capita income requires the support of the industry and specifically manufacturing sector, which can not only generate goods and services for consumption, but would also generate employment for the large population of India. But the irony is that manufacturing also leads to destruction of the environment and the natural resources and might lead to significantly harsh conditions for the future generations.

Sustainable manufacturing as a strategy could be adopted to achieve lesser environmental impact and also leading to optimal management of natural resources. This could be implemented successfully if companies and the government sector invest substantial resources to innovate technologies, which are environmentally sustainable. The outputs of such innovative activities are entitled to be protected under the IP rights regime. The irony with the IP regime is that it facilitates the creation of monopoly power in the hands of IP right holders, using which they can exclude all others from copying it. But if that happens, then the very purpose of innovating to achieve sustainability would be defeated. This is where India as a country needs to relook at the IP strategies available to ensure that it has sufficient access to technology which can help in the proliferation of sustainable manufacturing technologies.

This chapter provides for two levels of strategies, both relating to IP rights, which can be adopted by India, in order to achieve sustainable manufacturing in the country. The first level is the IP policy strategies that can be adopted by India, in light of the international treaties like TRIPS, the WTO system, as well as other treaties, conventions and protocols. The second level is the IP strategies that can be adopted by the non-governmental sector including the private commercial sector as well as the academic sector (both public funded as well as private funded). While the former analyses the TRIPS agreement and tries to understand how the objectives stipulated therein have been captured by the Indian IP legislations, the latter looked at strategies like investing towards R&D, licensing of technology, patent pools and copyright collectives, open source and open innovations, and also government initiatives that could ensure the implementation of sustainable manufacturing technology in India.

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Part II
Sustainable Process Management

Chapter 5
A System Framework for a Sustainable Approach to Maintenance

R. P. Mishra and Palash Mungi

Abstract Maintenance has a noteworthy capacity in enhancing performance of facilities, be it excavation of natural resources or manufacturing a small pin. The significant role of the maintenance is mostly about producing a facility with utmost sustainability. For example, what maintenance emphasizes on is that it is more valuable to the users and environment to ensure that the existing facility is in optimum performance and at the same time discouraging the construction of new facilities. The obligations and duties of present-day maintenance associations are principally worried about the formation of sustainable future. This paper aims to propose a system framework for a sustainable approach to maintenance. Sustainable maintenance includes cooperation of numerous frameworks, simple or perplexing, with respect to manufacturing, overhauling, assembly, ecology, economics, society, and environment while carrying out the maintenance act. The proposed write-up is an attempt to move toward a sustainable approach to maintenance in its most ideal path by any sector or industry.

5.1 Introduction and Literature Review

5.1.1 Introduction

In a world of highly competitive business environment, producers expect from their businesses to bring profit at each conceivable preferred standpoint. Organizations often seek lean manufacturing as a method to be at advantageous position. Various firms promote activities to accomplish brilliance in performance coupled with unwavering quality. Sadly, only a handful of organizations address the noteworthy collaborations of lean and maintenance excellence. That is, only a few firms utilize the energy of the blend of lean assembling and lean maintenance.

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Unfortunately, we do not live in a perfect world. No physical resource works impeccably until the end of time. In many associations, breakdowns are normal. Quality and productivity misfortunes are high. Delivery deadlines are not met. It is because that mainly there are issues related to equipment; breakdowns are mostly blamed to maintenance for all the problems of plants and facilities. In reality, these inherent issues are shared by every personnel involved in the organization, at least to some or large extent. It is the most common practice in which the action is taken quickly as the production is in demand by just getting it run somehow. Mostly, the action is reactive not preventive.

Implementing sustainable levels of maintenance is utmost necessary for long-term survivability of all kinds of industries. The framework of sustainable manufacturing including maintenance forms considers both monetary and natural factors. Sustainable plans of action and ecological constraints are challenges, even for business tycoons. Any organization's supply chain in regard to the environment can be gauged by many ways. But still today there is no such regulatory standard to govern it completely. The usage of energy in exploitative way, which has considerably affected the ecology and climate, has become an alarming issue. The manufacturing sector is also incurring a day-by-day-increasing manufacturing cost. More energy effective techniques can save a lot during the lifespan of the equipment. Not considering it as a pre-requisite will create high chances that the plant will bring about unsuitably higher working cost. This will reduce the potential of an organization to compete globally. So, the culture of maintenance needs to be changed to compete with overall competition. It must not be the same by limiting its scope to "act when broke"; instead, it must be prepared well in advance before the breakdown occurs. If appropriate installations of systems, infrastructure, processes, and procedures are in order with their effective execution coupled with a sustainable approach, the loss can be minimized. This will ensure the operation is stable; manufacturing output is highest and quality is optimum. This, if achieved, could be called as maintenance excellence. By stating the role of maintenance activity in a newer way, as a part of a total productive maintenance involving sustainability, it will strive to provide the infrastructure, processes, etc. that will positively result in improved output and better return on investment in the long run. Particularly, small but significant changes such as reducing cost of production per piece, decreased maintenance cost, and highly stable process can assure minimum harm to the environment and the mother Earth.

5.2 Literature Review

The manufacturing sector has faced a couple of changes in last 30 years like changes in approaches, technologies, customer expectations, and attitudes of suppliers as well as competition in the market (Ahuja & Khamba, 2008). In today's uncertain environment, the global competition among organizations has put tremendous pressure of demand on the manufacturing firms (Miyake, Enkawa, & Fleury, 1995). The global market has seen an enhanced pressure from customers and competitors in both manufacturing as well as service sector (Basu, 2001). The global marketplace demands improvements in a company's performance by focusing on cost-cutting, increasing productivity and quality levels, and ensuring on-time deliveries for customer satisfactory (Raouf, 1994). Organizations to survive in today's high market competition must address the requirement for diverse product range. In such a case, slow, steady improvements in manufacturing operations are not acceptable (Barratt & Oke, 2007). Thus, the organizations must improve at a faster pace than their competitors, if they are to become or remain leaders in the industry. With increased worldwide competition, focus is on increasing efficiency which can be done by means of economies of scale and internal (Rodrigues & Hatakeyama, 2006). Nowadays, each of the lean and agile approaches is considered by many organizations. It should be noted that in lean and agile production, each one holds its own advantages and strengths and weaknesses. Lean supply chain goal is responding to current demand with lowest prices while in agile supply chain flexibility, speed and innovation are important. It should be noted that these two are complementary (Gilaninia et al. 2011).

Thus, from reviewing a certain literature, it is evident that the limitations and the loopholes of the conventional maintenance process, in the past, have adversely affected the organizational competitiveness. This has further reduced the output and efficiency of production facilities. This has deteriorated the reliability of production facilities, lowering availability of equipment, increased stocks, and hence causing undesired performance.

5.3 The Performance Elements and Sustainability

Sustainability is often defined as the tolerance capacity of a system and how far it can remain diverse and productive despite bearing changes in surroundings. But today, sustainability has changed its definition and has widened its scope to a great extent by merging the progress of mankind to the natural survival of the environment. Before going into this, let us first see the basic elements of performance through this flow chart as a function of time. Please refer the figure for details as mentioned in (Jasiulewicz-Kaczmarek, 2013). The main content of the figure in brief can be explained as follows. Unit cost: Batch/mass production; Financial aspects: Lean manufacturing; Financial and environmental aspects: Green Manufacturing; and Financial, environmental and Social aspects: Sustainable manufacturing. The manufacturing process has correction with the maintenance as follows: Reactive maintenance (necessary evil); preventive maintenance (Technical matter); lean maintenance (Profit contribution); green maintenance (Business partner); and sustainable maintenance (Competitive factor). For details, please refer to the figure mentioned in (Jasiulewicz-Kaczmarek, 2013) (Fig. 5.1).

It is clear from above that if we plot the progressive improvement in stages of maintenance activities we can finally land up as a sustainable approach to it as time elapses. Soon, we can start from conventional reactive maintenance to sustainable maintenance with corresponding manufacturing activity.

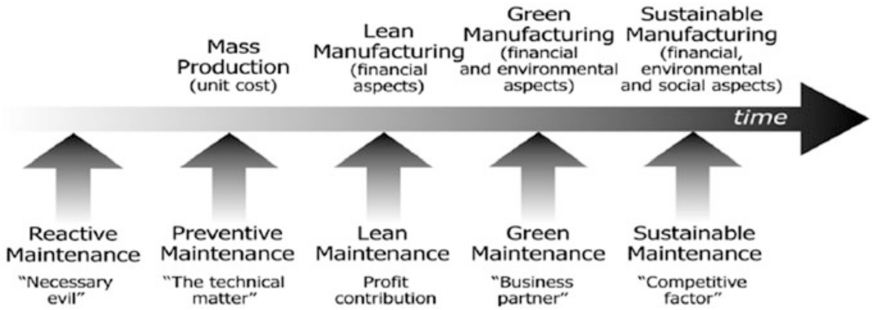


Fig. 5.1 Basic elements of performance. *Source* Jasiulewicz-Kaczmarek (2013)

A production system consists of various equipments and all equipments should be available with reliability at the highest possible level possible, thereby ensuring stability. The maintenance department ensures that the equipment is in order and maintains their sustainability to serve longer. This has a significant role in a manufacturing system and it can facilitate sustenance through utilization of high assets to increase the overall profitability. If we look at last few decades, the theory of maintenance has fundamentally changed according to the new manufacturing practice.

From 1991 to 1995, the green maintenance started gaining popularity. The thinking was like, "the waste and environmental impact should also be minimal". Green maintenance is a kind of management in which maintenance operations are performed in an environmentally friendly way. It is a maintenance activity in which the decision-making is crucial, that is, for example, to go for reactive, preventive, or proactive maintenance. Next, to go for what extent of warehousing, managing used materials and quality of fluids, lubricants, etc. to attain sustainability as much as possible (Fig. 5.2).

The green maintenance can be achieved through green manufacturing by setting a goal of reducing environmental impact caused due to production process and maintenance. Some proposed techniques can be (1) green waste reduction techniques, (2) process redesign, (3) product redesign, (4) LCA, (5) rapid prototyping, and (6) waste segregation. The possible results can help us to reach toward green maintenance by reducing cost and wasted energy with minimal risk to worker's health. The reference figure can be obtained from (Stuchly & Jasiulewicz-Kaczmarek, 2014).

Next, sustainability is an act of blending. The United Nation's 1987 Report of the World Commission on Environment and Development says, "our common future noted that sustainable development meets the needs of the present without compromising the well-being of future generations." Broadly, there are three spheres through which sustainability can be explained: Environmental, social, and economic sphere, which can further be used as two mixed spheres at a time. The blend of the three spheres can help us to move toward sustainability. For more

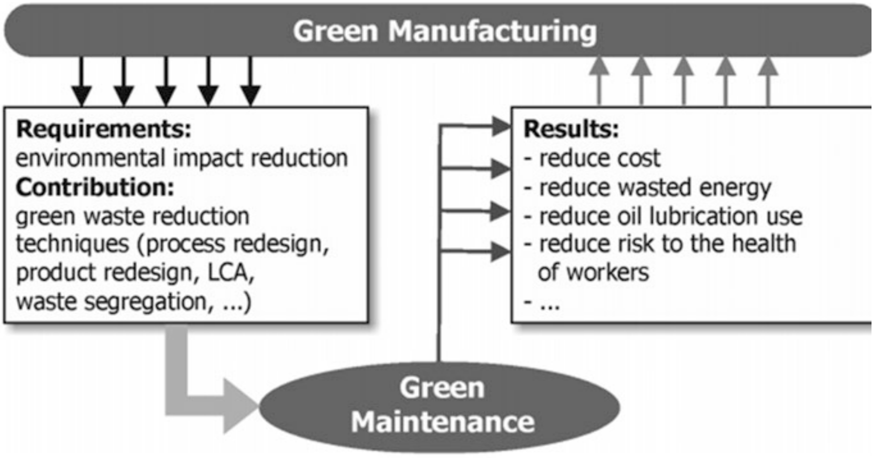


Fig. 5.2 Reaching green maintenance through green manufacturing

explanation, please refer to the figure from 2002 University of Michigan, Sustainable assessment[1] (Fig. 5.3).

Facilities and maintenance managers are finding ways to do more with less. Cost reduction is a continuous goal. In addition to these fundamentals objectives, many are challenged to adopt sustainable practices like reducing water usage, creating an efficient energy plan, eliminating harmful chemicals, reducing waste, and developing practical recycling programs. Inter-dependencies of various forms of sustainability can be explained through inter-relation of sustainable requirements, architecture, design, implementation, testing, and maintenance. The description of the interrelationship of various elements is explained by Durdik et al. (2012) by suitable figure and can be referred (Fig. 5.4).

5.4 Primary and Secondary Responsibilities for an Effective Maintenance Performance

5.4.1 Primary Functions

(a) Maintenance of existing plant equipment:

This activity represents the physical reason for the existence of the maintenance professional. Responsibility here is simple to make necessary repairs to production

[1]Sustainability 2002 Assessment and Reporting for the University of Michigan's Ann Arbor Campus. Available at http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.610.5308&rep=rep1&type=pdf. Accessed October 10, 2017.

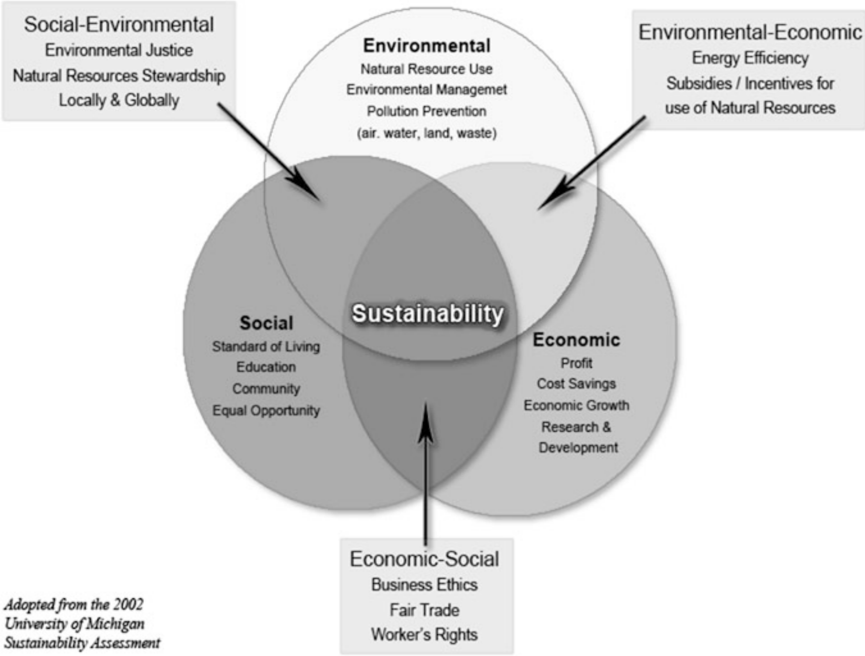
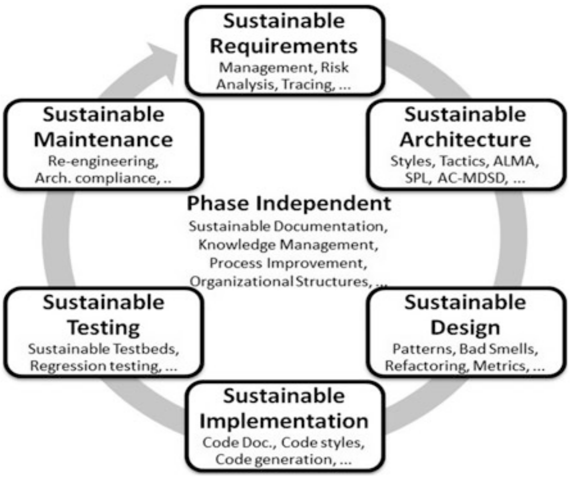


Fig. 5.3 The three spheres of sustainability. *Source* 2002 University of Michigan, Sustainable assessment

Fig. 5.4 Inter-dependencies of sustainability. *Source* Sustainability Guidelines for Long-Living Software Systems Zoya Durdik, Benjamin Klatt



machinery quickly and economically and to anticipate these repairs and employ preventive maintenance where possible to prevent them.

(b) Maintenance of existing plant buildings and grounds.

The repairs to buildings and to the external property of any plant—roads, railroad tracks, in-plant sewer systems, and water supply facilities—are among the duties generally assigned to the maintenance engineering group. Additional aspects of buildings and grounds maintenance may be included in this area of responsibility. Repairs and minor alterations to buildings—roofing, painting, and glass replacement—or the unique craft skills required to service electrical or plumbing systems or the like are most logically the purview of maintenance engineering personnel. Road repairs and the maintenance of tracks and switches, fences, or outlying structures may also be so assigned. It is important to isolate cost records for general cleanup from routine maintenance and repair so that management will have a true picture of the true expense required to maintain the plant and its equipment.

(c) Equipment inspection and lubrication.

Traditionally, all equipment inspections and lubrication have been assigned to the maintenance organization or function. While inspections that require special tools or partial disassembly of equipment must be retained within the maintenance function, the use of trained operators or production personnel in this critical task will provide more effective use of plant personnel. The same is true of lubrication. Because of their proximity to the production systems, operators are ideally suited for routine lubrication tasks.

(d) Utilities generation and distribution.

In any plant generating its own electricity and providing its own process steam, the powerhouse assumes the functions of a small public utilities company and may justify an operating department of its own. However, this activity logically falls within the realm of maintenance engineering. It can be administered either as a separate function or as part of some other function, depending on management's requirements.

(e) Alterations and new installations.

Three factors generally determine to what extent this area involves the maintenance department: plant size, multi-plant company size, and company policy. In a small plant of a one-plant company, this type of work may be handled by outside contractors. But its administration and that of the maintenance force should be under the same management. In a small plant within a multi-plant company, the majority of new installations and major alterations may be performed by a company-wide central engineering department. In a large plant, a separate organization should handle the major portion of this work.

5.4.2 Secondary Functions

(a) Storekeeping. The control of mechanical stores lies usually within the maintenance engineering group's area because of the close relationship of this activity with other maintenance tasks.
(b) Plant protection. This category usually includes two distinct subgroups: guards or watchmen, and fire control squads. Incorporation of these functions with maintenance engineering is generally common practice. The inclusion of the fire control group is important since its members are almost always drawn from the craft elements.
(c) Waste disposal. This function and that of yard maintenance are usually combined as specific assignments of the maintenance department. Salvage: If a large part of plant activity concerns off grade products, a special salvage unit should be set up. But if salvage involves mechanical equipment, such as scrap lumber, paper, containers, and so on, it should be assigned to maintenance.
(d) Insurance administration. This category includes claims, process equipment and pressure-vessel inspection, liaison with underwriters' representatives, and the handling of insurance recommendations. These functions are normally included with maintenance since it is here that most of the information will originate.
(e) Other services. The maintenance engineering department often seems to be a catchall for many other odd activities that no other single department can or want to handle. But care must be taken not to dilute the primary responsibilities of maintenance with these secondary services.

5.5 Redefining Maintenance Through Incorporating Sustainability

Maintenance is a significant activity for ensuring the safety, smooth operation, and to achieve maximum output. Maintenance-related issues vary during each of the three broad life cycle phases—Design and Construction, Sustainment and Operations, and Disposal. These issues have impact on the safety, reliability, and maintainability of the machine or equipment. Sadly, many organizations are not at all aware of these issues they must address during each life cycle phase. The maintenance process must provide a comprehensive life cycle approach to reduce failures of parts, eliminate defects, and avoid accidents (Fig. 5.5).

The elimination of breakdowns and other sources of energy waste can help us to lead toward sustainable maintenance approach. The adverse effects of maintenance activities are not confined to the boundary of the plant. Due to increased frequency of breakdowns, the delivery of the product delays leading to lack of satisfaction to customers. This makes company's bad reputation. Breakdowns also influence quality. Poor quality reduces the selling price and the number of customers due to

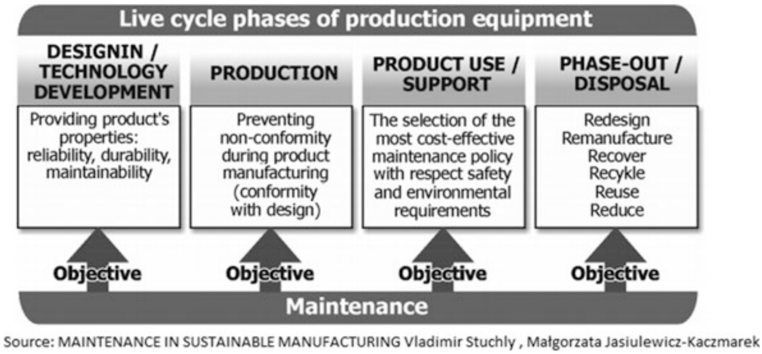


Fig. 5.5 Maintenance level vis-à-vis life cycle of a production equipment

loss of trust in the company. Hence, because these breakdowns are unpredictable and uncontrollable in nature, they are typically the main source of safety and environmental hazards. Such organizations with low safety reputation and high environmental hazard rates also lose status in labor market and in the society as a whole. In contemporary maintenance, both financial aspects should be included with the balance between environmental (green) and social aspects of actions. From the sustainable point of view, maintenance is focused on providing systems, procedures, and trainings which build operative knowledge and skills. This helps to prevent or eliminate losses, environmental incidents, and problems associated with safety and health. The sustainable thinking can change the actual practice vis-a-vis theoretical approach by practically incorporating sustainable indicators and assessment of maintenance processes. This would result in uniting economy, society, and environment. For more details, please refer to the figure from the report of Ministry of transportation Ontario, Canada (2017).

5.6 Considerations for Sustainable Maintenance Operations

Facilities and maintenance managers are faced with finding ways to do more with less. Cost reduction is a goal which is never achieved as it is continuous. In addition to these fundamental objectives, many are challenged to adopt sustainable practices like reducing water usage, creating an efficient energy plan, eliminating harmful chemicals, reducing waste, and developing practical recycling programs (Fig. 5.6).

Following 10 initiatives can help to achieve sustainability objectives by reducing operating costs of residential buildings, office complexes, or university campuses, taking these as examples for explaining our case study that how considerations for sustainable maintenance operations can be made.

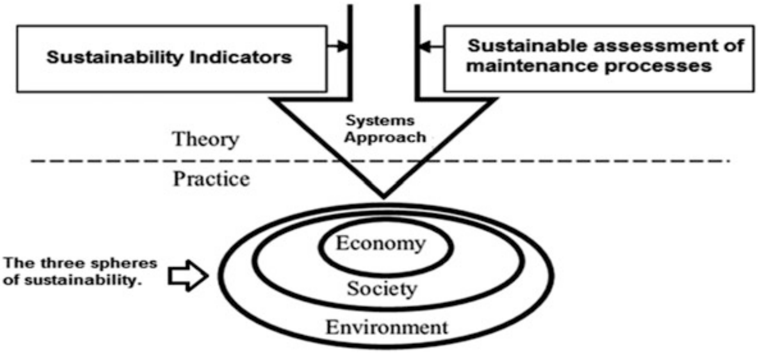


Fig. 5.6 How sustainable thinking can change the actual practice vis-a-vis theoretical approach. *Source* Ministry of Transportation Ontario, Canada

5.6.1 Education and Awareness

Announce the initiative to create a more sustainable environment. This first step will help to achieve buy-in and explain why certain changes will take place around the facility. The education and awareness for sustainability is the first step for the success of the desired maintenance operations.

5.6.2 Water Reduction

Besides suggestions to reduce water usage in office bathrooms, the installation of low-flow toilets and sink sensors will limit the amount of water being used. Efficient laundry facilities and dishwashers can also save up to 50% of the water used in older models.

5.6.3 Energy Reductions

Newer facilities have added supplemental power capability such as solar and wind power. But straightforward energy conservation is an answer. Turning off lights when not needed and replacing old incandescent light bulbs with newer, more efficient CFLs (compact fluorescent) can reduce electricity usage by 75%. LED lights, though more expensive, last 20 times longer than incandescent and use about the same energy as the CFL. Installing sensors in hallways and less-used areas of the building reduces wasted energy as well.

5.6.4 Heating and Air Conditioning

Highly efficient heat pumps and air conditioning save money are expensive to purchase and install but the payback is surprisingly short when compared with older models. To help offset the costs, governments and power companies offer rebates and incentives for adopting more efficient systems. State-of-the-art thermostats are now included that allow for remote adjustments and settings that adapt automatically to atmospheric changes. This technology eliminates costly over-compensating and inefficiency. As an additional sustainable feature, the latest air conditioning systems use newer refrigerants that are less harmful to the environment and the ozone layer.

5.6.5 Landscaping

More efficient watering systems with sensors that measure rainfall and moisture in the soil will eliminate unnecessary watering. Highly efficient drip irrigation systems are extremely effective in watering plant beds and shrub areas. Consider planting varieties that require less water and use recycled natural mulching materials and compost to help retain the moisture.

5.6.6 Rainwater Collection

Establish a system that collects rainwater for use on landscaping. This further reduces the cost of more expensive potable water usage.

5.6.7 Sustainable Cleansers

Using harmful chemicals for cleaning is bad for people and harmful to the groundwater. Many producers have reformulated cleansers to achieve the same results with more favorable components.

5.6.8 Paints/Parking Lot Striping

Rather than applying the traditional petroleum-based paints for parking lot and pathway striping, the latest trend is to use soy-based paints for this purpose. Striping paint has a low-VOC (volatile organic compound) rating which will not emit highly toxic fumes while being applied or drying.

5.6.9 Recycling

Formulate an efficient recycling plan. Make it easy for the tenants to separate and recycle by providing the appropriate containers and announcing the pick-up schedule.

5.6.10 Composting

Find an available space to set up and encourage composting of organic material and food wastes. This compost will provide an eco-friendly supplement to the growing areas and will reduce the use of chemical fertilizers that can bleed into the groundwater.

5.7 Conclusion

This paper sums up the process by taking into account every necessary step and the framework required to manage maintenance incorporating the idea of sustainability, and hence can be called as sustainable maintenance. Maintenance-related issues occur during three life cycle phases—Design and Construction, Sustainment and Operations, and Disposal. Maintenance managers need to be cognizant of the unique issues each life cycle phase presents and what tools are available, or what type of questions to be asked, to ensure an asset's maintenance program is providing a safe, reliable, and cost-effective product for their riders. Through a case of residential buildings, office complexes, or university campuses, ten initiatives are

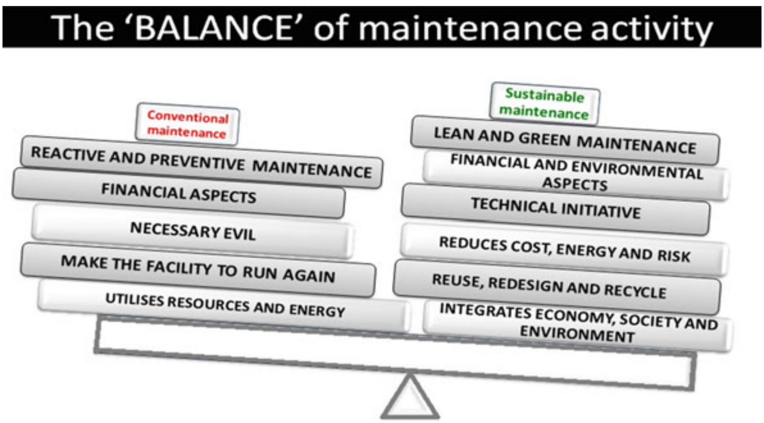


Fig. 5.7 The balance of maintenance activity (own study)

explained. Additional initiatives in similar way can be implemented in small, medium, as well as large organizations as well. The facilities and maintenance managers are faced with finding ways to do more with less but the most significant goal must be to achieve sustainability howsoever high the installation cost may be as the future can be lightened by investing in the present.

Some sustainable practices like reducing water usage, creating an efficient energy plan, eliminating harmful chemicals, reducing waste, and developing practical recycling programs can effectively lead us toward sustainability. These initiatives reduce operating costs by integrating 3 Ps—People, Profit, and Planet by minimizing detrimental environmental impacts. In a nutshell, by comparing the conventional maintenance with sustainable maintenance, a balance of maintenance activity can be imagined in which the weightage is more toward the sustainable side as shown in Fig. 5.7. Now, the decision is purely pending on us where we want to direct us to save our future generations and why.

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Chapter 6
Modelling Factors Influencing Lean Concept Adoption in a Food Processing SME for Ensuring Sustainability

S. Vinodh and Dhiraj Patil

Abstract Lean concepts application in food processing domain facilitate Small and Medium Enterprises (SMEs) to acquire core competence through waste elimination and streamlined process. 16 factors inducing lean concepts in food processing domain were identified based on the literature review and expert opinion. Interpretive Structural Modelling (ISM) approach is used to develop the structural model. The dominant factors identified include 'Supplier development', 'Employee involvement in problem solving' and 'Adoption of statistical process control for identifying process variation'. Also, MICMAC analysis is conducted to categorize the factors. Influential factors for lean adoption are being correlated with corresponding sustainability dimensions.

Keywords Lean management · Sustainable manufacturing · Food processing

6.1 Introduction

Lean concepts are increasingly gaining importance due to the potential to streamline the process by means of waste elimination (Manzouri et al. 2014). Lean concepts are applied in manufacturing context and have the potential in service domains in recent days. The benefits of adopting lean in food processing domain include increased efficiency and decrease in cost of production (Rauch et al. 2016). Lean manufacturing adoption in food processing SME also helps in improving the customer value by providing additional value-added services (Lehtinen and Torkko 2005). In order to facilitate lean concepts adoption in the service domain, a structural model is to be developed. The objectives of the present study include identifying factors influencing lean concept adoption in food processing enterprise

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and developing a structural model for the same. The developed structural model depicts the dominant factors. The factors were categorized into four basic types through MICMAC analysis. The factors are related to the corresponding sustainability dimensions. The practical inferences are being derived.

6.2 Literature Review

The literature has been reviewed from the viewpoint of lean application in the food sector. Lehtinen and Torkko (2005) discussed the case of a company functioning as a contract manufacturer in the food industry that deployed lean concepts. The research also provided vital insights on problem understanding during the production process. With the help of Value Stream Mapping tool, the research depicted that there is a lot of waste in surplus inventory. Simons and Zokaei (2005) tried to introduce lean concepts to a new sector, ‘red meat industry’. This study limited itself to the specific area of the red meat industry, ‘cutting room’. The case study approach was carried out in two traditional and three advanced cutting rooms. This study identified 25% gap in advanced and traditional cutting rooms. This gap was due to the adoption of some of the lean techniques by advanced cutting rooms. The study also identified the gap in the application of logistics and operations management concepts in red meat industry. Zarei, Fakhrzad and Paghaleh (2011) focused on reduction in cost by using tools such as Just In Time (JIT). An attempt has been made using Quality Function Deployment (QFD) to identify the important lean enablers to be implemented in the food sector. A case study approach was carried out to identify practical implications. Noorwali (2013) developed a model containing steps that will help to reduce variability in food processing systems. The study tried to continue these steps using lean approach, Taguchi, simulation and correlation. Lean was used to identify seven types of wastes in the food processing units. Taguchi method was used for designing the framework. Correlation analysis was used to identify the variables that are more important in the context of food processing units. Manzouri et al. (2013) conducted a survey to identify the factors to be considered while implementing lean in the food sector. The questionnaire was developed and distributed to some of the halal food firms in Malaysia. The study found that more than 70% firms have not implemented lean. Market competition, uncertainty, lack of customer awareness are some of the barriers identified in implementing lean. Dora et al. (2014) developed a systematic questionnaire to collect data. Two control variables affecting the implementation of lean tools were investigated, namely company size and country of origin. The study found that application of lean in the food sector is still very low. Also, some of the lean tools like TPM, employee involvement are more prevalently used as compared to tools like flow, pull, SPC. Some of the characteristics of food sector like perishable products, extremely variable raw materials, etc., are the major barriers found in the implementation of lean concepts in food SMEs. Dora, Kumar and Gellynck (2016) studied the contextual factors for implementing lean practices in SMEs. They have found some barriers in the successful implementation of lean practices in SMEs. They are inflexible layout, small size of enterprise and traditional setup. Ashraf, Rashid and Rashid (2017) analyse the implementation of 5S tool in the food and beverage industry. They concluded that by implementing 5S industries can increase productivity, reduce rejection rate and enhance its space utilization. Powell et al. (2017) studied the adoption of lean Six Sigma concept in the food processing industry. They have done an analysis to find the effect of adoption of lean Six Sigma on sustainability. They have found several important factors regarding lean Six Sigma that can enhance environmental sustainability. Though few studies are reported in the context of lean application in the food sector, no attempt has been made to the best knowledge of authors on developing a model indicating the hierarchy of factors with reference to lean application in the food sector.

6.3 Methodology

This study was conducted for the identification of appropriate factors for enhancing the performance of food processing Small and Medium Enterprises (SMEs). For this purpose, Interpretive Structural Modelling (ISM) methodology is used, which is an established procedure to recognize relationships among specific entities which defines a problem. ISM modelling steps are the following:

1. ISM starts with recognizing the elements pertaining to the problem either by survey or through expert opinion.
2. Next step is to establish a contextual relationship between elements based on which pairs of elements would be investigated.
3. Develop a Structural Self-Interaction Matrix (SSIM). SSIM depicting the pair-wise relationship among elements of the system. Depending upon factor A influences factor B or factor B influences factor B or both factors influence each other or A and B are unrelated, symbols V, A, X and O are used respectively.
4. Develop an initial reachability matrix from SSIM. The symbols V, A, X and O are replaced by 1 and 0 depending upon the condition. There will be two columns in the reachability matrix, namely (i, j) column and (j, i) column. As symbol V signifies factor A influences factor B, then we will enter 1 in (i, j) column and 0 in (j, i) column. A similar analogy will be done for other symbols.
5. Develop final reachability matrix by incorporating the transitivity rule which states that if criterion ‘a’ is related to ‘b’ and ‘b’ is related to ‘c’, then ‘a’ is related to ‘c’ (Kumar & Kumar, 2015).
6. Partition the final reachability matrix into various levels based on three sets: reachability set, antecedent set and intersection set.
7. Draw the digraph with reference to the relationship indicated in the final reachability matrix.
8. Transform the final digraph into ISM model by replacing element nodes using statements.

9. The MICMAC analysis will be done at last which involves the development of graph and MICMAC rank based on their driving and dependence power.

6.4 Case Study

This section reports a case study of a food processing SME, which is aiming at lean concepts deployment. A hierarchical model based on ISM approach is developed in which the influential factors and their relationships are systematically presented.

6.4.1 Identification of Factors

This phase of identification of factors is done by review of literature and opinion from experts. By doing this, 16 factors are identified that may influence the implementation of lean concepts in food processing SMEs. Table 6.1 contains the factors along with brief description and references.

6.4.2 Development of SSIM Matrix

To find the conceptual relationship between 16 factors, expert opinion is used to find the relation between these factors. The relation was found based on the following four alternatives:

- Factor A influences Factor B (OR)
- Factor B influences Factor A (OR)
- Both factors A and B influence each other (OR)
- Factors A and B are unrelated.

Table 6.2 represents the conceptual relationship between factors.

6.4.3 Development of Initial Reachability Matrix

The symbols V, A, X, O given in Table 6.2 are replaced by binary values ‘1’ and ‘0’ as per the conditions explained in methodology. Table 6.3 represents the initial reachability matrix.

Table 6.1 Identified factors for lean implementation in food processing SMEs

Factors	Explanation	References
1. Customer–firm relationship	Customer–firm relationship will help the firm in understanding the requirements of the customer. Depending upon the changing requirements of the customer, the firm can adapt itself	Shah and Ward (2007)
2. Customer feedback	Customer feedback gives customers the perception that the company values them and readily satisfies their requirements. The inputs given by the customers will also be helpful in supplier development and understanding the discrepancies in the process	Shah and Ward (2007)
3. Supply lead time	Supply lead time is nothing but the elapsed time between placing of an order to the supplier and receipt of the product. Shorter lead time allows businesses to be more flexible, prevent loss of sales and also increases cash flow	Lehtinen and Torkko (2005)
4. Supplier development	Supplier development will help the firm in aspects such as reduction in supply lead time, decrease in time for a product to reach the market as well reduction in inventory cost. It also helps in increased responsiveness to changing customer needs and market dynamics	Lehtinen and Torkko (2005), Upadhye, Deshmukh and Garg, (2010)
5. Supplier readiness in lean implementation	Supplier readiness in lean implementation helps the firm in streamlining its processes and removing the wastes. Supplier readiness will help the firm in increasing the flexibility	Shah and Ward (2007)
6. Employee involvement in problem-solving	Employee involvement in problem-solving will result in the improved morale of the employees. This will result in improved innovation and productivity improvement	Leana, Ahlbrandt and Murrell (1992)
7. Employee readiness in lean implementation	Appropriate training and motivation to be provided to employees to ensure their readiness for lean implementation in food industry	Armenakis, Harris and Mossholder (1993)
8. Adoption of kanban for production control	It is a visual indication used to depict demand for the product and it facilitates pull production in food sector	Alfnes, Røstad and Strandhagen (2000), Gargouri and Hammadi (2002)
9. Setup time reduction	Setup time reduction helps the company in achieving shorter lead time and increased capacity. This will help in increased flexibility to satisfy customer demands	Reiner and Trcka (2004)

(continued)

Table 6.1 (continued)

Factors	Explanation	References
10. Adoption of SPC to identify process variation	SPC include approaches for quality control by deploying statistical methods. SPC provides scope for error detection and enhances consistent production quality	Taylor (1996), Kumar et al. (2006)
11. Adoption of preventive maintenance plan	Preventive maintenance enables consistent practices designed for performance improvement. The preventive maintenance of equipment will help to enhance equipment life and prevents any unplanned maintenance activity	Upadhye et al. (2010)
12. Adoption of kaizen	Kaizen is the practice of continuous improvement. Continuous small improvements result in major improvement. Adoption of kaizen facilitates in improved productivity and quality improvement, faster delivery, cost reduction and customer satisfaction	Upadhye et al. (2010), Engelund, Breum and Friis (2009)
13. Adoption of JIT	Adoption of JIT technology facilitates timely production and timely delivery of food to the customer. This will help in inventory reduction and streamlining the process	Lehtinen and Torkko (2005), He and Hayya (2002), Safayeni et al. (1991)
14. Adoption of poka-yoke	Poka-yoke enables that the operators do not commit any mistakes during operation. The processes which can go out of control are identified and possible remedial measures are suggested	Kellogg, Youngdahl and Bowen (1997)
15. Attempt to eliminate wastes	Elimination of wastes will help in streamlining the process. This will help the firm in aspects such as reduction in inventory, reduction in overproduction, reduction in defects, etc	Manzouri et al. (2014)
16. Operational flexibility	Food processing technologies and methods to be incorporated with adequate flexibility for enhancing customer requirements	Lehtinen and Torkko (2005)

6.4.4 *Development of Final Reachability Matrix*

Initial reachability matrix is converted into final reachability matrix by applying transitivity rule. According to transitivity rule, if x is related to y and y is related to z, then x is related to z. In this study, only first-level transitivity is considered. Table 6.4 represents the final reachability matrix.

Table 6.2 Structural self-interaction matrix (SSIM)

→ j i ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	_															
2	X	_														
3	X	X	_													
4	A	O	X	_												
5	V	A	X	X	_											
6	V	A	V	V	V	_										
7	V	A	V	V	X	X	_									
8	V	O	V	V	X	X	X	_								
9	V	O	V	A	X	V	A	X	_							
10	V	A	V	O	V	V	X	O	V	_						
11	V	O	V	A	O	V	X	O	O	A	_					
12	V	A	V	A	V	X	X	X	V	O	X	_				
13	V	A	V	A	V	A	A	X	V	A	A	X	_			
14	V	A	V	O	A	A	X	A	V	X	A	X	V	_		
15	V	A	V	V	X	V	A	A	V	A	A	X	V	A	_	
16	A	A	X	A	A	A	A	A	A	A	A	A	A	A	A	_

Table 6.3 Initial reachability matrix

→ j i ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1
2	1	1	1	0	1	1	1	0	0	1	0	1	1	1	1	1
3	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	1
4	0	0	1	1	1	0	0	0	1	0	1	1	1	0	0	1
5	1	0	1	1	1	0	1	1	1	0	0	0	0	1	1	1
6	1	0	1	1	1	1	1	1	0	0	0	1	1	1	0	1
7	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	0	1	1	1	1	1	1	1	0	0	1	1	1	1	1
9	1	0	1	0	1	1	0	1	1	0	0	0	0	0	0	1
10	1	0	1	0	1	1	1	0	1	1	1	0	1	1	1	1
11	1	0	1	0	0	1	1	0	0	0	1	1	1	1	1	1
12	1	0	1	0	1	1	1	1	1	0	1	1	1	1	1	1
13	1	0	1	0	1	0	0	1	1	0	0	1	1	0	0	1
14	1	0	1	0	0	0	1	0	1	1	0	1	1	1	1	1
15	1	0	1	1	1	1	0	0	1	0	0	1	1	0	1	1
16	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 6.4 Final reachability matrix

→ j i ↓	1. Customer firm relationship	2. Customer feedback	3. Supply lead time	4. Supplier development	5. Supplier readiness in lean implementation	6. Employee involvement in problem solving	7. Employee readiness in lean implementation	8. Adoption of Kanban for production control	9. Set up time reduction
1. Customer firm relationship	1	1	1	1	1[a]	0	1[a]	0	1[a]
2. Customer feedback	1	1	1	1[a]	1	1	1	1[a]	1[a]
3. Supply lead time	1	1	1	1	1	0	0	1[a]	0
4. Supplier development	1[a]	1[a]	1	1	1	1[a]	1[a]	1[a]	1
5. Supplier readiness in lean implementation	1	1[a]	1	1	1	0	1	1	1
6. Employee involvement in problem solving	1	1[a]	1	1	1	1	1	1	1[a]
7. Employee readiness in lean implementation	1	1[a]	1	1	1	1	1	1	1
8. Adoption of Kanban for production control	1	1[a]	1	1	1	1	1	1	1
9. Set up time reduction	1	1[a]	1	1[a]	1	1	1[a]	1	1
10. Adoption of SPC to identify process variation	1	1[a]	1	0	1	1	1	0	1

(continued)

Table 6.4 (continued)

→ j i ↓	1. Customer firm relationship	2. Customer feedback	3. Supply lead time	4. Supplier development	5. Supplier readiness in lean implementation	6. Employee involvement in problem solving	7. Employee readiness in lean implementation	8. Adoption of Kanban for production control	9. Set up time reduction
11. Adoption of preventive maintenance plan	1	1[a]	1	0	0	1	1	1[a]	1[a]
12. Adoption of kaizen	1	1[a]	1	1[a]	1	1	1	1	1
13. Adoption of JIT	1	1[a]	1	1[a]	1	1[a]	1[a]	1	1
14. Adoption of Pokayoke	1	1[a]	1	0	0	1[a]	1	1[a]	1
15. Attempt to eliminate wastes	1	1[a]	1	1	1	1	1[a]	1[a]	1
16. Operational flexibility	1[a]	1[a]	1	1[a]	1[a]	0	0	0	0
Dependence power	16	16	16	13	14	12	14	13	14

→ j i ↓	10. Adoption of SPC to identify process variation	11. Adoption of preventive maintenance plan	12. Adoption of kaizen	13. Adoption of JIT	14. Adoption of Pokayoke	15. Attempt to eliminate wastes	16. Operational flexibility	Driving power
1. Customer firm relationship	1[a]	1[a]	1[a]	1[a]	0	1[a]	1	13
2. Customer feedback	1	1[a]	1	1	1	1	1	16
3. Supply lead time	0	0	1[a]	1[a]	0	1[a]	1	10
4. Supplier development	0	1	1	1	0	1[a]	1	14
5. Supplier readiness in lean implementation	0	0	1[a]	1[a]	1	1	1	13

(continued)

Table 6.4 (continued)

→ j i ↓	10. Adoption of SPC to identify process variation	11. Adoption of preventive maintenance plan	12. Adoption of kaizen	13. Adoption of JIT	14. Adoption of Pokayoke	15. Attempt to eliminate wastes	16. Operational flexibility	Driving power
6. Employee involvement in problem solving	1[a]	1[a]	1	1	1	1[a]	1	16
7. Employee readiness in lean implementation	1	1	1	1	1	1	1	16
8. Adoption of Kanban for production control	0	1[a]	1	1	1	1	1	15
9. Set up time reduction	0	0	1[a]	1[a]	1[a]	1[a]	1	14
10. Adoption of SPC to identify process variation	1	1	1[a]	1	1	1	1	14
11. Adoption of preventive maintenance plan	1[a]	1	1	1	1	1	1	14
12. Adoption of kaizen	1[a]	1	1	1	1	1	1	16
13. Adoption of JIT	0	1[a]	1	1	0	1[a]	1	14
14. Adoption of Pokayoke	1	0	1	1	1	1	1	13
15. Attempt to eliminate wastes	0	0	1	1	0	1	1	14
16. Operational flexibility	0	0	0	0	0	0	1	6
Dependence power	8	10	15	15	10	15	16	

[a]Represents the first-level transitive connection

6.4.5 Level Partition on Reachability Matrix

From the final reachability matrix, reachability sets and antecedent sets are formulated. For a factor, '1' in the row constitutes the reachability set and '1' in the column constitutes the antecedent set. For example, for factor 1, factors 1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 15, 16 constitute the reachability set and factors 1–16 constitute the antecedent set.

Intersection set contains the common elements between antecedent and reachability set. The factor for which reachability set and intersection set matches is considered as level 1. From Table 6.5, factors 1, 2, 3 and 16 will constitute level 1. The factors occupied in level 1 will be removed from further iterations. Similarly, other iterations are performed. Tables 6.5, 6.6, 6.7, 6.8 and 6.9 constitute the iteration performed for level partition.

Table 6.5 Iteration 1

Factors	Reachability set	Antecedent set	Intersection set	Level
1	1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 15, 16	L1
2	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	L1
3	1, 2, 3, 4, 5, 8, 12, 13, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 8, 12, 13, 15, 16	L1
4	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 15, 16	
5	1, 2, 3, 4, 5, 7, 8, 9, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 15, 16	1, 2, 3, 45, 7, 8, 9, 12, 13, 15, 16	
6	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
7	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
8	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16	2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15	2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15	
9	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 14, 15, 16	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 4, 5, 6, 7, 8, 9, 12, 13, 14, 15, 16	
10	1, 2, 3, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 6, 7, 10, 11, 12, 14	1, 2, 6, 7, 10, 11, 12, 14	
11	1, 2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 4, 6, 7, 8, 10, 11, 12, 13	1, 2, 6, 7, 8, 10, 11, 12, 13	
12	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
13	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 15	
14	1, 2, 3, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16	2, 5, 6, 7, 8, 9, 10, 11, 12, 14	2, 6, 7, 8, 9, 10, 12, 14	
15	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 15, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 15	
16	1, 2, 3, 4, 5, 16	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	1, 2, 3, 4, 5, 16	L1

Table 6.6 Iteration 2

Factors	Reachability set	Antecedent set	Intersection set	Level
4	4, 5, 6, 7, 8, 9, 11, 12, 13, 15	4, 5, 6, 7, 8, 9, 12, 13, 15	4, 5, 6, 7, 8, 9, 12, 13, 15	
5	4, 5, 7, 8, 9, 12, 13, 14, 15	4, 5, 6, 7, 8, 9, 10, 12, 13, 15, 16	4, 5, 7, 8, 9, 12, 13, 15	
6	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	
7	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	L2
8	4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15	4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15	4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15	L2
9	4, 5, 6, 7, 8, 9, 12, 13, 14, 15	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 5, 6, 7, 8, 9, 12, 13, 14, 15	L2
10	5, 6, 7, 9, 10, 11, 12, 13, 14, 15	6, 7, 10, 11, 12, 14	6, 7, 10, 11, 12, 14	
11	6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 6, 7, 8, 10, 11, 12, 13	6, 7, 8, 10, 11, 12, 13	
12	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	L2
13	4, 5, 6, 7, 8, 9, 11, 12, 13, 15	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 5, 6, 7, 8, 9, 11, 12, 13, 15	L2
14	6, 7, 8, 9, 10, 12, 13, 14, 15	5, 6, 7, 8, 9, 10, 11, 12, 14	6, 7, 8, 9, 10, 12, 14	
15	4, 5, 6, 7, 8, 9, 12, 13, 15	4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15	4, 5, 6, 7, 8, 9, 12, 13, 15	L2

Table 6.7 Iteration 3

Factors	Reachability set	Antecedent set	Intersection set	Level
4	4, 5, 6, 11	4, 5, 6	4, 5, 6	
5	4, 5, 14	4, 5, 6, 10, 16	4, 5	
6	4, 5, 6, 10, 11, 14	4, 6, 10, 11, 14	4, 6, 10, 11, 14	
10	5, 6, 10, 11, 14	6, 10, 11, 14	6, 10, 11, 14	
11	6, 10, 11, 14	4, 6, 10, 11	6, 10, 11	
14	6, 10, 14	5, 6, 10, 11, 14	6, 10, 14	L3

Table 6.8 Iteration 4

Factors	Reachability set	Antecedent set	Intersection set	Level
4	4, 5, 6, 11	4, 5, 6	4, 5, 6	
5	4, 5	4, 5, 6, 10, 16	4, 5	L4
6	4, 5, 6, 10, 11	4, 6, 10, 11	4, 6, 10, 11	
10	5, 6, 10, 11	6, 10, 11	6, 10, 11	
11	6, 10, 11	4, 6, 10, 11	6, 10, 11	L4

Table 6.9 Iteration 5

Factors	Reachability set	Antecedent set	Intersection set	Level
4	4, 6	4, 6	4, 6	L5
6	4, 6, 10	4, 6, 10	4, 6, 10	L5
10	6, 10	6, 10	6, 10	L5

6.4.6 Development of Digraph

In the iterations performed for level partition, factors eliminated in the first iteration will occupy the topmost position in the digraph. The factors eliminated in the last iteration, i.e. iteration 5 will occupy the bottom most position. Afterwards, each node in the digraph is connected depending on the relation obtained in the final reachability matrix. Figure 6.1 represents the obtained digraph.

6.4.7 Development of MICMAC Graph

Dependence power and driving power are calculated for each factor. For example, dependence power for factor 1 is nothing but the number of ones in the column of factor 1 and driving power is the addition of a number of ones in a row of factor 1.

MICMAC graph consists of four clusters. Four clusters are autonomous cluster, dependent cluster, linkage cluster and driving cluster. Figure 6.2 represents the MICMAC graph.

6.4.8 Development of MICMAC Rank

In this step, the driving power of a factor is divided by its dependence power. Driving as well as dependence power can be obtained from the final reachability matrix. The ranks are assigned in descending order, i.e. the highest ratio obtained is assigned 1.

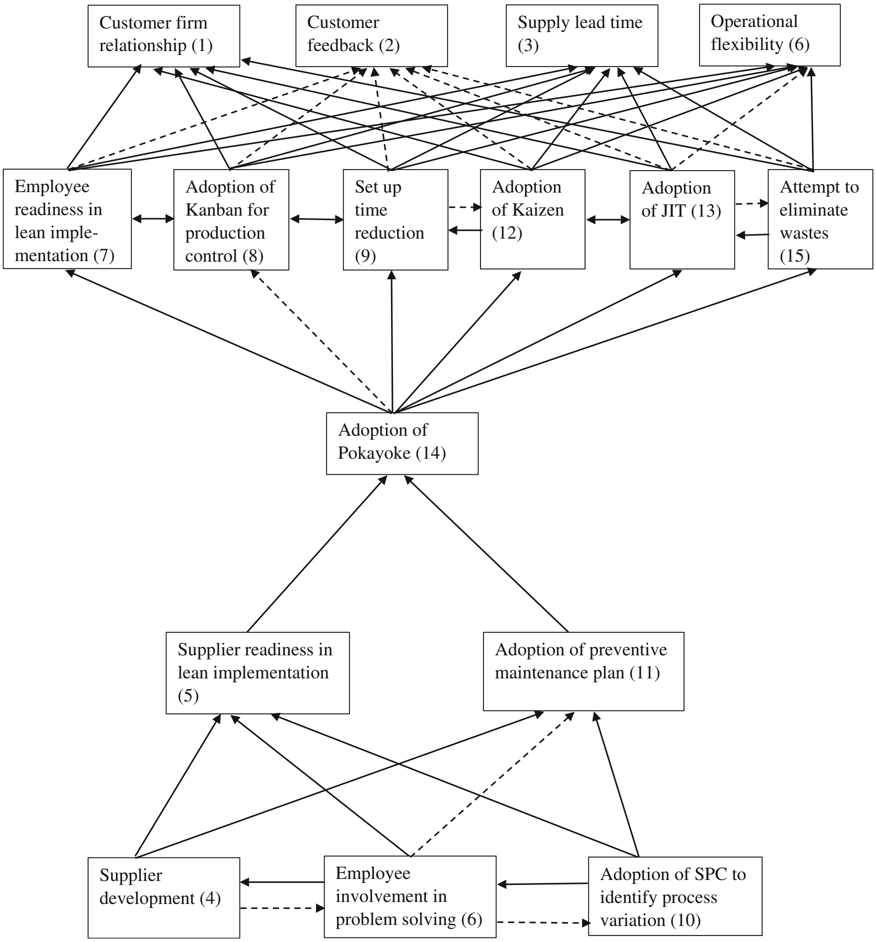

Fig. 6.1 Developed digraph model

Highest rank represents the most important factor and lowest rank signifies the least important factor (Attri, Dev, & Sharma, 2013). Table 6.10 represents the obtained MICMAC ranks. Table 6.10 signifies that the adoption of Statistical Process Control (SPC) being the most important factor and operational flexibility as a least important factor.

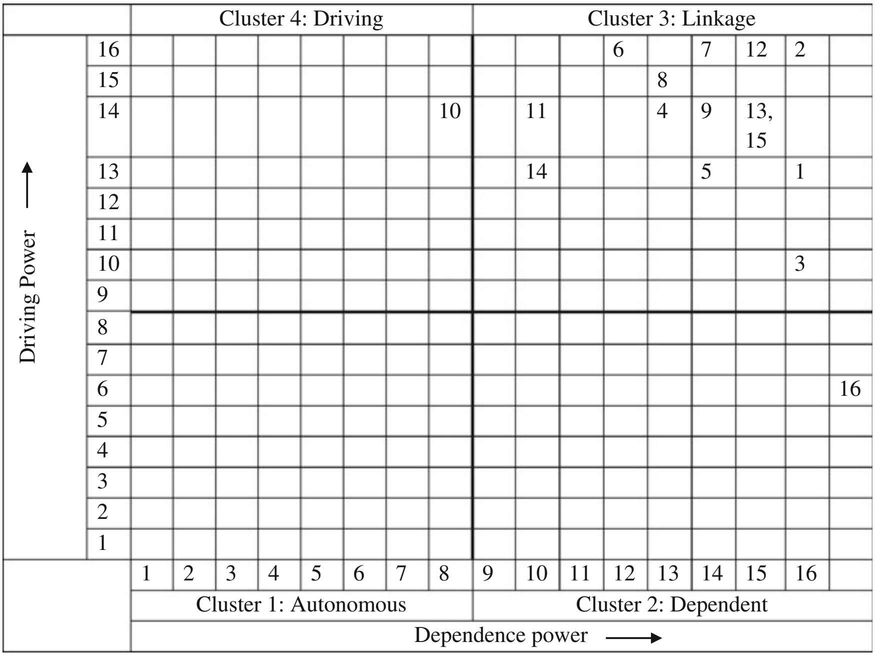

Fig. 6.2 MICMAC graph

Table 6.10 MICMAC rank analysis

Factors	Ratio	Rank
10. Adoption of SPC to identify process variation	1.75	1
11. Adoption of preventive maintenance plan	1.4	2
6. Employee involvement in problem-solving	1.33	3
14. Adoption of poka-yoke	1.3	4
8. Adoption of kanban for production control	1.154	5
7. Employee readiness in lean implementation	1.143	6
4. Supplier development	1.077	7
12. Adoption of kaizen	1.067	8
2. Customer feedback	1	9
9. Setup time reduction	1	10
13. Adoption of JIT	0.933	11
15. Attempt to eliminate wastes	0.933	12
5. Supplier readiness in lean implementation	0.928	13
1. Customer–firm relationship	0.8125	14
3. Supply lead time	0.625	15
16. Operational flexibility	0.375	16

6.5 Results and Discussions

Interpretive Structural Modelling (ISM) was helpful for finding the interrelationship amongst the factors. ISM was also helpful in finding which factor is most important and which one is least with the help of MICMAC rank analysis. Following are the important results derived from the study:

1. Driving factors: From the MICMAC graph, factor 10 (adoption of SPC) to identify the process variation is found to be the driving factor. Driving factor is the one which has high driving power and weak dependence on other factors. Thus, these factors can be considered as most important factors for implementation success of lean concepts in food processing SMEs.
2. Dependent factors: Factor 16 (operational flexibility) is found to be the dependent factor. Dependent factors are those which have high dependence power and low driving power. As these factors have high dependence power, a small change in other factors can affect these factors significantly.
3. Linkage factors: Linkage factors are those which have high driving as well as high dependence power. Customer–firm relationship (1), customer feedback (2), supply lead time (3), supplier development (4), supplier readiness in lean implementation (5), employee involvement in problem-solving (6), employee readiness in lean implementation (7), adoption of kanban for production control (8), setup time reduction (9), adoption of preventive maintenance plan (11), adoption of kaizen (12), adoption of JIT (13), adoption of pPoka-yoke (14) and attempt to eliminate wastes (15) are the factors which constitute the linkage cluster.
4. Autonomous factors: Autonomous factors are those which have low driving as well as low dependence power. There are no autonomous factors found in this study.

The factors are being correlated with the Triple Bottom Line sustainability dimensions and are shown in Table 6.11.

Table 6.11 Correlation of factors with TBL sustainability dimension

No.	Factor	Level in ISM model	Dimension of sustainability
1	Customer–firm relationship	1	Social sustainability
2	Customer feedback	1	Social sustainability
3	Supply lead time	1	Economic sustainability
4	Supplier development	5	Social sustainability
5	Supplier readiness in lean implementation	4	Social sustainability
6	Employee involvement in problem-solving	5	Social sustainability
7	Employee readiness in lean implementation	2	Social sustainability
8	Adoption of kanban for production control	2	Environmental sustainability
9	Setup time reduction	2	Economic sustainability
10	Adoption of SPC to identify process variation	5	Environmental sustainability
11	Adoption of preventive maintenance plan	4	Environmental sustainability
12	Adoption of kaizen	2	Environmental sustainability
13	Adoption of JIT	2	Economic sustainability
14	Adoption of poka-yoke	3	Environmental sustainability
15	Attempt to eliminate wastes	2	Environmental sustainability
16	Operational flexibility	1	Environmental sustainability

6.6 Conclusions

Lean concepts are being applied in service domain to facilitate the streamlined process and value addition from a customer viewpoint. Recently, lean concepts finds application in food processing SMEs due to increase in efficiency and to reduce the cost of production. Factors influencing lean concepts in food processing domain were identified. A structural model is being developed and dominant factors were analysed. MICMAC analysis is being conducted to categorize the factors. Also, the influential factors are related to the corresponding sustainability dimensions. The practical inferences are being highlighted. MICMAC analysis is being done to categorize the factors. The conduct of the study would facilitate the food processing units to systematically deploy lean concepts for ensuring sustainable benefits. In the present study, the developed relationships among factors are not statistically validated. In future, statistical validation could be done using Structural Equation Modelling (SEM) approach.

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Part III
Sustainable Supply Chain Management

Chapter 7
Modelling Intermodal Freight Transportation Promotion for Sustainable Supply Chain in India

Aalok Kumar and A. Ramesh

Abstract Freight transportation planning is an important part of the country's economy. Due to increased demand of the freight in today's supply chain, an optimal mix of existing mode of transportation is required. Intermodal freight transportation is a combination of at least two different modes of transportation. In this chapter, a levelized cost analysis method is used to determine the total levelized cost of the vehicle over its useful life. Also, the total cost varies due to externalities with the given length of route. An intermodal shift of the rail–road mode is also calculated and the optimal cost corresponding to that route was found. In this chapter, all the parameters related to the levelized cost of vehicle is fixed and averaged for a given route length.

Keywords Intermodal freight transportation · Externalities · Modal shift
Levelized cost analysis

7.1 Introduction

Freight transportation is an important function of supply chain management. It involves different stakeholders of supply chain (manufacturers, retailers, customers, and logistics service providers) who directly or indirectly are affected by choosing a transportation mode. Due to a significant increase in the number of vehicles on road and to fulfil the consumer demand, a large fleet of vehicles are deployed on roads, but this causes severe ecological problems. To meet the customer demand with the consideration of environmental impact of their choices in an organization's supply chain, a proper mix of transportation modes are required. Due to the excessive

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freight transportation using a single mode, environmental and social impacts increase on the supply chains and logistics activities. These environmental and social impacts are related to the greenhouse gas emissions, traffic congestion, and traffic accidents.

In India, most of the road traffic is dependent on the finite petroleum resources and also there is a huge imbalance between the share of transportation mode, which will impose heavy burden on Indian roads whereas rail, inland waterway, and air modes are still highly underutilized. To strike a balance of freight transportation in future supply chains, an optimal mix of the modes is necessary. Modal balancing promotes its global competitiveness and economic viability by ensuring that freight is moved efficiently and reliably between points of origin to destination. On the other hand, the impact of the transportation on the environment and society should also be minimized. To improve the sustainability performance of freight transportation, government and supply chain organizations require more competitive modelling in terms of sustainability, cost, and optimal modal sharing. In this regard, European Union document 'A Sustainable Future for Transport' (European Commission, 2009) shows the effect of freight transportation on environment and society. In freight transportation, this would appear to be a reasonable assessment of these problems, in terms of atmospheric pollutant emissions and traffic safety. The European Union does involve in a lot of improvement activities and suggests and implements various sustainable approaches to freight transportation. On similar lines, the Indian government has also been promoting shifting of transportation modes from traditional roadways to rail and inland waterways. Indian government has planned for a target to achieve rail–road modal sharing of 50% each by the end of the year 2032, i.e, 15th five-year plan. Indian Railways is also developing a dedicated freight corridor along the country's major industrial zone [Delhi–Mumbai Industrial Corridor (DMIC) and Delhi–Kolkata Industrial Corridor (DKIC)] which will provide a good modal shift from road to other viable options of transportation. This dedicated freight corridor will be operational by the year 2019.

As we know that GHG emissions, through the well-known link with global warming, pose arguably the greatest threat to society in the medium to long term. Despite that, there is not much development in the area of GHG emission reduction in India and other developing countries. According to Environment assessment agency (EAA) report (2015), level of CO_2 emissions in India is 2.47 billion tons in 2015, which was 5.1% higher than the year 2014. Similar results are observed for the years 2007 and 2013, and below average growth rate of 6.8% for the 2006–2014 period (Please see Fig. 7.1).

This report also shows that if India does not frame and implement certain regulations regarding carbon emissions, then it is likely that it will surpass the European Union by 2020. The European Union is exhibiting positive changes as it has been showing a steady decrease in emissions between 2006 and 2015 at an average rate of 1.9% per year. India's level of emissions has already exceeded the total emissions by Russian Federation in the year 2009. At present, India has become one of the countries with the highest level of carbon emissions among the developing countries. China and the United States have also shown a significant

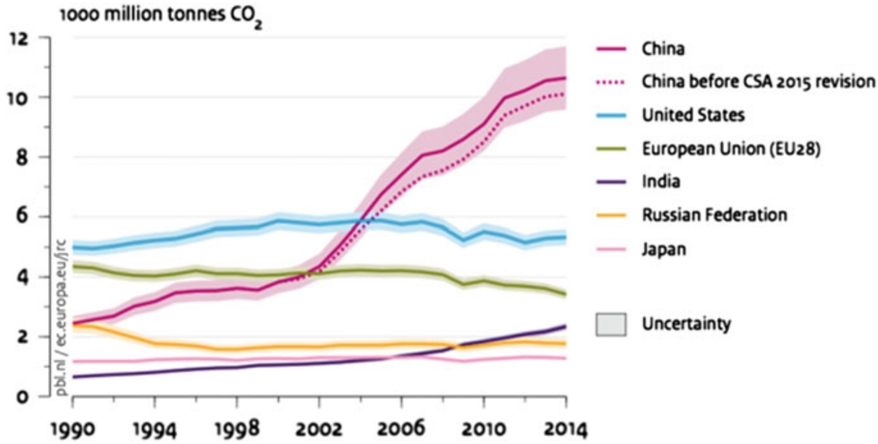


Fig. 7.1 Emission trends of the world major emission emitting countries. *Source* IEA 2014 and NBS 2015

reduction in emissions in the year 2015. However, India's per capita emissions of 1.9 tons CO_2 per capita is more than all European Countries.

Another major negative externalities of the freight transportation are congestion. Freight transport is a cause and also a victim of congestion. Indian ports, transport nodes, terminals, and regional freight hubs already suffer from congestion. Due to a significant increase in urban freight, congestion problem in cities is also prominent. Congestion on the road networks will hence become a major barrier for on time delivery of the freight which will, in turn, impose high operating cost of the logistics and also increase the level of emissions. As population and incomes (and hence total consumption) continue to grow and trade continues to expand, such that congestion is likely to get worse unless effective solutions are found, and it will have its most noticeable impact in major urban areas, which are forecasted to have exponential growth in the future.

In India, transportation sector contributes to a significant amount to the economic growth of the nation. As per a 2015 McKinsey report, ~14% of GDP was spent on logistics and transportation activities, whereas other developing countries spend only 8%. Due to Make in India and other manufacturing initiatives of the government, a significant growth in manufacturing, retail, FMCG and e-commerce sectors is observed which are forecasted to create a growth of 13.35% CAGR by 2020. This growth will also increase the demand for urban freight in Indian cities. Hence, urban freight planning is an important part of intermodal freight transportation in India. In India, roads carry around 63% of the total freight movement on highways and state roads, whereas the Indian Railways carry only 27% and inland waterway and sea covers approximately 7% of freight transportation. Thus, there is a huge modal imbalance among the existing modes of transportation. Indian government should plan for a proper mix of modes which will help in reducing the externalities and increase the cost competitiveness of the freight transportation (Fig. 7.2).

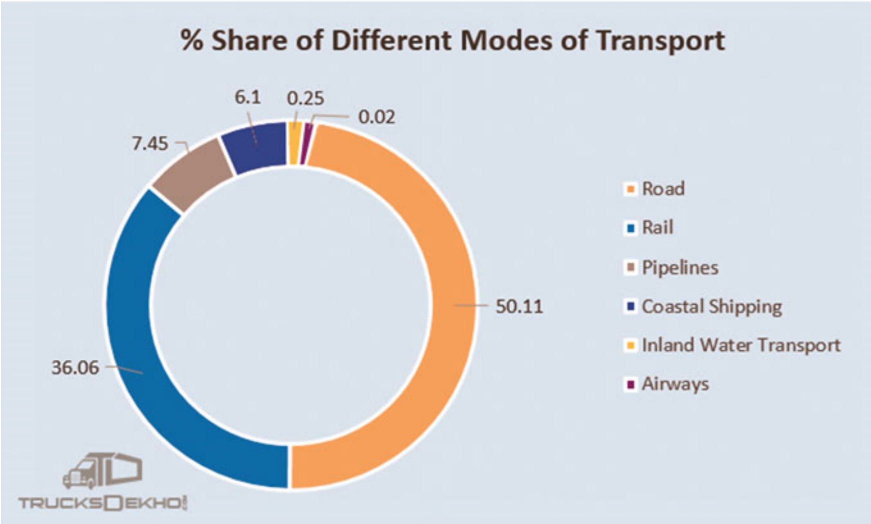


Fig. 7.2 Percentage modal sharing in India in the year (2015–2016). *Source* Cardekho.com, road versus rail transport in India

Railway ministry report (Railway Ministry, India report July 2017) shows that in the financial year 2017, around 1107.10 million tons of freight (combination of different commodities) was transported by railways and it is expected to grow to 2165 million tons by the financial year 2020. The commodities transported included goods like coal, iron, steel, fertilizers, cement, petrochemicals and agricultural products, and other products. Government is also promoting inland waterway freight transportation from Allahabad (Uttar Pradesh) to Haldia (West Bengal) to reduce the burden of road and rail.

While examining recent trends of freight transport, it was found that it is necessary to consider individual transport modes and not just the total transport flow. To help in projecting trends into the future, it is also instructive to examine the relationship between externalities, economic growth and freight transport use. The use of freight transport has remained relatively closely coupled to economic growth (unlike passenger transport, which has recently been growing less slowly). Due to the flexibility, timely delivery and better utilization of ICTs, road mode will provide a dominant nature in freight transportation, but it also put a heavy burden on the environment and society. To overcome these externalities of road mode, government has to promote intermodal freight transportation in the same way of promoting passenger transport in cities and country.

7.2 What Is Intermodal Freight Transportation?

The concept of intermodal transportation arose in the late 90s in European Union countries. Although the term intermodal transportation is used authoritatively in the literature, the definitions given by different authors is based on their application area. A similar lack of precision can be observed in the use of terms such as multimodal transportation and combined transportation, as in some occasions they are used as synonyms for intermodal transportation, and in others as types of intermodal transportation or vice versa.

Multimodal freight transportation is defined as the transportation mode of goods by a combination of at least two different existing modes of transportation (UNECE, 2009). Transportation unit can be a box, a standard container, a swap body, a rail/road container or vessel. Whereas, Intermodal freight transportation (IFT) is a special type of multimodal freight transportation where the same loading unit is used for transporting goods from origin to destination and that unit is called ITU, and in this, no handling is required when changing modes (Crainic & Kim, 2007). Intermodal terminals provide to companies the flexibility and the economies of scale of using multiple freight distribution modes. Despite lack of precision, the literature indicates that combining two or more types of transportation in a logistics network provides the means to move the freight from its point of origin to its destination economically and in a way that is operationally viable (Meng & Wang, 2011a). Typically, these transportation modes include truck, railroad, ship, and air. Pipeline mode is not much considered due to its peculiar property of carrying only liquid freight. Transportation by air is also least preferred because of its cost and it can only be used for those commodities having a short life or low weight-to-volume ratios. Planning of intermodal freight transportation positively influences the national economy by optimizing the use of country's available transportation modes.

Researchers' interest in intermodal freight transport was first observed in the 1990s. During the initial years of this research area, researchers focused on specific research problems, mainly related to planning, opportunity costs (Bontekoning, Macharis, & Trip, 2004) and transport system modelling (Macharis & Bontekoning, 2004). Woxenius (2007) discuss the various network topologies used in the intermodal freight transportation network design. Alumur and Kara (2008) discuss extensive hub location problem used for efficient deliveries of intermodal freight transportation. Subsequently, extant literature addressed the issues related to the selection of transportation mode used in intermodal systems, transport policy (Macharis, Pekin, Caris, & Jourquin, 2011) and planning and analyses undertaken in concrete geographic areas (Mathisen & Sandberg, 2014). Hanseen et al. (2012) provided a generalized transport model for intermodal freight transport in which the objective is to determine the optimal location of the intermodal terminal. In this work, they also determine the scheduling of two drivers or a single driver in case of the truck.

7.3 Why Is Sustainability Harder to Achieve in Freight Transportation Than Public Transportation in India?

Sustainability in freight transport may well be harder to achieve than for passenger transport. There are many reasons for this, including the long-time horizons on achieving more sustainable fuels, factors relating to the nature of goods that are moved, the need for significant price changes to induce modal shift and due to the lack of innovation in sustainable freight transport modes. Due to the globalization of the supply chains, the demand for the freight is increasing day by day, which will require more vehicles in the transportation network.

There are various other reasons to believe that sustainability in freight transport use may well be harder to achieve than for passenger transport. These include the following:

(a) Modal sharing in freight transportation is not balanced in India.
(b) Decisions regarding freight transport may be more price sensitive for freight (particularly the 'cross elasticities' reflecting the likelihood of a modal shift in response to price changes), especially for time-sensitive and higher value freight (Graham & Glaister, 2004). Hence as long as road freight remains cheaper and flexible to use than rail and inland waterway, it will remain the dominant mode among all transportation modes.
(c) Due to continous increment in the freight volume more number of freight container is required.
(d) There are fewer opportunities for 'e-substitution' (European Commission, 2009) for freight (people may well be able to work from home, but goods still have to be moved from origin to destination.
(e) There are fewer decision-makers for freight hence decisions are 'lumpy', and smooth transitions in response to policy changes are less likely.
(f) Railway freight trains have low priority on the network (the same origin–destination pair) compared to passenger traffic in India. Because in India, only passenger fares are subsidized while freight charges are high compared to other countries.
(g) There also have been far less innovation for freight in the rail network than for passenger traffic. Punctuality maintained by the freight trains is also another major issue.
(h) Industrial regions of states (mostly) are not well connected with the rail and inland waterway, so there is less popularity of the modal shift from road to other modes.

7.4 Options for Greater Sustainability in Freight Transport

The following options will play a vital role in the development of the intermodal freight transportation in Indian transport industry;

7.4.1 *Pricing*

Given that we have identified that freight transport decision-makers are essentially cost driven, pricing is an appropriate mechanism by which one can try to change the behaviour of the shippers. In India, majority of road transportation (for freight) is owned by private organizations and they are the sole decision-makers about the pricing policy for the freight. In case of the rail freight, transportation prices of the freight are set by the ministry of railway. Due to the uneven distribution of the freight prices per ton (agriculture and commodities are having low prices whereas the cost of carrying coal, petrochemical products and cement are high), shippers do not have incentives to change transportation modes. While rising transport costs due to energy prices generally may not be desirable, they do have the major benefit of promoting the more energy-efficient and more sustainable rail and water transport modes against the less sustainable road and air freight. Hence, it is also likely that policymakers will have to implement other ways of influencing the prices paid by transport users so that more sustainable modes of transport are chosen by shippers. A further advantage of regulated road pricing, particularly when implemented in urban areas, is that exemptions could be given for greener vehicles such as electric vehicles which would encourage their use. Due to unclear pricing policies and lack of intermodal terminal infrastructure, transshipment and holding cost, shippers are not willing to switch to other modes of transportation.

7.4.2 *Alternative Fuels*

Environmental impact of intermodal freight transportation can be reduced by the promotion of alternatives fuels and renewable technology. The economy of a country greatly depends on energy consumption by various transportation modes. Energy consumption by transportation modes in developed countries is around 20–25% of all energy that is consumed (Rodrigue, Comtois, & Slack, 2009). Majority of the Indian road and rail freight transportation sector vehicles are dependent on diesel compared to other fuels/electricity. Diesel, among other fuels, is also considered to be one of the ‘dirtiest’ fuels with high levels of particulate matter and NO_x emissions. Other fossil fuels like natural gas, propane and methanol can also be used as alternative transportation fuels but require a more complicated engine configuration. The major issue that arises when promoting these alternative options is the large capital investments required in distribution facilities as compared with conventional fuels (which already have these facilities in existence). The other issues that are related to these alternative fuels are in terms its energy density, fuel efficiency, configuration and type of the engine, and also storage capacity to cover an equivalent distance with the conventional diesel-based vehicle.

The following options are available for alternative fuels to reduce the petroleum costs and pollutant emissions.

(a) **Biogas** is produced by the fermentation reaction of energy crops (sugar cane, corn, cereals, etc.). However, their production requires a large cultivation area. It is also estimated that one hectare of wheat produces less than 1000 L of transportation fuel per year and that is used by one passenger car travelling 10,000 km per year (Rodrigue et al. 2009). The production rate of biogas depends on the solar energy, absorbing capacity of plants and their photosynthesis reaction. Due to the low rate and productivity of the biomass, it will unable to meet the energy needs of the country's transportation sector sufficiently.

(b) **Hydrogen** is also known as the future energy source which is used by the energy sector. The production of hydrogen is based on the electrolysis of water forming natural gas, or oxidation and steam forming other fossil fuels (Khare & Sharma, 2003). The hydrogen cells are two times more efficient than gasoline. Due to production and storage difficulty, this option is also not viable for large-scale consumption. Besides, hydrogen is also highly inflammable.

(c) **Electric** batteries are considered as an alternative source in the transportation sector. Due to the lack of storage capacity and load carrying capacity, the development of electric vehicles is not viable for long driving ranges and different speeds comparable to those of conventional fuel (petrol and diesel)-powered vehicles. The recent development of hybrid vehicles which is the combination of internal combustion engine and batteries provides interesting opportunities, and by combining the efficiency of electricity gives the vehicles the flexibility of a long driving range. For the small load distribution in the urban area, vehicles with this option should be promoted and that will definitely reduce the adverse effects of city freight transportation. Vehicle and facilities at intermodal terminals should use alternative options compared to traditional power sources for higher sustainability.

7.4.3 Mode Shift

Modal shift is clearly one of the major opportunities to reduce unbalancing of transportation modes. Indian rail and inland waterway transportation with greater capacity and low level of congestion attract a significant change in modal shares. Improved efficiency and environmental performance of existing modes are encouraging many governments to promote the more efficient use of existing modes. However, such measures are largely predicated on removing existing inefficiencies, which will be exhausted long before targets such as those for carbon reduction are reached. Hence, this is only a partial solution. Time has to come to set new objectives for modal shift, developing intermodality, and reducing congestion which improve the safety and quality of transportation service. Achieving a modal shift is, however not an easy task in India because there are different ministries and their policy intervention about the transportation modes. The alternative mode of transportation is required to fulfil shippers' logistical requirements and also to improve their supply chain performance. In this respect, researchers show the different qualitative and quantitative criteria that are to be taken into account in freight choice decision (Cullinane & Toy, 2000; Beuthe et al. 2003; Kreutzberge 2008). These criteria are related to cost/price/rate, the speed and reliability of delivery, loss and damage (safety), flexibility, availability of infrastructure and its capacity, regulation/legislation, controllability/traceability, its environmental effects, etc. These attributes indicate that shippers' decisions about the modal shift are not entirely based on the transportation cost. The combination of rail and road mode in India was carrying about 87% of total freight in the year 2007–2008. In the 12th five-year plan of Indian government, it was estimated that the modal share of rail and road should be in ratio 35:65 in 12th five-year plan, 39:61 in 13th plan, 45:55 in 14th plan and 50:50 in 15th plan. So, Indian government aims to achieve 50:50 modal shift in the year 2032. With the elasticity at 1.2, total freight traffic is expected to grow 9.3% per annum and reach 13,000 billion tons km (BTKM) in 2032 from 2000 BTKM in 2011–12. Rail modal sharing is growing by 12% and road by 8% annual rate and is projected to achieve 50:50 target by 2032 (according to National transport development policy committee, Govt. of India, 2013 report). The issue really lies in the impact on the competitive balance between modes, which would seem to be undesirable.

7.4.4 Information and Communication Technology (ICT)

Due to an increase in freight demand, fuel prices, road infrastructure cost and congestion on many road networks, new and innovative solutions are required in transport operations. It is hard to execute supply chain and logistical processes in today's business environment without the involvement of some kind of technology. Due to the involvement of a wide variety of operators in intermodal transportation, lack of technological integration can limit the growth of intermodality. Information and communication technology (ICT) is expected to play a vital role in ensuring the future efficiency and sustainability of freight (EC, 2009). Tseng, Yue, and Taylor (2005) suggested that the most commonly used ICTs were: GPS (Global Positioning Systems) for monitoring and locating vehicle, GIS (Geographical

Information Systems) which provide the basic geographical database for making easier delivery and to find the optimal route to the destination and advance information system, which assists the managers and workers with a real-time data about the demand and number of vehicles required to fulfil the demand. Tseng et al. (2005) derived the integration of these three systems (GPS, GIS and AIS) to provide better service quality, to reduce unnecessary trips by vehicle and improved loading rate of the vehicle. The influence of technological solution service providers could play an important strategic role by promoting greater ICT adoption by network actors (Harris, Wang, & Wang, 2015). Islam, Zunder, and Jorna (2013) evaluate unimodal transportation systems and compare their performance with intermodal systems to facilitate decision-making. Mason, Ribera, Farris and Kirk (2003) discuss that ICT and its applications not only aid transportation decisions but they also help shippers to execute and optimize transportation decisions, like routing, scheduling, monitoring and tracking of goods (Gilmore & Tompkins, 2000) and also aid the flow of information along the marketing channel (Wiegmans, Nijkamp, & Masurel, 2001). Marchet, Perotti, and Mangiaracina (2012) and Giannopoulus (2004, 2009) discuss that information technology is an aid to logistics activities and helps carriers to improve the effectiveness and efficiency of the service that they provide. However, poorly integrated transportation network creates inadequate flow in an intermodal transport system (Almotairi, Flodén, Stefansson, & Woxenius, 2011). ICT also enables firms with linkage to cloud computing, social networking and hence wireless communication has further revolutionized the way information is shared and supply chains are structured. The world of ICT is fast changing, and we can be reasonably confident that new applications will emerge to address the above discussed and other related opportunities.

7.4.5 Intelligent Transport Systems (ITS)

The major objective of intelligent transportation systems (ITS) is to provide innovative services for the different transport modes and better traffic management. ITS is a combination of the application of ICTs, with the available transport-related infrastructure and the legislative/policy of the country to optimize transport efficiency and operational sustainability in the near future (Giannopoulos, 2009). The advanced level of ICT solutions can increase the data flow and information quality while allowing real-time data exchange in ITSs and traffic networks (Crainic & Kim, 2007). The introduction of intelligent transport systems will start to offer opportunities for improved sustainability. ITS includes smart road pricing, providing alternative routes to the vehicle in the most congested time or peak hours driving and other similar services. A long-term goal of ITS is Intelligent Speed Adaptation, which could improve both safety and fuel consumption, and perhaps even enable computerized vehicle control.

7.5 Modelling of the Transportation Cost

Transportation cost is an important factor in the economy of any nation, a region or a city. In today's global business era low costs concern to be competitive. Therefore, it is necessary to obtain the total transportation of a particular mode and try to minimize its internal cost and its environmental impact. In the literature, many studies have been trying to minimize transportation cost. McCann (2001) deals with the optimal size of the vehicle and structure of the total transport cost with respect to the carrying distance. Sahin et al. (2014) make an economic analysis based on levelized cost function for transportation mode selection and its variability with distance.

The total cost of any freight transportation is the combination of the internal and external costs. Janic (2007, 2008) developed a total transportation cost in which he considers the internal and external effect of transportation on road, rail and waterway mode. He used data from European countries to show the effect of the external cost (emission, pollution and accident) on the total cost of the freight transportation by road, rail and inland waterway.

Sengupta and Cohan (2017) used lifecycle management method with levelized cost method for evaluating alternative fuel vehicle and its environmental effect. They find with the help of a case study that the CNG sedans and trucks provide 11% emissions reductions, but have 25 and 63% higher levelized costs, respectively.

Janic (2007) defines internal cost as the combination of the capital cost, fuel cost, operational and maintenance cost. The external cost of the transportation involves congestion cost and emission and accident cost of the transportation. Moreover, a specifically designed cost method which takes probable price increment during the useful economic life of a specific transportation mode. For this propose, a more realistic cost analysis method is used and that method is called '*the levelized cost analysis method*'. Sahin et al. (2009) also used levelized cost method for economic analysis of the alternative modes of transportation with the case study of a problem based in Turkey.

This method is most commonly used for the cost analysis of the power plants cost estimation. In this chapter, the relationship between the operational parameters of the vehicle and the cargo transportation cost is established by using this method. The road and rail mode comparison is based on the total transportation costs. Proposed methodology in this study leads to determine the optimal cost per ton with the modal distance sharing. Also, shows the effect of congestion on the modal sharing.

The net present value (NPV) of overall useful life cycle costs for different modes of transportation was computed by the formula:

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{C_{\mathrm{t}}}{(1+r)^{t}}. \tag{7.1}$$

In Eq. (7.1), n is the useful life of the vehicle (different for trucks and rail wagons), C_{t} is the particular cost incurred in year t, and r is the discount rate. These calculations took the initial price related to every component of the transportation cost (for example operational cost, annual capital cost, fuel and lubricant cost, maintenance and repair cost and also the external cost of transportation). This cost also depends on the vehicle kilometre travelled (VKT) and fuel prices. This approach to calculating NPV with a 5% discount rate has been considered by Gilmore and Lave (2013). The method of levelized cost per kilometre were computed by first annualizing the calculated NPV values using the formula provided by Park, Shin and Yoon (2011).

In a similar way, annualized equivalent cost (INR/year) of an NPV for n years at a discount rate of r is as follows:.

$$A = \mathrm{NPV}\left[\frac{r(1+r)^{n}}{(1+r)^{n}-1}\right]. \tag{7.2}$$

The levelized cost (INR/km) then comes from this annual cost divided by annual load travelled by a mode.

So from Eq. (7.1), we can develop a composite formula for total cost of a transportation mode.

$$\mathrm{CT} = \sum_{t=1}^{n} \frac{[C_{\mathrm{k}}(t) + C_{\mathrm{f}}(t) + C_{\mathrm{mr}}(t) + C_{\mathrm{ext}}(t)]}{(1+r)^{t}} \tag{7.3}$$

In Eq. (7.3), $C_{\mathrm{k}}(t)$ is the time-dependent annual capital cost, $C_{\mathrm{f}}(t)$ is the cost of fuel and lubricants, $C_{\mathrm{mr}}(t)$ is the cost of maintenance and repair, $C_{\mathrm{ext}}(t)$ and is the combined cost of the accidents, carbon emission by a transport mode. This equation represents the NPV on the date of vehicle's initial operations of all the cost incurred during the useful life of the vehicle. The annual cost series along the economic life of the vehicle is given by

$$C_{\mathrm{a}} = \frac{\mathrm{CT}}{\sum_{t=1}^{n}(1+r)^{-t}}. \tag{7.4}$$

If the annual carrying capacity of the vehicle in time t is given by $Y(t)$, then the uniform cargo cost per unit is defined as

$$U_{\mathrm{t}} = \frac{C_{\mathrm{a}}}{\sum_{t=1}^{n} Y(t)}. \tag{7.5}$$

7.5.1 Annual Capital Cost of the Vehicle

The annual capital cost of the vehicle is calculated by the initial investment of the transportation vehicle and it is linearly decreasing in nature. This cost consists of two main factors namely its principal payments and the interest component of the vehicle during the economic life.

$$C_{\mathrm{k}}(t) = \frac{I_{\mathrm{c}}}{n} + I_{\mathrm{c}}\left(1 - \frac{t-1}{n}\right)i \tag{7.6}$$

In Eq. (7.6), i is the interest rate which is also referred as the recovering factor form a transportation vehicle over a useful life period.

7.5.2 Annual Cost of the Fuel Expenses

The annual cost of the vehicle during the economic lifetime depends on the price of the fuel at initial operation of the vehicle and it is assumed these prices change over a period of n, and that incremental factor is called as the *escalation factor* of fuel prices during different time period, t due to uneven distribution of the vehicle on the route there is also a problem of congestion increase the fuel consumption and consequently increases the total cost of the fuel. But the effect of congestion is not considered by any study which is based on the levelized cost of transportation. In this chapter, we consider congestion-based fuel cost as a time-dependent fuel consumption based which is different from the distance based consumption of the vehicle.

So the total fuel cost over the period n due to distance travelled under normal and congestion dependent distance calculated by

$$C_{\mathrm{f}}(t) = C_0(1 + e_{\mathrm{f}})^t. \tag{7.7}$$

The value of the C_0 depends on the total number of the annual trips, mileage of the vehicle and price of the fuel per litre.

$$C_0 = \mathrm{LNB_f}P_{\mathrm{f}} + (\text{time spent in congestion} * \text{fuel consumption}\left(\frac{\mathrm{lt}}{\mathrm{hr}}\right) * P_{\mathrm{f}}. \tag{7.8}$$

Time spent in congestion is calculated with the average time spent by a truck in one trip.

Where L is the route length in kilometre, N is the number of trips per year, B_f is the fuel consumption by vehicle litre per kilometre and price of the fuel used per litre (INR/Lt).

Number of the trips is calculated as

$$N = \frac{\text{Annual time available} - \text{Annual time spent in maintenance and repair} - \text{annual time being idle at depot}}{\text{time spent in given route length} + \text{waiting time for next loading for delivery} + \text{time spent in congestion}}$$

$$N = \frac{8760 - Z_m - Z_i}{Z_d + Z_s + T_c}. \quad (7.9)$$

Considering 365 days as a working period.

The term Z_d depends on the vehicle speed over the given route length, so

$$Z_d = \frac{L}{S_v}, \quad (7.10)$$

where S_v is the speed of the vehicle.

7.5.3 Annual Maintenance and Repair Cost

To avoid the failure of the vehicle, there is a regular schedule of the maintenance and repair of the vehicle in the route of failure. This maintenance cost increases with time and life of the vehicle. Some authors also consider the insurance cost as a function of time and value of the vehicle. For this study, we do not consider the insurance premium paid by the transport owner due to lack of availability of the data. The annual maintenance cost with increasing factor are calculated by

$$C_r(t) = C_{mo}(1 + e_m)^t. \quad (7.11)$$

7.5.4 The Amount of Average Cargo Per Year

The amount of the annual transportable cargo is calculated by

$$T_a = C_v K N, \quad (7.12)$$

where C_v is the cargo carrying capacity of the vehicle in ton, K is the utilization factor of the vehicle capacity and N is the number of annual trips.

Put the value of N from Eqs. (7.9) to (7.12)

$$T_a = C_v K \left[\frac{(8760 - Z_m - Z_i) S_v}{L + S_v (Z_s + T_c)} \right]. \tag{7.13}$$

Levelized unit cargo investment cost can be found as follows:

$$U_c = \frac{\sum_{t=1}^{n} C_k(t)(1+r)^{-t}}{T_a \sum_{t=1}^{n} (1+r)^{-t}}. \tag{7.14}$$

Put the value of T_a from Eq. (7.13) into Eq. (7.14)

$$U_c = \frac{\sum_{t=1}^{n} C_k(t)(1+r)^{-t}}{C_v K \left[\frac{(8760 - Z_m - Z_i) S_v}{L + S_v (Z_s + T_c)} \right] \sum_{t=1}^{n} (1+r)^{-t}}. \tag{7.15}$$

Levelized unit cost of fuel per unit of cargo carrying is calculated as follows:

$$U_f = \frac{\sum_{t=1}^{n} C_f(t)(1+r)^{-t}}{T_a \sum_{t=1}^{n} (1+r)^{-t}}. \tag{7.16}$$

Levelized cost of the maintenance and repair cost per unit of cargo is calculated as

$$U_m = \frac{\sum_{t=1}^{n} C_{mr}(t)(1+r)^{-t}}{T_a \sum_{t=1}^{n} (1+r)^{-t}} \tag{7.17}$$

External cost of the accidents, emission of per unit of cargo is as follows:

$$U_{ex} = \frac{(C_{ac} + C_{em}) L \sum_{t=1}^{n} (1+e_x)^t (1+r)^{-t}}{(1+e_x)^t \sum_{t=1}^{n} (1+r)^{-t}} * \left(\frac{K^*}{K} \right) \tag{7.18}$$

where $C_{ac,}$ C_{em} are the specific cost of accidents and specific cost of carbon emission per ton kilometre of freight transportation by mode. e_x is the incremental rate of these factors assumed in this chapter as a same increment rate in both the externalities but this varies from countries or region to region. K^* is the reference utilization factor and K is mode-specific utilization factor.

Finally, total cost of transportation per ton is found as follows:

$$U_{total} = U_c + U_{mr} + U_f + U_{ex} \tag{7.19}$$

Also, the specific cost, (INR/ton/km) is calculated by

$$U_{KL} = \frac{U_{total}}{L} \text{ (INR/ton/km)}. \tag{7.20}$$

7.5.5 Development of Intermodal Cost Model

The promotion of the intermodal freight transportation is required to mitigate the huge transportation cost by a single mode of transportation. For intermodal freight transportation, the specific cost of the unit freight cost per unit length is considered as an important criterion for mode selection. Previously, derived and discussed factor affect the transportation mode selection. These factors can vary from different transportation modes and also with respect to country legislation and transportation rules. All costs along the useful life of the vehicle are calculated in the certain time interval. Also, the amount of the cargo carried by various modes varies from year to year and from route to route, it depends on the annual demand and the transportation (road/rail) conditions. Therefore, freight transportation cost can be determined by levelized cost analysis method.

For this chapter, we consider the intermodal competition between the rail and road mode of freight transportation.

So, the total transportation cost by combining both the mode for a given route length is determined by

$$U_{\text{total}} = X \cdot (U_{\text{L}})_{\text{road}} L + Y \cdot (U_{\text{L}})_{\text{rail}} L. \tag{7.21}$$

Equation (7.22) can be extended for the waterway and air mode by given equation as follows:

$$U_{\text{total}} = X \cdot (U_{\text{L}})_{\text{road}} L + Y \cdot (U_{\text{L}})_{\text{rail}} L + Z \cdot (U_{\text{L}})_{\text{waterway}} L + V \cdot (U_{\text{L}})_{\text{air}} L, \tag{7.22}$$

where Z is the proportion of total route length covered by the waterway and $V = (1 - X–Y–Z)$ is the distance travelled by air. Due to lack of data available on inland waterway freight transportation and air freight transportation, we only considered road and rail mode of freight transportation. In this chapter, the given data in Table 7.1 is related to the Delhi–Mumbai route which is 1385-km long by road and 1460-km long by rail. For simplicity, we consider an approximate trip distance of 1500 km.

The specific intermodal transportation cost per unit freight per unit distance is

$$U_{\text{KL}} = X \cdot (U_{\text{L}})_{\text{road}} L + Y \cdot (U_{\text{L}})_{\text{rail}} L, \tag{7.23}$$

where X, Y are the sharing ratios by the road and rail respectively. Thus, the intermodal freight transportation cost can be realized as follows:

If $X = 0$, then only rail mode is available between origin and destination and
If $Y = 0$, then only road mode is available between origin and destination.
If the value of X and Y lies between 0 and 1, then there is an option for intermodal freight transportation.

Table 7.1 Data related to road and rail mode of freight transportation in India

Description of the vehicle	Symbol	Unit	Road freight transportation	Rail freight transportation
Investment cost of the vehicle	I_c	INR	20,00,000	1,80,000,000
Useful life	n	Year	15	20
Travelling speed	Vs	KMPH	30	25
Freight carrying capacity	C_v	Ton	20	1100
Annual maintenance and repair time	Z_m	H	600	1800
Annual idle time	Z_i	H	2400	1700
Vehicle mileage	B_f	Lt/Km	3.75	10
Price of fuel	P_f	INR	60	60
Route length	L	Km	1500	1500
Increment cost of fuel price	e_f		4%	4%
Increment cost of external cost	e_x		3%	3%
Increment cost of maintenance and repair	e_m		3%	3%
Cost of accident per ton km	C_{ac}	Rs/ ton-km	2.8	0.35
Cost of emission per ton km	C_e	Rs/ ton-km	0.202	0.05
Utilization factor of vehicle	K		80%	70%
Reference utilization factor of vehicle	K^*		90%	90%
Interest rate	i		8%	8%
Discount factor	r		10%	10%
Waiting time between trip	Z_s	H	8	20
Operational and maintenance cost	C_{mo}	Rs per km	8	15

Sources Planning Commission of India report on transport vol. I, II, III, Indian Railways report (2017), www.ibef.org, www.indianrailways.gov.in/, TCI-IIM Calcutta 2009 report, National Highway Authority of India accident data, Morgan Stanley (2015) report on Indian railway, Avendus report, November 2016

The following data is prepared from different sources of Indian Railways, Planning Commission of India, and TCI-IIM Calcutta joint research project on operational efficiency of the freight transportation.

In this given illustration, the interest rate i is assumed to be 8%, the discount rate r is 10%, the escalation rate for future fuel costs as 4%, the escalation rate for maintenance and repair as 3% and escalation rate for external costs are also considered as 3%.

This chapter gives an in-depth knowledge of the variation of total cost with the vehicle loading (vehicle utilizing factor), amount of external cost paid by the transport user and also to determine the modal competition for a given distance (in this illustration distance is 1500 km) and in this chapter we also determine the optimal mix of X and Y for optimal level of total cost.

But in case of intermodal freight transportation handling and stocking cost at the intermodal terminal is also considered.

7.6 Result and Discussion

With the use of Microsoft Excel 2013, following data are used in Eqs. (7.13), (7.15), (7.17), (7.18), (7.19) and (7.10). From the analysis of the levelized fuel cost/ton-km with respect to vehicle utilization factor result shows decreasing relationship. The result from this analysis shows that if we improve the vehicle loading from 50 to 90% or 95% then there is a significant drop in cost/ton-km of freight transportation. In India, freight trains are running at an average utilization of 70%, if we improve the loading up to 90% then a cost optimality would arrive in train transportation. Results are shown in Fig. 7.3.

Figure 7.4 shows that there is a significant decrese in external cost (accident and emission) of road transportation with improved load factor of vehicle.

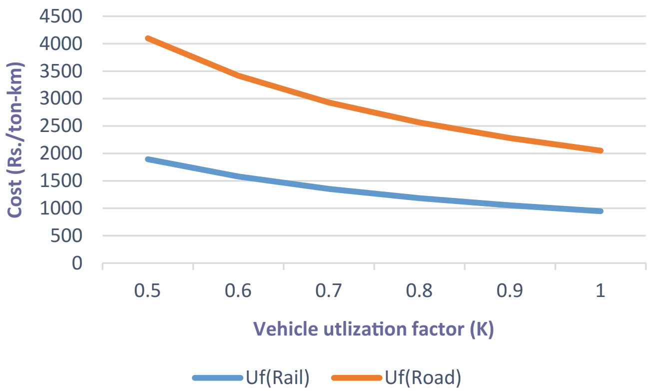
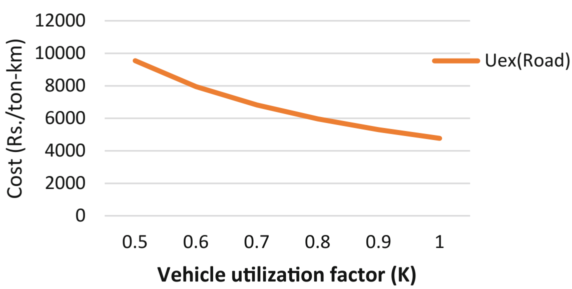


Fig. 7.3 Variation of total levelized fuel cost with the vehicle utilization factor (K)

Fig. 7.4 Variation of total levelized external cost with the vehicle utilization factor (K)



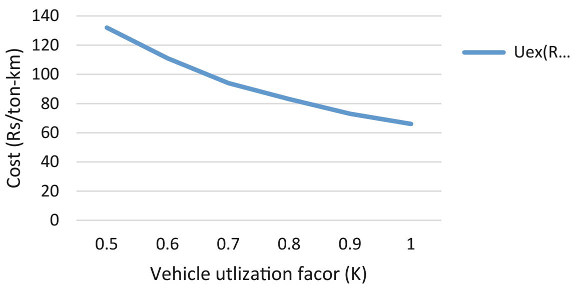


Fig. 7.5 Variation of total levelized external cost with the vehicle utilization factor (*K*)

The improved loading factor also reduces the annual trips made by vehicles resultly reduces the annual fuel and maintenance cost. In the same way, the rail freight transportation also reduces the negative externalities of the transportation by better utilization of vehicle capacity. (Shown in Fig. 7.5).

Figure 7.6 shows that the rail requires heavy investment cost/ton-km when compared with the road mode of transportation. So from these results, the government should develop good road infrastructure for short-distance freight transportation.

Figure 7.7 shows that the rail mode is environmentally and social sustainable mode of transportation for any distance with respect to the total cost/ton-km.

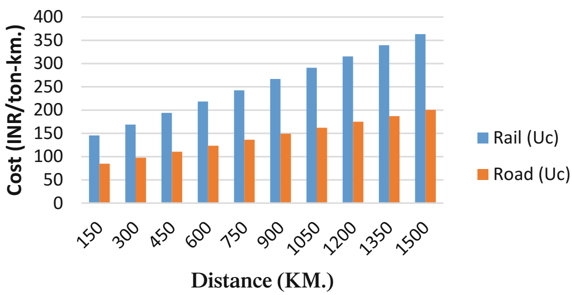


Fig. 7.6 Levelized investment cost comparison with route length

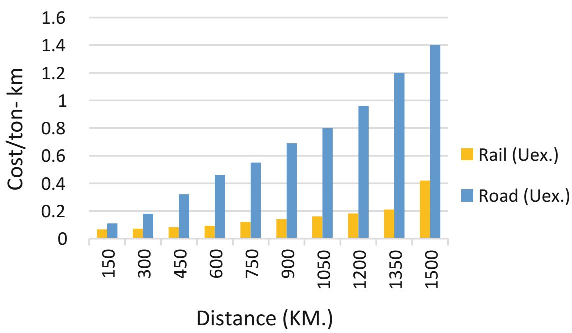


Fig. 7.7 Variation of levelized cost with route length

7.6.1 Relationship of Total Cost/Ton-Km with Distance

Figure 7.8 is drawn with the help of Eq. (7.23). In this relationship, we consider different values of X (road mode) with the proportion of total route length. For example, when $X = 0$, then there is no road mode is existence and the total distance is covered by rail only. When $X = 0.2$ then distance travelled by road is calculated by $0.2 \times 1500 = 300$ km and the remaining distance $1500 - 300 = 1200$ km is covered by other modes, i.e. rail. The remaining variations of X are followed in the same manner.

Figure 7.8 also shows that rail mode is a viable option when distance is more than 1200 km for this route length (1500 km) and also shows that intermodal transportation with the optimal route length of 310 km by the road-only mode and 1190 km by the rail mode. From these results, if we promote intermodality in freight transportation then there is a significant saving of total cost. For the given set of data, if we use only road mode then the total levelized cost is Rs. 11,968 whereas for rail-only mode the cost required is Rs. 4256, there is huge cost saving, but rail mode requires high investment cost compared to the total levelized cost of the road. So, if intermodality is promoted for this route length, a sustainable solution of freight transportation is achieved because of low external cost of the railway freight transportation.

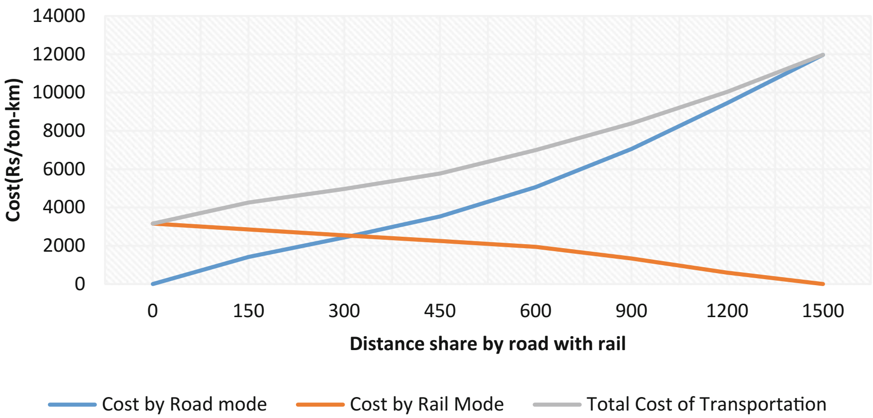


Fig. 7.8 Promotion of intermodal freight transportation based on the total cost/ton-km of rail and road mode

7.7 Conclusion

From these results, we can say that there is a significant cost saving due to the intermodality in freight transportation. Due to the heavy congestion on the NH-8 (Delhi–Mumbai National Highway), cost of negative externalities by road mode is higher which can be overcome by the adoption of the rail mode of transportation. Also, the rail freight wagon is underutilized, if we improve their loading factor it reduces the per unit fuel cost, maintenance and repair cost as well as the amount of negative externalities. In this illustration it is clear that rail freight transportation are more environmentally sustainable than road transportation. This study shows that the modal shift occurs at the distance of 300 km from the origin. Vehicle speed is also a big barrier to develop an intermodal framework for countries. In this very low speeds, the road/rail vehicle is considered, which increases fuel cost over a route length.

7.8 Limitation and Future Scope of the Study

This study represents only a fixed data with average values over all the road and rail routes of India. But, this data varies from route to route. In this study, average congestion time is considered as the same for simplicity of calculation, but in reality, every route will have their different patterns of congestion over a period of day, week, month or year. In this study, we also assume the escalation rate of fuel, maintenance and repair and external cost to be constant which also varies over the life of the vehicle and the economic condition of the country.

The following ideas can be incorporated into future studies:

(a) Real data with route-specific information can be incorporated to verify the real modal shift distance for various routes. This can help us to identify if there is a pattern in the modal shift distance.
(b) Pattern of the congestion on route and railway network also can be incorporated which gives the actual number of trips made by the vehicle.
(c) Also the handling and stocking cost at the intermodal terminal and the individual road and rail terminal can be considered.
(d) Actual capacity of the truck and rail wagon to be considered because in India the loading utilization of vehicle depends on the type of commodities (coal, cement, vegetables, etc.).
(e) Real maintenance and repair cost per kilometer can be incorporated into the model for robust results.

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Chapter 8
Indian Logistics Industry: Towards Creating a Sustainable Integrated Logistics Network

K. Ganesh and M. S. Gajanand

Abstract The logistics sector in India is evolving rapidly and growth is dominated by changing tax structure and rising investments in infrastructure and technology. Whilst the majority market share in the logistics market is held by land (road and rail) transport, waterways and air cargo are also crucial for international trade. This chapter provides an overview of the logistics market in India and describes the factors that drive the growth and challenges faced by the industry. It provides a brief overview of road freight transport, rail freight transport, air cargo transport and ocean freight transport and the challenges faced in the Indian logistics market. The growth factors outlining the impact of policy decisions and the various future investment opportunities available are discussed. The chapter also presents key strategies to create a sustainable integrated logistics network.

Keywords Logistics industry in India · Challenges in logistics
Logistics growth drivers · Integrated logistics network · Sustainable logistics

8.1 Introduction

Intense competition and globalization have forced the logistics service providers to deliver to their customers the right material, at the right time and place at the lowest cost. The Indian logistics industry is currently estimated at USD 5 Billion and expected to grow at a rate of 11% over next few years (Fig. 8.1). Amongst emerging countries, India ranks second in terms of attractiveness for the logistics market. However, when compared to developed nations, India lacks in performance

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Managing the Asian Century, https://doi.org/10.1007/978-981-10-8010-4_8

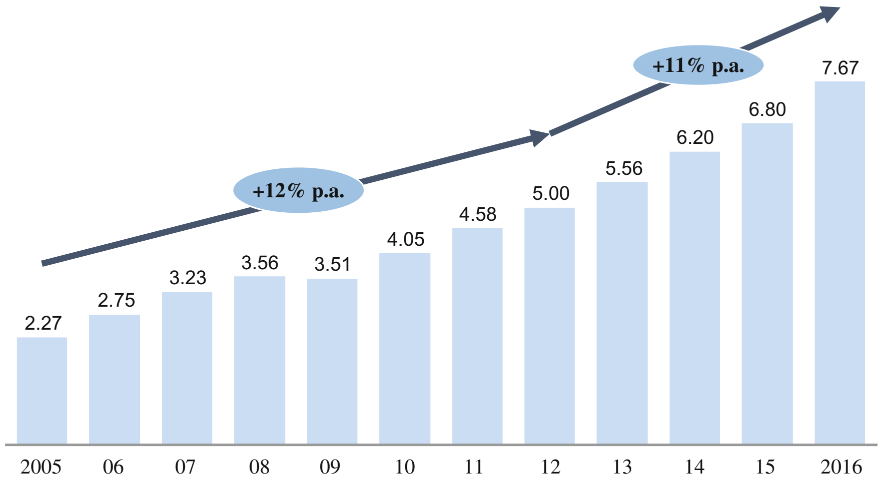
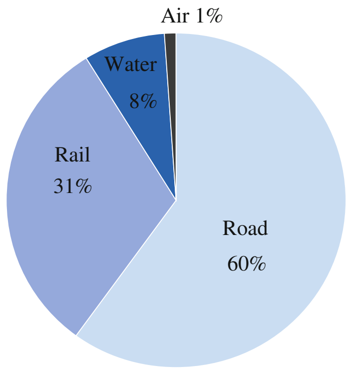


Fig. 8.1 India contract logistics market size (USD Billions)

Fig. 8.2 Share of mode of transport in total freight volumes handled



due to inadequate support infrastructure such as roads, ports and telecom. This has led to a situation where the value created is limited. Public–private partnerships (PPP), private equity (PE) and joint ventures (JV) are the main source of funding apart from public sector investments.

India is highly dependent on land transport as 60% of freight transport is by road networks (Fig. 8.2). Commercial freight vehicles for road transport are increasing alongside the increase in the freight volumes. High growth opportunities are present in the air cargo segment. Rail transport is saturated and hence has limited growth opportunities, whilst growth in ocean transport is limited due to infrastructure issues.

However, the present government is keen in developing an enabling infrastructure and in creating regulations and tax reforms to improve the logistics sector in India.

8.2 Indian Logistics Industry

This section presents the various growth drivers and major challenges faced by the Indian logistics industry. The state of the various modes of transport available and aspects to improve the present logistics network have also been discussed in this section.

8.2.1 *Growth Drivers*

Changing tax structure and rising investments in infrastructure will drive the growth of the industry in future. Figure 8.3 presents the factors that drive the growth of the logistics industry in India.

(a) ***Investment in transportation infrastructure***:

Rise in budgetary allocation for road transport and highways is a key enabler which will help to improve the logistics sector. In recent years, reasonable increment in the budgetary allocation by the government for road transport and highways can be observed (JLL, 2015).

(b) ***Emergence of organized retail***:

With the Indian government allowing 51% FDI in the retail sector, global retailers are seeking for entry in the Indian market which is expected to grow at about 11–12%. With growing retail, the need for providing value-adding logistics solutions is on the rise.

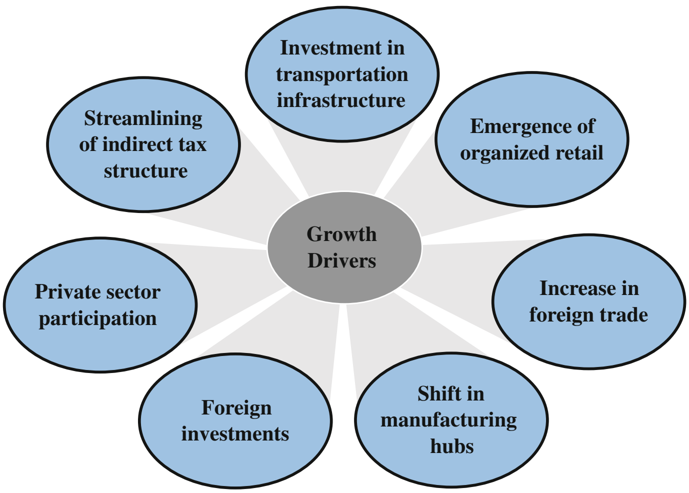


Fig. 8.3 Factors driving the growth of the industry

(c) ***Increase in foreign trade***:

Despite the setback faced by Indian exports due to the global slowdown, merchandise exports have recorded a highest compound annual growth rate (CAGR) in recent years. Imports are also increasing at a decent rate. Increasing exports–imports, especially of physical goods will require logistics solutions.

(d) ***Shift in manufacturing hubs***:

With the growing demand of fast-moving commercial goods (FMCG) and electronic products in India, several MNCs have shown growing interest in setting up manufacturing facilities in India to cater to domestic demand as well as for the export market. The shift in manufacturing capabilities to tier II and tier III cities will increase logistics demand.

(e) ***Foreign investments***:

Inflow of foreign investments along with technology and strategy is on the rise. Foreign direct investment (FDI) is allowed for roads, highways, ports and harbours. Bringing in know-how from foreign market and leveraging existing capabilities will help to improve the logistics infrastructure (Asian Development Bank, 2012). Improving automation and technology adoption will help to improve processes and to streamline operations. Foreign investments will also allow indirect access to new geographies and customers.

(f) ***Private sector participation***:

The government encouraging investment in infrastructure through participation of private sector is an encouraging step and a viable option to fill up the investment gap.

(g) ***Streamlining of indirect tax structure***:

The multiple and differential state-level taxes that existed lead to higher carrying cost. Removal of the state-level Value-Added Tax (VAT) and introduction of the uniform Goods and Services Tax (GST) are expected to lower the overall logistics cost. GST has replaced a host of indirect taxes, central excise, service tax and various other state-level duties such as sales tax and octroi[1] within a single umbrella.

8.2.2 Major Challenges

Despite growth, the logistics sector has its share of challenges. The major challenges faced by the industry along with their impact are presented in Table 8.1.

[1]Local Tax collected by the state government.

Table 8.1 Challenges faced by the Indian logistics industry

Challenges	Impact
Inadequate infrastructure expansion: Expansion of logistics infrastructure has not been unable to keep up with the growth pace	With India's expanding position in world trade, transport volume has climbed rapidly in recent years. Transport capacities have already reached their limits
High logistics cost: Cost of logistics in India accounts for 14% of the total value of goods compared an industry average of 6–8%	Logistics costs in India are amongst the world's highest, which will make it difficult for India to position itself as a global logistics hub in years ahead
Rising fuel prices: Government excise and tax rates have led to high fuel prices	High fuel prices increase the cost of logistics which adversely effects the competitiveness of the economy
Low technology use: Due to lack of awareness and skilled labour	This restricts the scope of increasing efficiency and productivity
High level of fragmentation: The industry is comprised of small operators who do not have access to enough capital and technology	The turnaround time for freight transport in India is uncertain and high, thereby increasing the cost

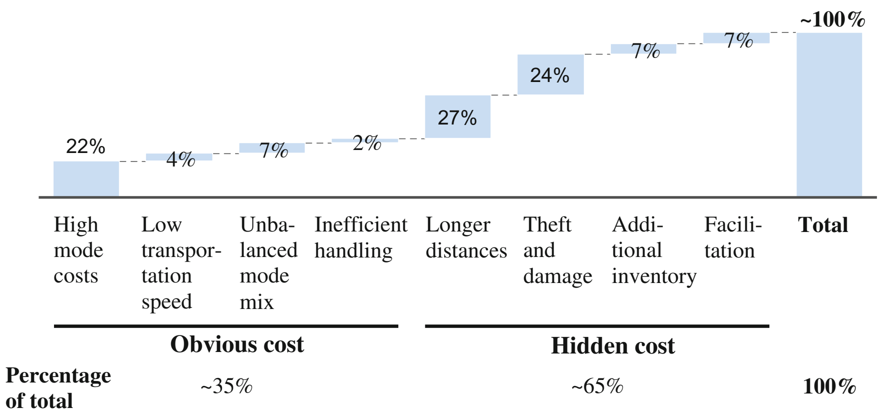


Fig. 8.4 Inefficiencies in India's logistics network (% additional amount spent)

Logistics users in India spend about USD 45 billion more than required due to inefficiencies in the logistics system. Inefficiencies in India's logistics network in terms of the additional amount spent vis-à-vis the best-in-class operating costs are presented in Fig. 8.4.

The estimate on longer distances is based on longer average distances travelled relative to other large countries. For instance, the average distance travelled by coal in India is close to 500 km versus around 400 km in China.

The logistics sector has attracted a large amount of investment over the years and in the future the sector could witness the same due to rising demand for logistics.

The government aims to significantly increase the investment on logistics infrastructure. Private sector is also investing large sums in the Indian logistics industry. Despite over an estimated USD 500 billion investments by 2020, user industries will most likely face even bigger challenges than today. Emissions are expected to increase by $\sim$150% up to 190 million tonnes of CO_2 equivalent in 2020.

The logistics sector is also in the consolidation phase with an increase in total number of acquisition deals over the years. Majority of the acquisitions in the past have been made by Indian companies. The logistics sector will undergo further consolidation owing to large number of unorganized players and the need for economies of scale, improvement of efficiency and wider penetration. The growth of 3PLs (third-party logistics) will increase the need for larger players to diversify.

According to the present logistics spending structure in the industry, 54% of the market is outsourced out of which a major part is unorganized with low barriers to entry. Unorganized players are those which have limited coverage (like between 2 and 3 Indian cities), usually small fleet operators, with low asset base and majority of them do not maintain formal accounts. Scepticism on safety and security as well as complex tax structure has resulted in the remaining 46% of logistics being handled in-house by the companies themselves. The industry has low entry barriers on account of easy financing options, low capital requirements and no licensing needs.

8.2.3 Road Freight Transport

National Highways constitute about 2% of the total road network and account for more than 40% of total road freight. The length of district, rural and other roads is about 4,455,511 km. Around 163,898 km constitute of State Highways and only 70,934 km of National Highways. Of this, only half of the total road length is paved. India has low average trucking speed of 30–40 kmph as against the global average of 60–80 kmph. Road Freight Transport is a highly fragmented industry with few carriers enjoying scale benefits. The major players include TCI, Adani Logistics Limited, Arshiya and GATI. The industry also largely constitutes of several unorganized players.

Challenges:

- Inadequate road network coverage
- Roads are congested and poor quality
- Rural areas have poor access to roads
- High level of fragmentation in the trucking industry with 70–75% of truck owners operating a maximum of five trucks each.

Drivers of Growth:

- Development of National Highways
- Evolution of trucking community
- Encourage use of larger trucks

- Linking National and State Highways
- Provision for last mile connectivity
- Central Road Fund.

8.2.4 Rail Freight Transport

India has the fourth largest railway network in the world and forms approximately 6% of the length of railway lines worldwide. India has the largest rail network in Asia spanning 64,456 km with more than 7133 railway stations. Indian Railways operates 19,000 trains daily, transporting 2.65 MMT of freight. India's rail infrastructure suffers from chronic under-investment. Rail networks in India are oversaturated and thus rapidly losing market share to roadways. The share of railways in total freight movement across all modes of transport had declined from 89% in 1951 to about 31% at present. However, rail freight traffic has registered slow growth in past few years. Coal contributes to the major portion of the revenues earned through rail freight movement in India. Iron and cement are also significant contributors. The major players include Container Corporation of India Ltd. (Concor), Arshiya, Gateway Rail and Central Provinces Railway Company.

Challenges:

- Severe capacity constraints
- Freight transportation costs by rail are very high
- Important rail networks are oversaturated
- Transit times are long and uncertain
- Rail terminal quality is poor
- Less flexibility in carrying different types of products
- Railway carriage not easy for industries which cannot provide full train loads.

Drivers of Growth:

- Dedicated freight corridors which would improve service delivery and generate additional freight-carrying capacity
- Adaption of high-end technology to track freight
- Reduction in unit cost of transportation by speeding operations and increasing productivity
- Creating warehousing facilities alongside railway lines so that direct unloading can be facilitated.

8.2.5 Air Cargo Transport

India has 125 airports, including several international airports. Air freight in India has low penetration. The use of air freight is increasing, however the development of related infrastructure needs to quickly increase. International cargo, which accounts for two-thirds of total cargo, is largely concentrated in the metro airports of Mumbai, Delhi, Chennai, Bangalore and Hyderabad. The Delhi and Mumbai airports collectively handle around 50% of India's domestic and international air cargo. The volume of freight handled by air is expected to go up by about 10% annually for the next 20 years. There is not much seasonal variation in monthly cargo handled by airports in India. March has relatively higher volumes whilst the volumes handled in January and February are low compared to the volumes handled throughout the year. The major players include GATI, Arshiya and Aqua logistics.

Challenges:

- Air traffic has been growing rapidly leading to severe strain on infrastructure at major airports
- Inadequate cargo handling and storage infrastructure
- Excess Capacity
- High fuel costs Jet fuel is 60% more expensive in India compared to major competing hubs and claims 50% of the total operational costs of airlines
- No connectivity to isolated regions.

Drivers of Growth:

- Improved air cargo infrastructure at airports
- Emergence of new cargo hubs
- Heightened focus on developing existing cargo terminals and related infrastructure
- Development of airports in tier II and tier III cities.

8.2.6 Ocean Freight Transport

India has 12 major and 187 minor and intermediate ports along its 7500-km-long coastline. They serve country's growing foreign trade in petroleum products, iron ore, coal and movement of containers. India's ports need to significantly ramp up capacity and efficiency to meet surging demand. Whereas, the inland water transportation is heavily underutilized. Despite being the major mode for international trade, cargo handled by ports in India has increased only by about 5% annually in past few years. The share of non-major ports in traffic volumes handled is increasing gradually. The 12 major ports in India are over-burdened and the growing utilization of non-major ports may come as a respite for major ports. There is still a long way to go considering the fact that India has 187 non-major ports.

The fee levied per TEU (Twenty-foot equivalent unit, a measure used for capacity in container transportation) has been increasing annually. Compared to other Asian countries the fee levied in India is very high. The major players in water freight transport include Adani Logistics Limited, Aqua logistics, TCI and GATI.

Challenges:

- Low capacity at ports
- Inefficient operating systems
- High turnaround times
- Inadequate depth at ports
- Coastal shipping has not taken off.

Drivers of Growth:

- Improve capacity utilization which will make ports profitable even with low traffic volumes
- Enhance port infrastructure
- Improve efficiency by making significant investment in the modernization of the infrastructure
- Provide focused training to key personnel would help improve talent-pool shortages and develop skills required in the shipping sector
- Focus on development of Inland waterways.

8.2.7 Towards an Improved Logistics Network

A comprehensive national policy, focused investments and inter-sector coordination will facilitate the desired growth towards achieving a better logistics network in India (McKinsey Report, 2010). Components of logistics act as separate entities with no coordination amongst them. A structured approach is needed to move from strategy to implementation (Fig. 8.5).

A national integrated logistics policy that concentrates on the following aspects would facilitate trade and drive change in a synchronized manner.

(i) ***Focused investments***:

An approach to direct investment into alternative traffic modes to road, particularly rail and coastal shipping, will ease traffic congestion and lower logistics costs.

(ii) ***Skill development***:

Creating focused, sustained training programs to face the growing complexity in managing supply chains will enable the personnel to adapt quickly to changing demands (KPMG Report, 2007).

(iii) ***Technology adaption***:

Increasing the use of RFID, vehicle tracking technologies, warehouse management systems, etc., will help to make logistics solutions more efficient.

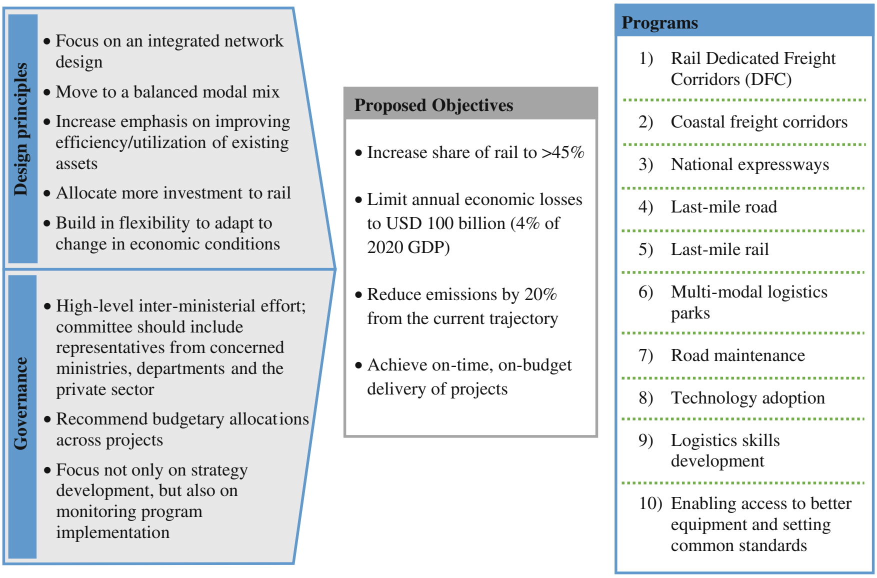


Fig. 8.5 Programs for an improved logistics network

(iv) ***Inter-sector coordination***:

An integrated transport approach that promotes inter-sector coordination of road, railways and shipping departments should be developed.

An efficient logistics infrastructure strategy requires a shift along four key dimensions as shown in Fig. 8.6 (McKinsey Report, 2010).

8.3 The Trucking Industry in India

Trucking is the most popular transport mode in India due to its flexibility. Trucking handles about 60% of all freight tonnage hauled in the country. India's trucking industry has had a much better growth than the trucking industry in most developed countries. Figure 8.7 shows the revenue of the top 10 road freight companies in India.

Growth drivers for Indian trucking industry:

- Greater coverage, such as last mile connectivity and higher flexibility for door to door delivery
- Acceleration in industrial production and changes in consumption patterns

			Shift	From current trajectory …	… to balanced modal mix
a)	**Network structure**	**Network components and mode**	Corridors (rail and water)	~4[1]	7
			Connectors (expressways)	5-7[2]	20-30
			Last mile links (road & rail)	NA[3]	~750
b)	**Enablers**	**Illustrative enabler to support network**	Logistics parks	NA	15-20
c)	**Asset efficiency**	**Illustrative shift**	Percent of toll booths with electronic tolling	<50%[4]	>90%
d)	**Investment allocation**	**Share of spend percent[5]**	Water	~10	~10
			Rail	~40	50
			Road	50	~40

Note:
[1] No focused last mile programme in current plans
[2] Expressways only
[3] Two rail Dedicated Freight Corridors (DFCs) planned, plus coastal corridors
[4] Assuming all current manual toll booths not upgraded, whereas all new toll booths created have electronic tolling lanes
[5] 100% = ~USD 500 billion over the next decade

Fig. 8.6 Required shift in key dimensions

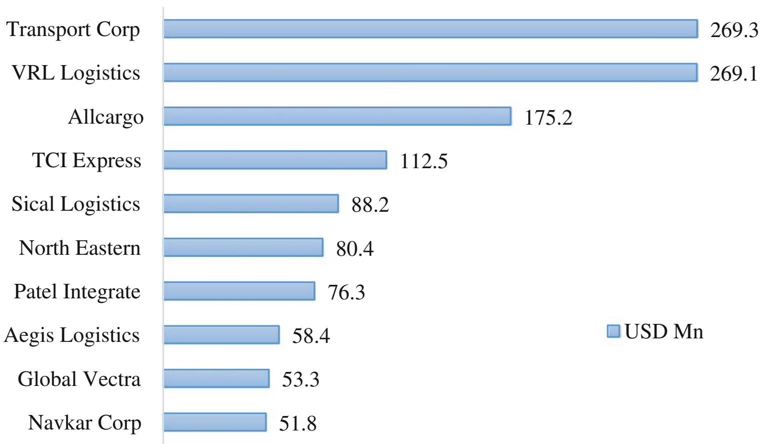


Fig. 8.7 Revenues of top road freight companies in India

- Improvement in road infrastructure quality, with India having third largest road network in the world
- Lack of suitable rail infrastructure—suboptimal rail capacity, difficulty in last mile reach and commodity-dependent cost economics.

Challenges for Indian trucking industry:

- Fuel prices constitute 50–60% of operating costs in trucking and are increasing year by year
- Lack of trained manpower
- Poor average trucking speed, a mere 20 miles/hour compared to 60 miles/hour in the West
- Inadequate highway infrastructure, with National Highways forming only 2% of India's road network but handling 40% of the traffic
- Cascading impact of taxes like custom duty, cess, sales tax/VAT, excise duty, service tax on transportation
- Fragmented industry with few carriers enjoying scale benefits.

India's trucking industry is quite competitive, putting pressure on carrier profitability. India Road Freight rate index (IRFI), a measure of freight rates, is dynamic and highly dependent on fuel prices. Any changes in diesel price will have a direct influence on the profit margin. Also, the freight rates are dynamic due to seasonal fluctuations and supply/demand of trucks. Poor margins due to hike in fuel prices are passed on to customers at a lag of 1.5–2 months. Lack of differentiation in services often leads to commoditization and further price erosion. Many players are offering value-added services like supply chain solutions, thus influencing freight contract terms and cross-subsidized prices. With growth in road freight volumes, the annual growth rate for commercial freight vehicles is expected to increase.

8.4 Strategies to Create a Sustainable Integrated Logistics Network

This section presents three modules (Fig. 8.8) that logically build on each other, to shape and enable integrated logistics for the future.

The proposed framework is based on the following guiding principles:

- Enshrining compliance to high quality and safety standards
- Incorporating vision to achieve efficient best-in-class supply chain performance
- Protecting the robustness and flexibility of the supply chain to avoid stock-out costs
- Ensuring that sufficient initiatives are taken to reduce the impact on the environment

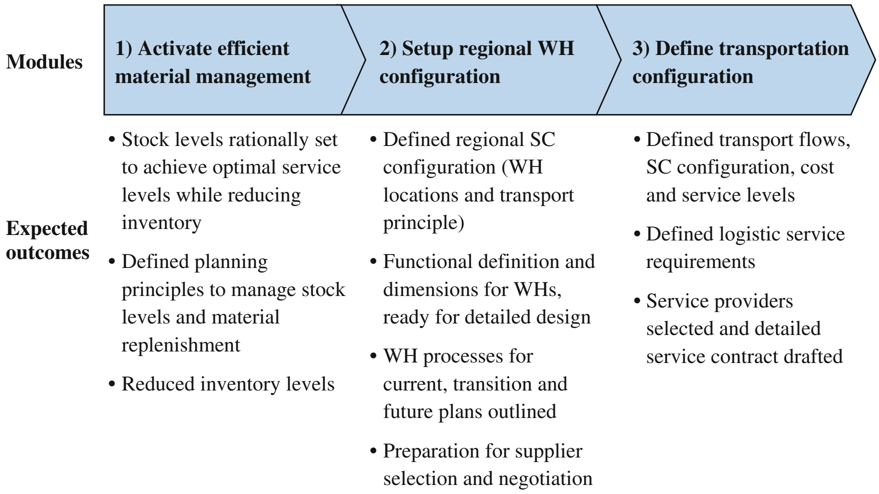


Fig. 8.8 Modules to enable an integrated logistics network

8.4.1 Module 1: Activate Efficient Material Management

Understanding the current inbound inventory management processes is the first step in setting the right priorities for the improvement effort. Table 8.2 presents a structured framework for assessing the current process and the corresponding best practice in the industry.

Creating transparency on the current inventory levels is very essential as it will also help to identify and reduce obsolete stock. The demand structure may be analysed to establish product clusters. This will help to define a methodology for inventory management based on the product cluster. Assess the target stock level and use it to adjust the stock to optimal levels. Detailed inventory management procedures and systems may be developed based on this analysis. Moreover, defined stock levels are a necessary input to dimension the warehouse functions in module 2.

8.4.2 Module 2: Set-Up Regional Warehouse Configuration

The schematic diagram of the proposed approach for setting up the regional warehouse configuration is presented in Fig. 8.9.

The first step would be to assess demand location by the SKU and lead time requirements by the product cluster to define the optimal supply chain set-up per product cluster. The materials may be classified based on

Table 8.2 Framework to achieve efficient material management

	Question	Best practice
Statistical algorithms	How do you set the appropriate inventory levels?	• Safety stock algorithm, considering demand/forecast, supply uncertainty and lead time • Distinguish between safety and cycle stock • 'Consuming' business units are closely involved in planning
Product life cycle	Do you apply special algorithms for inventory calculation for spare parts, life time buy and new product introduction?	• Special algorithms for all stages of product life cycle
Review cycle	How often do you adapt the parameters of safety/cycle stock?	• Constantly, based on measurement of uncertainty of demand/supply and turn rates
Preponement	Did you implement concepts like preponement of stock levels to central WH or supplier to reduce stock to minimum?	• Implemented/defined modules to be kept on a generic level • Leverage vendor managed inventories
Multilevel inventories	In case of multilevel storage—do you optimize deployment and level of local and central inventory?	• Transparency over the supply network, inventory level defined based on optimization algorithms
Obsolescence management	What process for obsolescence exists?	• Strict process in place, identifying 'dead' products in an early stage and initiating actions to reduce it from the beginning

- Demand criticality (safety, engine down risk, etc.),
- Lead time,
- Material value,
- Continuity of demand (sporadic, continuous), etc.

Some sample scenarios are presented in Table 8.3. The transport routes depend on shipment volumes. Low volumes may be trans-shipped for consolidation, whereas high volumes per shipment may be transported directly to the destination.

The next task would be to determine the supply chain set-up, stock levels per warehouse and delivery principles for different possible route configurations. Different scenarios have to be analysed to determine the optimal supply chain set-up and savings potential. A possible approach is given below:

(i) Analyse current set-up to draw baseline and understand product requirements.
(ii) Analyse the possibility of having fewer regional warehouses. Closure of selected regional warehouses may result in,

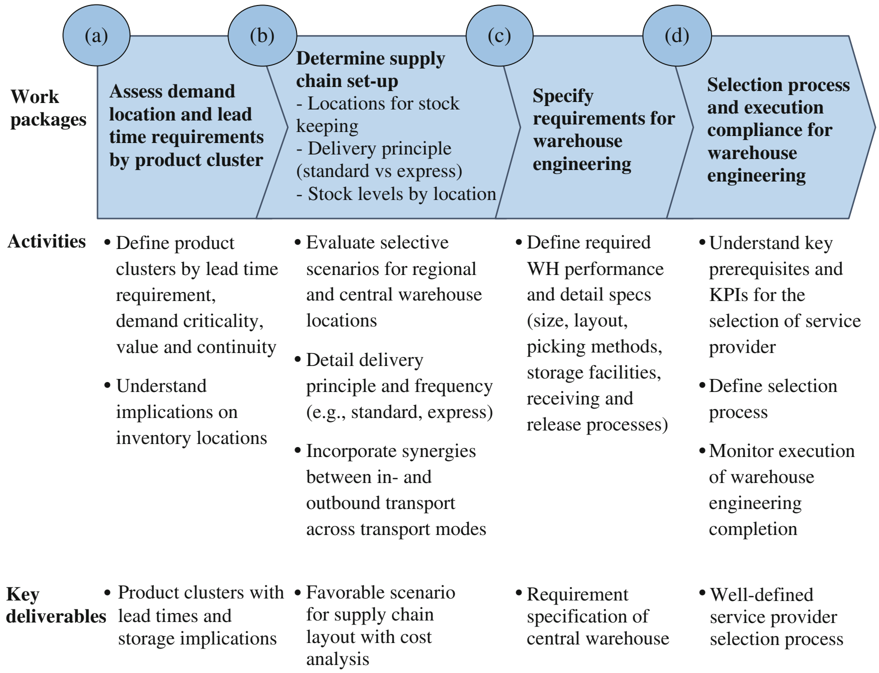


Fig. 8.9 Framework for warehouse configuration

Table 8.3 Cluster samples and implications

Sample cluster based on product characteristics	Implication on storage	Material supply principle
• Highly critical • Small lead time • Constant demand • Medium value	Local storage needed at a regional WH	Items may be shipped to the regional WH through the central WH or directly from the supplier
• Critical • Moderate lead time • Sporadic demand • High value	Local storage may not be required	Delivery from central warehouse through milk-runs or in full from the central WH
• Planned and uncritical • Long lead time • Sporadic demand • High value	Regional WH may not be required	Direct delivery from supplier location or from the central WH

- Inventory reduction and allows to run the supply chain with fewer locations
- Efficient milk-runs to ensure high service level

(iii) Consider the possibility of load consolidation on inbound volumes. Fewer and highly utilized transports help to reduce costs and risks of accidents.
(iv) Evaluate the additional investment required for scenarios with a central warehouse.
(v) For all the scenarios, determine warehouse dimension, performance and cost.
(vi) Summarize technical and functional warehouse specifications.

Products may be allocated to locations and flows, and infrastructure needs may be defined based on regional supply chain modelling. In terms of the mode of transport, rail may be used for inbound transportation of high-volume products with constant demand and for outbound transportation of high-volume products with constant volume. Direct delivery through road transport may be used for medium but volatile volumes with full truck loads. Road transport with consolidation in the central warehouse may be preferred for low volume and volatile demand. After arriving at these, the companies may adopt a selection process for outsourcing the warehouse engineering to a suitable logistics service provider.

8.4.3 Module 3: Define Transportation Configuration

Based on the outcomes of module 2, define the shipping routes and principles for the supply chain configuration. Evaluate different possible scenarios and identify an optimal cost solution at the required service level. Clearly defined warehouse locations are very important to configure the interregional supply chain (transportation mode and mix). Define the logistics service provider service portfolio for the different scenarios and prepare for the selection process of the logistics service provider. The expected end outcomes of this module may be achieved by concentrating on the following three areas:

(a) Logistics Cost optimization
(b) Logistics blueprint
(c) Designing logistics network of the future (based on ideas from SCM 4.0)

(a) **Logistics Cost optimization**

The important task in logistics cost reduction is to identify the Key Performance Indicators (KPIs) and to track them to get a comprehensive understanding of the various logistics costs involved. Evaluation of multi-modal transportation options (use of rail, sea, road, etc.) for domestic movements will add-on to achieve significant cost savings. Optimizing the investment on logistics infrastructure, i.e.

Table 8.4 Metrics to track logistics cost

Cost category	Measure	Metric
Inbound/outbound cost	Road/rail/ocean freight	Road: PTPK (Rs./T/Km)
	Distance moved	Lead (Km)
	Modal mix % (rail/road/sea/air)	Modal mix coefficient (Eg: % qty. moved by rail)
	Direct dispatch %	% quantity directly sent to customer from plant
	Utilization	% volume and weight utilized
In-plant cost	Loading/unloading cost	Labour cost (Rs./Tonne)
	Holding cost	Time (Hrs)
Warehousing cost	Rental and administration	Warehouse overheads (Rs./Tonne)
	Handling costs	Handling/day/FTE
Packaging costs	Packing material costs	Packaging cost/Product price

prioritizing investment in port berths, dedicated cranes, etc., will also help to reduce costs. The various cost drivers which will help to identify opportunities to optimize logistics costs are given in Table 8.4.

Optimizing the logistics cost may be gradually achieved in three different stages:

- Optimize near-term costs by 6–8% using tools such as improving operating efficiency, clean sheet negotiation, asset utilization, etc.
- Optimize costs by an additional 6–7% in the medium-term by architecting the supply chain
- Optimize costs by another 3–4% by leveraging advanced digital tools and infrastructure.

(b) **Logistics blueprint**

It is very essential to have a blueprint in order to undergo a reengineering in the existing logistics process. A distributed manufacturing network (e.g. blending and grinding units for cement; customization centres for steel) is expected to help improve the logistics performance. Identifying logistically optimal locations for setting up new green-field capacity in coastal areas will help to regulate the freight traffic.

Logistics flow optimization may be achieved through simulation of logistics network to identify moving bottlenecks (e.g. in mine and shipping logistics) and to analyse different network configurations. Reconfiguring the logistics network in terms of changing the dispatching or receiving ports, last mile connectivity, etc., helps to analyse for sourcing decisions.

(c) **Designing logistics network of the future**

Several Indian companies have started to implement various logistics innovations. Due to the evolving logistics industry, a company might have to design its own network architecture in order to win in the markets of the future. Coordinated tracking, scheduling dispatches and exception management, especially for trucks moving in a 300–400 km radius from a control tower may become an absolute requirement for any logistics service provider. Digitizing the indenting process (for instance, the transporter getting an SMS directly) to help manage multiple transporters will also become essential.

Vehicle tracking and analytics has seen rapid penetration in the market recently (PWC, 2016). The fast growing technology-enabled logistics using vehicle performance sensors, GPS tracking and data mining to optimize route planning will soon become a mandatory requirement. Companies have started to offer rapid and effective logistics management options using advanced transport management software and dynamic routing. Use of such systems will help to match demand and capacity dynamically. Apart from efficient data analytics tools to visualize all key metrics on a single platform (e.g. direct dispatch, % rail, earnings before interest, tax, depreciation and amortization (EBITDA) and volume in different km slabs), the use of advanced analytics to predict customer demand will give the logistics service provider a competitive advantage to survive in the rising competition.

Optimizing the shipping by influencing the ordering pattern of the customer has seen interesting improvements in the ecommerce space. Given that the last mile logistics incurs high costs, ecommerce companies such as Amazon and Flipkart are providing customers with the option of choosing from various delivery options at differential prices during order check out to help optimize shipping.

8.5 Move Towards Environmental Friendly and Sustainable Logistics

Consistent focus on meeting customer demand at the shortest time and at minimum cost has led to increase in social and environmental issues. Most of the logistics firms are actively working on various initiatives to reduce their harmful impact on the environment as a part of their move towards environment-friendly and sustainable logistics. This will also help to improve customer satisfaction and branding. Careful planning and execution is essential to accomplish this. Planning must be comprehensive and should include the need for creating new facilities as well as making modifications to existing facilities. The strategies outlined in the previous section will help to progressively move towards environmental friendly and sustainable logistics practices. In addition, the following moves will also help to a great extent.

(i) **Redesigning the logistics network** to aggregate the loads across the network will help to deploy the right type of vehicle to transport the aggregated loads. The idea is to get the most out of every vehicle without sacrificing on the service levels and ensuring damage-free deliveries.

(ii) Choosing the most **carbon-efficient mode of transportation** wherever possible will help in the reduction of greenhouse gases (GHGs).

(iii) Collaborating with third-party logistics service providers and other vendors to **upgrade the fleet with newer technology vehicles** will help to reduce fuel consumption and also to reduce accidents.

(iv) **Optimizing the load and the vehicles** by redesigning the various fixtures, packing, carrying fixture of the transport vehicle, etc., will help in obtaining higher capacity utilization. This has the possibility to lower fuel consumption and thereby reduce the resulting GHG emissions. This will also help to accommodate more number of items in the vehicle and may reduce the number of trips required.

8.6 Summary

The importance of logistics has moved from being just a support system to obtaining strategic advantage over the recent years. Customers of logistics services are seeking greater reliability at lower total cost consistently—whether across the globe or in one subcontinent. But as higher performance from greater end-to-end integration (supported by better visibility tools) has become more attainable in the recent days, the approaches of logistics service providers are expected to change. Proper infrastructure support by the government and rising fuel prices are major challenges in the growth of the logistics sector. Shifts in manufacturing hubs, emergence of organized retail and streamlining tax structure are key to the growth of the industry. Formation of national policy and inter-sector coordination coupled with due consideration for the environment are essential for sustainable industry growth.

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Chapter 9
Routing of Vehicles to Minimize Fuel Consumption: A Generic Mathematical Model

M. S. Gajanand

Abstract Rapid industrialization and increasing consumption of goods have had an adverse impact on the environment. The distribution of goods affects the local air quality, generates noise and vibration, causes accidents and is a significant contributor to global warming. Factors such as distance travelled, nature of the road, load carried, speed and other vehicle parameters affect the consumption of fuel and hence increase the emissions from vehicles. Minimizing the consumption of fuel helps to reduce the emission of harmful greenhouse gases and particulate matter. Taking an alternative route between the same pair of nodes with different length and velocity may result in reducing the fuel consumed. This chapter presents a mathematical model to evaluate alternative routes between nodes for routing a fleet of heterogeneous vehicles with the objective of minimizing the fuel consumption. The results provide insights on the impact of the solutions on the fuel consumed, usage of vehicles, distance travelled and cost.

Keywords Green logistics · Fuel consumption · Vehicle routing
Alternative routes · Heterogeneous vehicles

9.1 Introduction

Transportation forms a major portion of all the logistics activities associated with shifting an item from a source to a destination. Most organizations try to maximize their profit with strategies to reduce the cost of the activities associated with logistics. The focus was limited to minimizing the economic costs that the firms incur directly. Awareness of the environmental and social costs for the harmful emissions that arise due to logistics is a fairly recent development. There is a growing apprehension about the adverse impact of logistic practices on the

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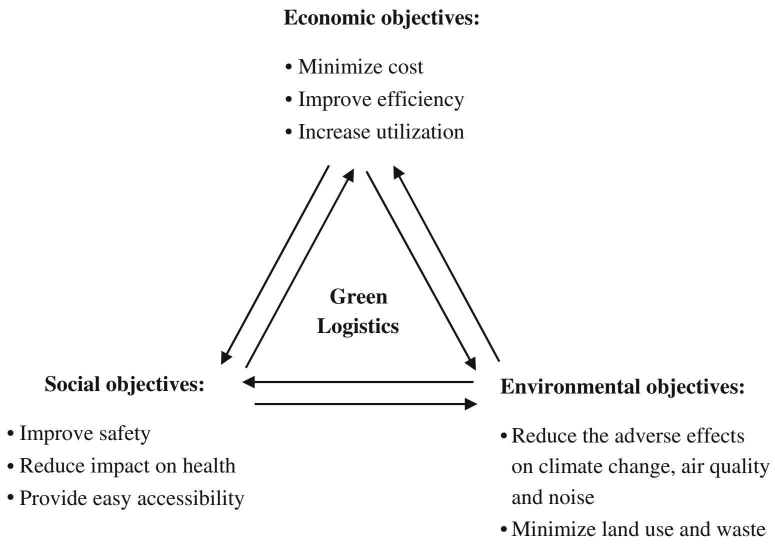

Fig. 9.1 Objectives of green logistics

environment (Sbihi & Eglese, 2007). Developed countries have started to insist on Green Logistics methods that focus on such considerations. They require the organizations to account for their carbon emissions in the form of carbon taxes.

Figure 9.1 shows the three key objectives and the important aspects considered under sustainable or green logistics.

McKinnon (2007) related the gross domestic product (GDP) of a country with the road tonne-km travelled and developed an analytical framework for green logistics which considered the relationship between logistical activities and its related environmental effects and costs. Concern for the environment has begun to influence the decision-making process in several sectors. Many firms have started looking for 'green supply chains' in recent years (Carbone & Moatti, 2011).

9.1.1 Challenges Faced in the Indian Context

India's freight transport relies primarily on roadways, with nearly 60% of the goods transported by volume via road. Although India has one of the largest road networks in the world, the quality of roads lags significantly behind others. The recent increase in production and transportation of goods has led to an increase in the use of heavy-duty vehicles. There is a clear relationship between the demand for goods and the increase in the road distance travelled.

The cost of freight transport (per tonne per km) by road being higher than other means of transport implies that India is depending on the costliest mode of travel for majority of its domestic freight transfers. Further, the increasing dependence on road transport is adverse for the environment as the emissions from road transport (especially from trucks) are higher than the emissions from rail and waterways. Road transport emits about three times more CO_2 equivalent per tonne-km compared to that of railways. Yet, India continues to transport a majority of its goods using roads including bulk materials such as steel, coal and cement.

9.1.2 Vehicle Routing Problem

Vehicle routing forms an important part of decisions pertaining to logistics. The distribution planning problem, also known as the truck dispatching problem (Dantzig & Ramser, 1959) or as the vehicle routing problem (VRP), is commonly addressed in logistics management. The classical VRP involves routing a fleet of vehicles based at a depot in order to serve a set of geographically distributed customers, with the objective of minimizing the total distance travelled or the total cost of distribution (Calvete, Galé, Oliveros, & Sánchez-Valverde, 2007). Each vehicle originates and terminates at the depot and customer demands are known. VRPs assume that a pair of nodes are connected either by undirected or directed arcs. The arc weight represents the distance or the cost incurred to traverse the arc.

Figure 9.2 shows a simple example of a route plan for a VRP, in which four vehicles are used to satisfy the demands of ten customers. Each vehicle starts from the depot (node ‘0’), visits a set of customers and returns to the depot.

Restrictions may exist on the capacity of a vehicle and on the time windows within which the service at a customer must begin. Additional constraints on the maximum distance travelled, on the maximum time spent on a trip and/or on the number of customer nodes visited may exist. Applications include the movement of

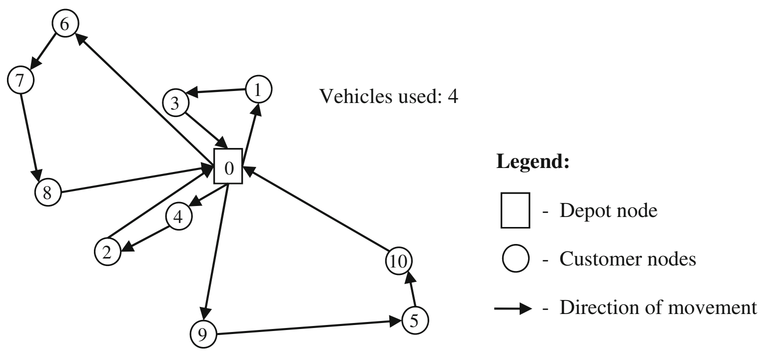

Fig. 9.2 Example of a route plan

industrial goods along a supply chain, courier services, public transport, urban solid waste collection and mobile catering services. These challenging problems belong to the class of NP-hard problems and require the decision-maker to come up with an efficient route plan in a short span of time.

9.2 Factoring the Consumption of Fuel

9.2.1 Greenhouse Gas Emissions

Reduction of greenhouse gases (GHG) has become an important criterion for the transportation of goods. According to the World Resources Institute (WRI), in 2005, the transportation sector accounted for about 14.3% of the world greenhouse gas emissions, among which road transport contributes to 10.5% (Huang, Shi, Zhao, & Van Woensel, 2012). A major component of the GHG contributing to global warming is carbon dioxide (CO_2) from the exhaust of freight vehicles.

Barth, Younglove, and Scora (2005) in order to establish the inherent relationship between fuel consumption and vehicular emissions (CO, HC, NO_x) analysed the various factors affecting the consumption of fuel. Their analysis shows that the emissions primarily depend on the rate of fuel usage. Figure 9.3 depicts the relationship between fuel use rate and NO_x emissions at different speeds and operating conditions.

The tailpipe emissions *EM* can be directly related to the fuel use rate *F* as

$EM = \delta_1 F + \delta_2$, (Bektas & Laporte, 2011)
where δ_1 and δ_2 are parameters indicative of various greenhouse gases.

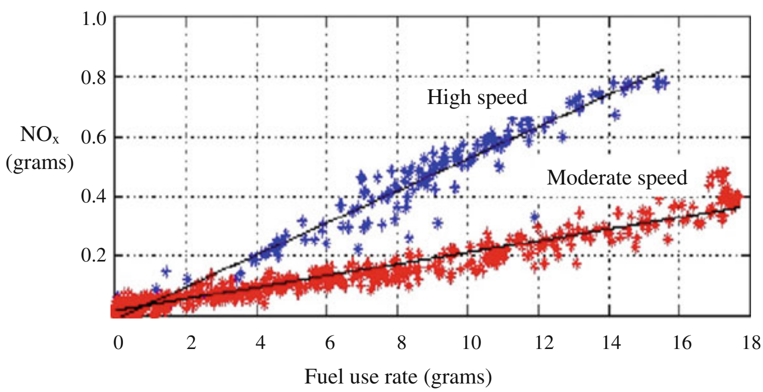

Fig. 9.3 Relationship between fuel use rate and NO_x emissions (Barth et al., 2005)

9.2.2 Importance of Fuel Consumption and Relationship with Other Objectives in Vehicle Routing

It is evident that the vehicular emissions (CO, HC, NO_x) are directly proportional to the consumption of fuel. Hence, minimizing the amount of fuel consumed is equivalent to reducing the greenhouse gas emissions thereby reducing the carbon footprint imparted by the deployment of vehicles for the logistics of distribution.

From a larger perspective, reducing the fuel consumption serves the twin purposes of reducing pollution and of retarding the depletion of oil resources. Global consumption of oil is estimated to be an alarming figure of 85.51 million barrels/day, of which India accounts for 3.182 million barrels/day (CIA, 2010). The need for reducing the usage of fuel has become an absolute necessity.

Routing the vehicles deployed for distribution of goods so as to minimize the total fuel consumed is a task for green logistics. The fuel consumed by the vehicles accounts for a substantial portion of the total cost incurred for distribution. It is also a measure of the carbon footprint which logistics firms are expected to reduce. We observe that most of the aspects of green logistics given in Fig. 9.1 can be achieved by minimizing the consumption of fuel.

The quantity of fuel consumed by a vehicle depends on several factors such as the size of the vehicle, engine parameters, nature of driving, gradient of the road track, speed of the vehicle and the load it carries apart from the distance travelled. At an operational level, a decision on the logistics of distribution can factor the consumption of fuel over various routing options since the conventional objective of minimizing distance travelled does not necessarily accomplish the environmental objective of minimizing fuel consumption.

The objective of minimizing the fuel consumption may not complement few typical objectives of vehicle routing. For instance, the objective of minimizing the total travel time would require vehicles to travel at a faster speed, which will increase the fuel consumed. However, the objective of minimizing the load-distance or the weighted load function (product of the load carried and the distance travelled), which is often used as a surrogate for the energy consumed by the vehicle, might work similar to the objective of minimizing the fuel consumption in most cases.

9.2.3 Choice of Route Taken

Most of the literature on VRP assumes that a pair of nodes is connected by undirected arcs. The arc weight represents the distance or the cost of traversing the arc. The route (or path) predominantly affects the fuel consumption as several factors (including the distance, the velocity of travel and the parameters associated with the road) depend on the choice of the route taken. Given a source and a destination, alternate paths or routes (with different characteristics) may exist between the two

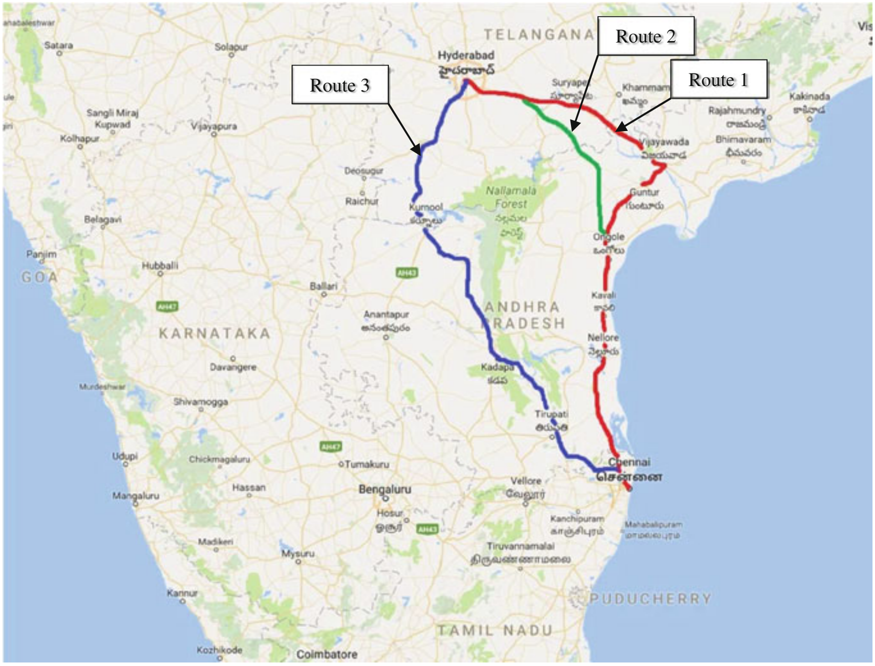

Fig. 9.4 Alternative routes between Chennai and Hyderabad

locations. The availability of multiple routes between two locations can be observed in countries such as India which rely heavily on road transport for freight movement. Figure 9.4 presents a few possible alternate routes between two major cities, Chennai and Hyderabad, in India.

When alternative paths or routes exist between a pair of nodes, it is necessary to evaluate the fuel consumed and the cost for traversing the route because the characteristics of the routes are different and so the fuel consumed if that route is taken is also different. The selection of the route to be travelled by a vehicle is an operational decision which can easily be implemented for a given network.

9.2.4 Factors Affecting the Fuel Consumed by a Vehicle

The consumption of fuel depends on the load, the vehicle parameters and the attributes of the route such as road angle, nature of road, traffic conditions, velocity and distance. The distance travelled d_{ijr} from node i to node j along route r is proportional to the fuel consumed. The velocity of travel VEL_{ijr} (in metre/second) from node i to node j along route r affects the fuel consumed to a great extent. Neither driving too slow nor driving too fast is desirable. Both will consume a significantly large quantity of fuel compared to driving at the optimal speed range. Similarly the acceleration a^v_{ijr} (in metre/second^2) has a significant impact on the fuel consumed. A constant acceleration is preferred to obtain fuel savings.

The factors specific to the characteristics of the route such as the road angle θ_{ijr} of the route r between node i and node j and the coefficient of rolling resistance C^{roll}_{ijr} directly affects the consumption of fuel. Driving uphill on a road even with a small slope will demand more power from the vehicle. The coefficient of rolling resistance is a measure of the friction between the surface of the road and the vehicle tyres.

Looking at the factors related to the vehicle, the total weight of a vehicle v (in kg) is the sum of its kerb weight W^v and load carried while travelling on a certain route. The fuel consumption is proportional to the load carried. The engine efficiency of the vehicle η^v and the drivetrain efficiency of the vehicle η^v are inversely related to the fuel consumed. Higher efficiencies will result in improved mileage for the vehicles. The engine displacement ϕ^v (in litre) and the power required by the accessories of the vehicle P^v_{acc} (in watt) contribute to the overall fuel consumed. The frontal surface area of the vehicle A^v (in m^2) and the coefficient of drag acting on the vehicle C^v_d have an adverse effect on the fuel consumed by the vehicle. More power will be required for a vehicle with a higher frontal surface area to overcome the air force acting on the vehicle. The vehicle engine speed S^v_{ijr} (in rev/second) while travelling from node i to node j along route r and the engine friction factor K^v_{ijr} also affect the fuel consumption.

9.2.5 Model to Estimate Fuel Consumption

Barth et al. (2005) and Barth and Boriboonsomsin (2009) present the relationship between the various factors that affect the fuel consumed by diesel engines.

Let $\alpha^v_{ijr} = a^v_{ijr} + g \cdot \sin\theta_{ijr} + g \cdot C^{\mathrm{roll}}_{ijr} \cdot \cos\theta_{ijr}$ and

$$\beta^v = \frac{1}{2} \cdot A^v \cdot \rho \cdot C^v_d$$

The fuel use rate is given by

$$F^v_{ijr} \approx \psi^v_{ijr}\left(K^v_{ijr} \cdot S^v_{ijr} \cdot \phi^v + \frac{1}{\xi^v \cdot \eta^v}\left(\alpha^v_{ijr} \cdot W^v \cdot \mathrm{VEL}_{ijr} + \alpha^v_{ijr} \cdot Q^v_{ijr} \cdot \mathrm{VEL}_{ijr} + \beta^v \cdot \mathrm{VEL}^3_{ijr}\right) + \frac{P^v_{acc}}{\eta^v}\right),$$

where $K^v_{ijr} = K^v_0 \cdot \left(1 + c \cdot \left(S^v_{ijr} - S^v_0\right)\right)$

$$\psi_{ijr}^{v} = \frac{1}{0.85} \cdot \frac{1}{43.2} \cdot \left(1 + b_1 \left(S_{ijr}^{v} - S_0^{v}\right)^2\right)$$

$$S_0^{v} \approx 30 \cdot \sqrt{\frac{3}{\phi^{v}}}$$

Assuming that the velocity of travel and other vehicle parameters remain constant on a particular route (Bektas & Laporte, 2011), the fuel consumed FC_{ijr}^{v} (mL) by a vehicle v travelling from node i to node j along route r can be estimated from the fuel use rate F_{ijr}^{v} as follows:

$$FC_{ijr}^{v} \approx F_{ijr}^{v} \cdot \left(\frac{d_{ijr}}{\mathrm{VEL}_{ijr}}\right),$$

where $\frac{d_{ijr}}{\mathrm{VEL}_{ijr}}$ is the time taken to travel the route.

9.3 Mathematical Formulation

The mathematical formulation for the vehicle routing problem presented in this section considers a heterogeneous fleet of vehicles and also the various factors that affect fuel consumption. This is adapted from the work of Gajanand and Narendran (2013), where the authors present an analysis for a case of homogeneous vehicles.

Consider a scenario where the logistics service provider operates a fleet of heterogeneous vehicles with different operating characteristics to fulfil the demand at the customer's location. The assumption is that the demand at any node is less than the load carrying capacity of the largest vehicle and that the demand cannot be split. Considering that the nature of the route has an effect on the fuel consumed by the vehicle, it is assumed that more than one route may exist between a pair of nodes. The model does not consider any time window for delivery.

A set of vehicles (V) are stationed at the depot node 0, of which a selected few vehicles $(v \in V)$ will be used to meet the demand of the N customers and return back to the depot. $R_{(i,j)}$ is the set of routes available between the nodes i and j, of which r is the route chosen $\left(r \in R_{(i,j)}\right)$. The set of all nodes, including all the customers and the depot, is denoted by N_0.

Let X_{ijr}^{v} be a binary decision variable that takes the value 1 if vehicle v travels from node i to node j along route r or 0 if it does not take that route and Q_{ijr}^{v} be the load carried by the vehicle v (in kg) while travelling from node i to node j along route r. Let DEM_i be the demand at customer node i (in kg) and CAP^{v} be the capacity of the vehicle v (in kg).

9.3.1 Model

The objective is to minimize the consumption of fuel based on parameters relating to vehicles, load, speed, distances and road conditions.

Minimize

$$\sum_{i\in N_0}\sum_{\substack{j\in N_0\\ j\neq i}}\sum_{r\in R_{(i,j)}}\sum_{v\in V}\frac{\psi^v_{ijr}\cdot d_{ijr}}{\mathrm{VEL}_{ijr}}\cdot\left[K^v_{ijr}\cdot S^v_{ijr}\cdot\phi^v+\frac{P^v_{acc}}{\eta^v}+\frac{1}{\xi^v\cdot\eta^v}\left(\alpha^v_{ijr}\cdot W^v\cdot\mathrm{VEL}_{ijr}+\beta^v\cdot\mathrm{VEL}^3_{ijr}\right)\right]\cdot X^v_{ijr}$$
$$+\sum_{i\in N_0}\sum_{\substack{j\in N_0\\ j\neq i}}\sum_{r\in R_{(i,j)}}\sum_{v\in V}\frac{\psi^v_{ijr}\cdot d_{ijr}}{\xi^v\cdot\eta^v}\cdot\alpha^v_{ijr}\cdot Q^v_{ijr} \tag{9.1}$$

Subject to

$$\sum_{j\in N}\sum_{r\in R_{(0,j)}}X^v_{0jr}\leq 1\quad\forall\, v\in V \tag{9.2}$$

$$\sum_{j\in N}\sum_{r\in R_{(0,j)}}\sum_{v\in V}X^v_{0jr}\leq V \tag{9.3}$$

$$\sum_{\substack{i\in N_0\\ i\neq j}}\sum_{r\in R_{(i,j)}}\sum_{v\in V}X^v_{ijr}=1\quad\forall\, j\in N \tag{9.4}$$

$$\sum_{\substack{i\in N_0\\ i\neq l}}\sum_{r\in R_{(i,l)}}X^v_{ilr}-\sum_{\substack{j\in N_0\\ j\neq l}}\sum_{r\in R_{(l,j)}}X^v_{ljr}=0\quad\forall\, v\in V,\forall\, l\in N \tag{9.5}$$

$$\sum_{\substack{i\in N_0\\ i\neq l}}\sum_{r\in R_{(i,l)}}\sum_{v\in V}Q^v_{ilr}-\sum_{\substack{j\in N_0\\ j\neq l}}\sum_{r\in R_{(l,j)}}\sum_{v\in V}Q^v_{ljr}=\mathrm{DEM}_l\quad\forall\, l\in N \tag{9.6}$$

$$\sum_{r\in R_{(i,j)}}\sum_{v\in V}Q^v_{ijr}\geq\sum_{r\in R_{(i,j)}}\sum_{v\in V}\mathrm{DEM}_j\cdot X^v_{ijr}\quad\forall\, i\in N_0,\forall\, j\in N\text{ and } j\neq i \tag{9.7}$$

$$Q^v_{ijr}\leq\left(\mathrm{CAP}^v-\mathrm{DEM}_i\right)\cdot X^v_{ijr}\quad\begin{array}{l}\forall\, i\in N_0,\forall\, j\in N\text{ and } j\neq i,\\ \forall\, r\in R_{(i,j)},\forall\, v\in V\end{array} \tag{9.8}$$

$$\mathrm{DEM}_0=0 \tag{9.9}$$

$$Q^v_{i0r}\leq 0\quad\forall\, i\in N,\forall\, r\in R_{(i,0)},\forall\, v\in V \tag{9.10}$$

$$Q^{v}_{ijr} \geq 0 \quad \begin{array}{l} \forall\, i \in N_0, \forall\, j \in N_0 \text{ and } j \neq i, \\ \forall\, r \in R_{(i,j)}, \forall\, v \in V \end{array} \tag{9.11}$$

$$X^{v}_{ijr} \in \{0, 1\} \quad \begin{array}{l} \forall\, i \in N_0, \forall\, j \in N_0 \text{ and } j \neq i, \\ \forall\, r \in R_{(i,j)}, \forall\, v = 1, \ldots, V \end{array} \tag{9.12}$$

Expression (9.2) is related to the routing constraints which indicate that a vehicle can either remain unutilized (since the demand may be satisfied with a lesser number of vehicles) or start from the depot and expression (9.3) limits the maximum number of vehicles used to the total number of vehicles available. Expressions (9.4) and (9.5) ensure that all the nodes are visited by exactly one vehicle and help in maintaining the sequential movement of vehicles from one node to another. Expression (9.6) is a constraint on the flow of goods and ensures that the demand at each node is satisfied. Expressions (9.7) and (9.8) link the load carried with the movement of vehicles and the vehicle capacity. There is no demand at the depot and the vehicles must return empty to the depot. This is given by expressions (9.9) and (9.10). Expressions (9.11) and (9.12) indicate the non-negativity restrictions on the load carried and the binary variables, respectively.

9.4 Illustration

Vehicles of two types (Type 1 and Type 2) that can be seen in India with different capacities and physical parameters are considered. The number of vehicles of each type is taken to be $\frac{|V|}{2}$ and they are stationed at the depot for deployment.

Type 1 vehicles are typical medium commercial vehicles (MCV), whose kerb weight is about 2.4 tonne, with a load carrying capacity of 3 tonne. The frontal surface area of each truck is 5 m^2 and the engine displacement is 2.96 l. Vehicles of type 2 are bigger and have a kerb weight of 3.6 tonne and a load carrying capacity of 6 tonne. The frontal surface area of each truck is 5 m^2 and the engine displacement is 3.78 l. The engine efficiency and the vehicle drivetrain efficiency of the vehicles are taken as 0.45 and 0.40, respectively (Bektas & Laporte, 2011). The assumption is that the air conditioner and other vehicle accessories are not used and hence the energy consumed for these purposes is ignored.

Hypothetical datasets are generated (Table 9.1) to test the model on varieties of scenarios and of problem instances and to analyse the impact on the consumption of fuel.

The coordinates of the customers are generated randomly and the depot is located at the centre. Three routes are assumed to exist between every pair of nodes and the distance to be traversed and the velocity of travel vary with each route. The Euclidean distance between a pair of nodes gives the route with the shortest distance between the nodes. This is multiplied by a factor γ, $1 \leq \gamma \leq 1.25$ to get the distance to be travelled for the second and the third routes. The velocity of travel

Table 9.1 Parameters for the generated problem instances

Demand type	1			2			3		
Min. demand (kg)	200			1200			200		
Max. demand (kg)	1200			3000			3000		
Number of nodes	10	20	30	10	20	30	10	20	30
Number of instances	5	5	5	5	5	5	5	5	5

along a route may take one of the five levels in the range [35, 55] km/hr (levels of 5 km/hr including 35 and 55) randomly.

The study considers three demand types based on the volumes and variability: low demand, moderate demand and demand with high variability. The demand is assumed to follow a uniform distribution between the minimum and maximum values of the demand given under each type in Table 9.1. For each combination of parameters, five instances are generated. Parameters such as $C_d = 0.7$, $C^{\text{roll}} = 0.01$, $a = 0$ and $\theta = 0$ are assumed to remain constant for all the routes and vehicles.

The generated problem instances were solved using ILOG CPLEX 9.0 and ILOG CONCERT technology on a desktop with an Intel Core i5 processor (3.10 GHz) and 4 GB RAM configuration. Each instance is solved for two different scenarios,

(i) **Scenario 1**: Homogeneous vehicle fleet where all the vehicles are of type 1.
(ii) **Scenario 2**: Heterogeneous vehicle fleet with equal number of vehicles of type 1 and type 2.

After solving for each scenario, the values obtained are tabulated and analysed. The results obtained for a sample problem instance indicate the effect of alternative routes. Figure 9.5 shows the route plan for the first instance with five nodes and demand type 1.

The figure gives the variations in the route chosen between two nodes. The sequence of visit of the nodes is very important as it determines the load carried between two nodes which in turn affects the fuel consumption.

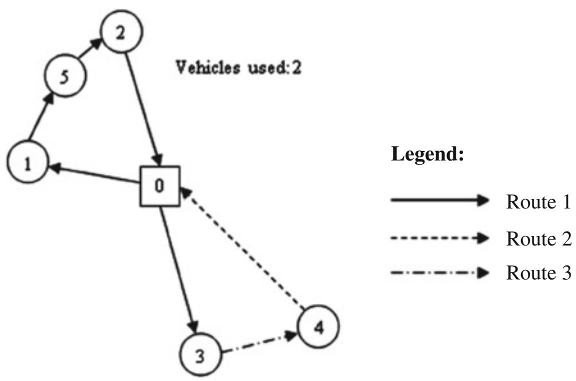

Fig. 9.5 Route plan for the first instance with five nodes and demand type 1

9.5 Results and Discussion

A comparison of the fuel consumed in the case of using a homogeneous fleet of vehicles (Scenario 1) and that of using a heterogeneous fleet of vehicles (Scenario 2) as described in the previous section is presented in Table 9.2 for each demand type.

The relative % deviation of the solution obtained for heterogeneous fleet from that of homogeneous fleet is calculated as follows:

$$\%\,\text{deviation} = \frac{\text{Heterogeneous Solution} - \text{Homogeneous Solution}}{\text{Homogeneous Solution}} \times 100\%$$

A negative % deviation indicates that the fuel consumed in the case of heterogeneous vehicles is higher than that of the case of homogeneous vehicles and vice versa if the % deviation is positive.

9.5.1 Role of the Sequence of Nodes Visited

In a typical VRP setting that considers undirected arcs, a reversal of the sequence of the nodes to be visited will not alter the value of the objective function to minimize the total distance travelled. In the current study, the fuel consumed on an arc depends on the load carried (flow of goods) and varies according to the sequence of nodes to be visited. The alternative route for travel between a pair of nodes is also chosen based the load carried between the two nodes. Hence, the result is sensitive to the actual sequence in which the nodes are visited.

9.5.2 Role of Demand Type

The choice of the type of vehicle used depends on the type of demand and how it varies among the customers. Both homogeneous and heterogeneous vehicle fleet have the same solution in the case of problems with low demand (type 1) and 10 nodes. This is due to the fact that the demands are small and they can be accommodated in fewer number of vehicles and only type 1 vehicles are used. The use of type 2 vehicles will increase fuel consumption since the number of almost-empty runs (relative to the capacity of the vehicles due to low demand) will go up while visiting more number of customers with the same vehicle.

Fewer vehicles from the heterogeneous fleet are used for problems with demand types 2 and 3 because a single higher capacity vehicle can accommodate the demand quantities of more number of customers thereby reducing the number of

Table 9.2 Comparison of results for the scenarios with homogeneous vehicles and heterogeneous vehicles

Number of nodes	Instance	Demand type 1			Demand type 2			Demand type 3		
		Homogeneous	Heterogeneous	% Deviation	Homogeneous	Heterogeneous	% Deviation	Homogeneous	Heterogeneous	% Deviation
10	1	70.76	70.76	0.00	135.95	120.06	11.69	94.84	93.47	1.44
	2	70.14	70.14	0.00	141.60	114.72	18.98	113.74	94.13	17.24
	3	70.93	70.93	0.00	143.61	121.90	15.12	100.43	93.95	6.45
	4	70.88	70.88	0.00	146.57	123.21	15.94	118.54	99.93	15.70
	5	70.30	70.30	0.00	136.15	119.53	12.21	112.16	97.55	13.03
20	1	125.34	140.19	−11.85	290.53	232.55	19.96	224.23	189.98	15.27
	2	119.72	128.47	−7.31	303.59	213.90	29.54	203.37	170.25	16.29
	3	113.88	106.79	6.23	255.42	197.56	22.65	196.17	167.62	14.55
	4	126.01	119.72	4.99	281.36	206.39	26.65	197.03	173.19	12.10
	5	126.09	123.61	1.97	283.71	221.04	22.09	227.20	190.21	16.28
30	1	193.00	176.22	8.69	454.97	328.23	27.86	327.11	271.11	17.12
	2	172.96	171.65	0.76	411.00	305.57	25.65	296.26	235.70	20.44
	3	183.70	169.11	7.94	442.69	335.64	24.18	350.35	275.24	21.44
	4	175.23	160.96	8.14	431.52	331.22	23.24	306.15	251.66	17.80
	5	186.43	168.25	9.75	439.57	321.14	26.94	326.71	272.16	16.70

vehicles required. The performance measures improve significantly when a heterogeneous fleet is used for problem instances with higher demands for the customers.

9.5.3 Practical Implications

A comparison of the solutions for the homogeneous and heterogeneous fleets provides insights into the pattern of usage of vehicles under different types of demand. A very high positive % deviation can be observed for all the instances in demand type 2 and 3 which indicates that a suitable mix of type 1 and type 2 vehicles is desirable when higher volumes of demand exist. The use of fewer vehicles of higher capacity has the possibility of reducing the consumption of fuel and the total cost.

9.6 Other Important Factors to Consider

The added condition that customer nodes must be visited for the delivery of goods only during specific time windows results in the extension known as VRP with time windows (VRPTW). In real life, a small deviation from the time window specified by the customer may be allowed (Tang, Pan, Fung, & Lau, 2009). Relaxing the strict time window restriction may result in a better solution in terms of the total distance or the fuel consumed or the number of vehicles used. Some common examples of routing problems with time windows are postal deliveries, bank deliveries, industrial refuse collection, national franchise restaurant services, school bus routing and Just-In-Time (JIT) manufacturing (Bräysy & Gendreau, 2005). In practice, restrictions on time windows may also be applicable for the routes in addition to nodes for VRPs.

Various extensions and variants of the VRP can be found in literature. Some of them are VRP with pickup and delivery, time-dependent VRP, multi-depot VRP, stochastic VRP, periodic VRP, dynamic VRP, fleet size and mix VRP, multi-compartment VRP, split-delivery VRP, open VRP, multi-echelon VRP and VRP with loading constraints (Lin, Choy, Ho, Chung, & Lam, 2014). Additional operating constraints on the maximum travel time and on the total distance travelled may apply. Surveys of VRPs, their extensions and different methods for solving them have been presented by Laporte (1992), Laporte and Osman (1995), Cordeau, Laporte, Savelsbergh, and Vigo (2007) and Golden, Raghavan, and Wasil (2008).

The VRP being an NP-hard problem will become increasingly difficult to solve using the mathematical model presented here when the number of nodes increases. Efficient algorithms are required to come up with solutions at a short duration since assigning vehicles to customers and creating a routing schedule is an operational decision that might require an immediate solution. The need for algorithms that can be embedded to a decision support system to facilitate interactive decision-making is on the rise.

9.7 Summary

A generic mathematical model which considers alternative routes between a pair of nodes for routing a fleet of heterogeneous vehicles to minimize fuel consumption is presented. Parameters such as type of the vehicle, velocity of travel, nature of the road, engine and other vehicle attributes, which influence the fuel consumed, are included in the model. The study provides an insight to the trade-offs involved and the factors to be considered while planning for environmental friendly routing of vehicles to minimize the fuel consumption. Minimizing the consumption of fuel will also provide economic benefits along with reduced degradation of the environment.

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Chapter 10
Impact of Policy on Closed-Loop Supply Chains of Lead–Acid Batteries

T. S. Krishnan and Sirish Kumar Gouda

Abstract The Indian government framed Batteries Rules 2001 to limit the negative environmental externalities in the closed-loop supply chain (CLSC) of used lead–acid batteries. But, even a decade and half after implementation of the policy, the negative externalities exist. Various sections of the society blame the government for lax enforcement and monitoring. In this context, we attempt to answer two questions: (1) why did the policy fail to meet its objectives? and (2) what are the implications of this for other policies? This chapter is intended to contribute to the growing literature on government policies and their impact on CLSC. Literature has not paid adequate attention to the nature of policy and gap between policy formulation and policy implementation. This paper helps to fill this existing gap in the literature using the case of Indian Batteries Rules 2001.

Keywords Lead–acid batteries · Closed-loop supply chain · Indian batteries rules

10.1 Introduction

A recent report puts the India lead–acid battery industry at $4.47 billion in the year 2016, and this market is expected to grow at a compounded rate of 8.36% till 2022.[1] This growth is backed by rapid growth in the downstream markets associated with telecommunication sector, automobile sector, information technology industry and

[1] https://www.techsciresearch.com/report/india-lead-acid-battery-market-by-type-sli-stationary-motive-by-application-automotive-telecommunication-ups-electric-vehicles-others-competition-forecast-opportunities/1087.html.

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energy sectors. This figure only considers the battery manufacturers registered with the government. Including the local battery brands, i.e. unregistered manufacturers increases the worth much more.

Lead is a recyclable metal. Technically, more than 99% of lead can be recycled from used lead–acid batteries. However, based on the technique used to recover the lead, about 85% of lead can be recovered from these batteries.[2] This lead can be refined and used again for manufacturing new batteries. The primary source of lead is lead mines. Refined lead (secondary lead) is a sustainable source of lead because the mines have limited resources. Rao (2011) also reported, based on a February 2010 publication from Brickwork Ratings, that only a quarter of India's lead requirement is estimated to be met by Hindustan Zinc Limited, the country's only lead miner. More than half is met by *closing the loop*, i.e. recycling lead from used batteries and the balance is met by imports.

Flapper, Nunen, and Wassenhove (2005) defined that the focus of closed-loop supply chains (CLSC) is on managing end-of-use and end-of-life products by recovering its value in a profitable way. The various stakeholders while closing the loop include manufacturers, dealers/distributors, third-party organisations and consumers. The firm closing the loop in this case may be the manufacturer, a distribution partner involved in the forward distribution or a third party not involved in the forward distribution.

A typical closed-loop supply chain for batteries in India would be as (Fig. 10.1). CLSC of lead–acid batteries has the following dimensions:

(a) **Economic**: The high economic value of lead, plastics, etc. in used batteries drives the battery recycling activity. Manufacturers prefer to use secondary lead than mined lead for producing new batteries because secondary lead is cheaper. Mined lead is expensive due to the high costs of extraction of a limited resource.
(b) **Efficiency**: More than 99% lead can be recovered from used batteries, only when recycling is done under controlled conditions. Controlled conditions in recycling facilities imply that proper machinery/equipment is used. This ensures that human interference in the recycling process is kept minimal and lead is not released into the environment while recycling.
(c) **Environment**: Efficient battery recycling reduces the need for mining new lead. Thus, it reduces environmental degradation due to mining. If battery recycling is not done under controlled conditions, lead gets emitted into the surrounding environment. This negatively impacts the environment (water, soil, etc.) and human health. Battery recycling reduces environmental degradation only when done in controlled conditions. Similar argument is applicable for battery manufacturing too. Battery manufacturing when done in uncontrolled conditions negatively impacts the health and environment due to lead emission.

[2]https://www.thebalance.com/the-amazing-story-of-lead-recycling-2877926.

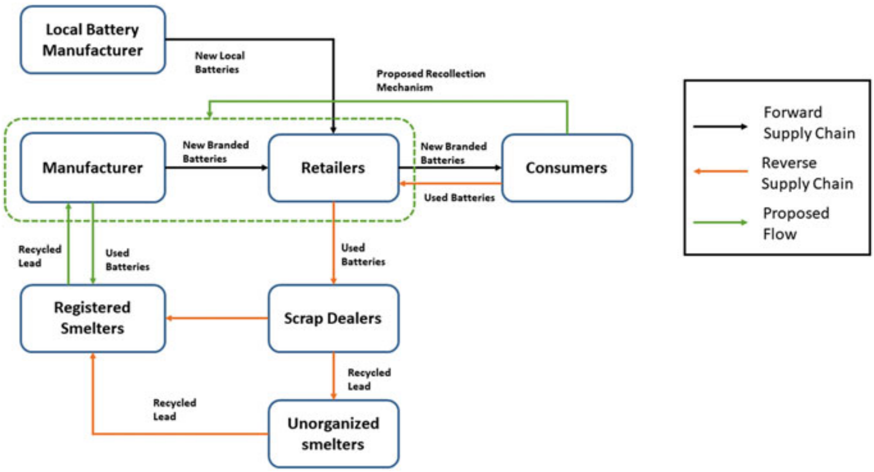

Fig. 10.1 Lead–acid battery closed-loop supply chain in India. Adapted from Gupt (2012)

10.1.1 Problem Description

Despite the promising growth in the industry and growing standardisation of the process of recycling and recovery, a significant portion of recycling is done in uncontrolled conditions, i.e. without using proper machinery/equipment (informal recyclers). These recyclers are not registered with the government and are loosely referred to as informal recyclers. They do not invest or invest very less in machinery/equipment and do not pay taxes. Hence, they can compete with formal recyclers (who are registered with the government) by quoting a higher price to purchase used batteries and selling secondary lead at a lower price. There is also the presence of informal battery manufacturers, who source secondary lead from informal recyclers and produce local battery brands. Based on the inputs provided by India Lead Zinc Development Association, Handique (2010a, 2010b) reported that out of 40–50 million batteries produced every year, 40% of them are produced in the informal sector which has increased to 45% according to the CPCB report (2016). The downside of this practice (informal recycling and manufacturing) is degradation of environment and human health due to emission of lead beyond permissible limits. These are negative externalities, i.e. pollution due to the activities of informal recyclers adversely affects nature and human health who are not directly involved in these activities. This is called as *production externalities*, i.e. externalities due to the process of production. The other form of negative externality occurs when consumers dispose the used batteries along with the municipal waste in waste dumps. Lead leaches from batteries into the groundwater. This is called as *product externalities*. Thus, CLSC of lead–acid batteries involves production externalities as well as product externalities. These externalities involve the provision of public goods like clean air and clean water. Private solutions to limit these externalities create a classic free-rider problem where one of the stakeholder will hope that the other stakeholder would take the responsibility of reducing these negative externalities and eventually neither one would. This is the rationale for regulatory intervention to limit the externalities in various countries.

There are several types of environmental policies that are currently in place or being planned in various countries to limit product externalities. These policies can be broadly divided into two categories. Focus of one category is to provide *up-stream solutions* (i.e. before producing the product) like forcing or incentivising manufacturers to make design changes to improve recyclability, reduce toxic materials, etc. For example, the Restriction of Hazardous Substances directive of the European Union restricts the usage of certain toxic materials while manufacturing products. The second category focuses on *downstream solutions* (i.e. after producing the product) like making the stakeholders of the CLSC responsible for the products they produce or consume. Some examples are the WEEE Directive of the European Union forces manufacturers to take back and recover end-of-life electrical and electronic products; the Californian legislation requires all consumers to pay a non-refundable fee when they purchase a laptop, computer, or television which are used to fund collection and recycling of all used electronics, Batteries Rules 2001 framed by MoEF, etc.

According to Ayyar (2009), problems can be distinguished on the basis of their visibility. The problem of production and product externalities in the CLSC of lead–acid batteries was an incipient crisis. The environmental advocacy groups and experts within the government recognised the emergence of problems with respect to lead–acid batteries that could turn out to be a crisis. The Ministry of Environment and Forests (MoEF) framed a policy in 2001 called the Batteries (Management and Handling) Rules to limit the negative externalities in the CLSC of lead–acid batteries.

Our interest is to understand the impact of different forms of policies on various stakeholders of the CLSC. Though there is a growing body of Operations Management literature in this area, they do not address the nature of policy and gap between policy formulation and policy implementation. The literature assumes the stakeholders of CLSC (like manufacturers, dealers, etc.) to comply fully with the policy, framed by the government, with or without a time delay. But, the case of lead–acid batteries in India is like this: though the government formulated a policy, the stakeholders of CLSC did not comply with the policy in the way it was anticipated. We attempt to find the reason behind this and its implications for other similar policies. This is consistent with the opinion provided by Atasu and Boyaci (2009) that 'there surely exist other possible impacts that are not yet readily observable' in this research area. They also called for empirical approaches to strengthen theory building in this research area.

10.2 The Policy: Batteries Management and Handling Rules (BMHR), 2001

Batteries Management and Handling Rules, 2001 (Also referred to in short as Batteries Rules, 2001) is an explicit policy with a set of rules made by the Ministry of Environment and Forests (MoEF) and announced by a notification in the media and gazette. Also, it is a sub-ordinate legislation, i.e. the Batteries rules 2001 are framed under Environmental Protection Act 1986. According to Ayyar (2009), 'technically, the sub-ordinate legislation is a statutory policy as the authority to make sub-ordinate legislation is delegated by the legislature to the executive'. Statutory policy is binding on every citizen. Officers responsible for implementation (like Central and State Pollution Control Boards, etc.) are bound to enforce the policy. The policy, based on a command-and-control approach, is aimed to limit production and product externalities.

Following are the salient features of the policy:

(a) Battery manufacturers who make new batteries are responsible to take back used batteries against new batteries sold to consumers. The consumers in this case do not include the following:

   i. Bulk consumers like government and private organisations who purchase batteries through a contract and
   ii. Original equipment manufacturers (OEMs) like car manufacturing companies who use lead–acid batteries as a component in their product

We call these consumers (other than bulk consumers and OEMs) as retail consumers. These rules are also applicable for manufacturers who repair used batteries and sell them in the market. Importers who import batteries and components for the purpose of sale are also included. Dealers, i.e. retailers who sell batteries to retail consumers, are also made responsible for collection. Dealers are also advised to give appropriate discounts for every used battery returned by the retail consumer.

The policy says that if the manufacturer/importer/dealer sells, say X number of new batteries to retail consumers (other than bulk consumers and OEMs), then he is responsible for collecting: 50% during the first year of implementation (**0.5X**), 75% during second year of implementation (**0.75X**) and 90% after second year of implementation or thereafter **(0.9X)**. These stakeholders in the CLSC also need to ensure that the collected used batteries are of similar type and specifications as that of new batteries which are sold to the customer. Collection centres for used batteries can be organised individually or collectively. Individual collection centre means that the manufacturer collects only his brand. Collective collection centre means that manufacturers jointly collect batteries, i.e. batteries of multiple brands can be deposited in the collection centre. They are also mandated to buy secondary lead only from formal recyclers. They are responsible for sending the collected batteries only to formal recyclers.

(b) The recyclers who recover lead from used batteries are responsible for getting themselves registered with the government, i.e. MoEF or an agency designated by it. This is to ensure that recyclers recover lead in controlled conditions. The process of getting registered ensures that recyclers have installed appropriate machinery/equipment for lead recovery.
(c) Bulk consumers and retail consumers are responsible for safe disposal of batteries used by them. They need to ensure that the batteries are deposited to the dealers/manufacturers/importers or any other designated collection centres. Bulk consumers, when auctioning scrap batteries must ensure that batteries are auctioned only to formal recyclers, i.e. recyclers registered with the government.
(d) All the actors involved, i.e. manufacturers, importers, dealers, and auctioneer are responsible for reporting to the respective State Pollution Control Boards (SPCBs), twice every year, regarding their sales and collection volume. The SPCBs are responsible for ensuring compliance with policy and submitting the compliance status report to the Central Pollution Control Board (CPCB) every year.

10.3 Impact of the Policy

Investigations by Occupational Knowledge (OK) International in 2010 revealed the failure of policy to limit externalities. OK International (2010) reported the poor compliance of battery manufacturers with the policy. The organisation used Right to Information Act to obtain compliance data from SPCBs as the data was not available with the CPCB. The data obtained indicated that very few manufacturers are complying with the policy. Even established battery manufacturers are falling short of the mandatory provision to take back 90% of batteries sold through dealers. According to the data provided by SPCBs, only Exide Industries Limited seems to be collecting more than 90% of batteries sold through dealers. Also, the recent reports from Handique (2010a, 2010b) and Rao (2011) highlight the presence of informal recyclers and informal battery manufacturers in various parts of the country.

To assess the impact of the policy, apart from analysing the latest independent reports and newspaper articles, we also talked to a few environmental advocacy groups. The following information is based on our observations from the above:

(a) The mandatory provisions of reporting to pollution control boards, etc. are overcome by bribery.
(b) Manufacturers source secondary lead from informal recyclers as they are cost-effective.
(c) Majority of the formal recyclers also pollute the environment, i.e. production externality. Most of the registered recyclers are small in size (number and total volume of business done) and among them very few are likely to follow

sufficient pollution controls and operate efficiently. Only two out of 336 recyclers that have been interviewed have a capacity that exceeds 50,000 tonnes per year (OK International, 2010). This size is considered in the industry as one which allows the operations to be cost-effective while still following adequate pollution controls.

(d) The bulk consumers auction their batteries to formal recyclers who in turn give a percentage of it to the informal recyclers. Formal recyclers do this either because of capacity constraints or because of other cost considerations. Some of our respondents informed that the data that formal recyclers report to the SPCBs are also manipulated.
(e) If bulk consumers do not get profitable payment from formal recyclers, they stack batteries in their warehouses because they cannot sell to informal recyclers either. Such batteries do not enter the recycling stream. Hence, there is a pile-up of waste that is toxic.
(f) Informal recycling is profitable due to the increasing lead prices and increasing demand for lead. Informal battery manufacturers source secondary lead from informal recyclers and market their local brands at a cheaper rate (more than 40% less) than the established brands. Some examples of local brands in India are Z-power, Active and Power-on.
(g) Retail consumers prefer to dispose the used batteries along with municipal waste or to informal recyclers. Disposing the batteries along with the municipal waste results in negative product externalities. As informal recyclers have meagre setup costs for recycling, they pass this benefit to the customers by paying a higher amount to the retail consumers for used batteries than the dealers.
(h) Though there are manufacturers and dealers who collect batteries and send to formal recyclers, they are few in number. Also, the so-called 'formal' recyclers recycle some fraction within their premises and outsource the rest to informal recyclers.

The result is that production externalities and product externalities continue to exist in the CLSC. In this context, we attempt to find reasons behind the policy failure. Here, we refer to policy failure as failure in translation of formulated policy into effective policy implementation.

10.4 Why Did the Policy Fail?

Interest groups in this research area and media mention the following reasons for the policy failure.

(a) Lack of strict monitoring and enforcement by the government authorities, i.e. from the angle of policy implementation.
(b) Lack of penalties for not 'obeying' the policy, i.e. from the angle of policy formulation.

According to the CPCB (2016) report, the following issues are pointed out about the implementation of the Battery rules:

(a) Data on the inventory and sales of batteries are not maintained by various SPCBs.
(b) Battery rules pertain only to lead–acid batteries sold in organised sector, whereas there are several other types of batteries like nickel–cadmium, lithium-ion and nickel metal hydride batteries used in the market.
(c) SPCBs have been consistently failing in providing in filing reports and annual compliance status to CPCB.
(d) There is a lot of confusion regarding the registration process mentioned by MoEF&CC and rules provided under Hazardous Waste Management rules.
(e) All key stakeholders like manufacturers, assemblers, reconditioners and auctioneers do not fall under the purview of these rules.
(f) OEMs are not provided with any responsibility under these rules.
(g) The rule mentions that manufacturers of the batteries are supposed to file returns only in the state in which they are selling and hence does not consider the overall network of sales.

However, in our opinion, these are the only symptoms of the real problem. We present two fundamental reasons behind the failure of this policy. They are described below.

10.5 Nature of Policy

We attempt to understand the nature of approach to limit negative environmental externalities. In this case, a command-and-control approach was taken. According to Stavins (2002), such approaches 'allow relatively little flexibility in the means of achieving goals'. Uniform standards were set for all firms in this approach and technology-based standards and performance-based standards were specified. Technology-based standards describes the technology/equipment that recyclers must use to get registered with the government. Performance-based standards set a uniform collection target (90% of retail sales) for all manufacturers, dealers and importers while allowing some flexibility in deciding how this target will be met. The flexibility implies that manufacturers could individually or collectively set up collection centres, dealers could collect batteries from consumers by giving discount offers, etc. Following are the issues with technology-based and performance-based standards in the case of Batteries Rules 2001:

(a) The technology/equipment appropriate for one recycler may not be appropriate for another recycler. Stavins (2002) noted that firm's manufacturing layout, operational configuration (structure and infrastructural elements), age of assets and other firm-specific and industry-specific factors could influence the decision to install a technology/equipment. Also, recyclers 'are responsible' for getting themselves registered. *There is no incentive for them to get registered or disincentive for not registering*. With a 100% policy implementation, the disincentive is that these recyclers would not get used batteries from the sources if they are not registered. Since the rules (that are laid down by the policy) are not followed by the sources of used batteries, the unregistered recyclers, i.e. informal recyclers, get their supply of used batteries.

(b) The uniform collection target set depends on the volume sold to retail consumers only. This is because the bulk consumers are responsible for giving/auctioning their used batteries only to registered recyclers. The uniform collection target may not be appropriate for all firms. There are some importers, manufacturers that majorly serve bulk customers who purchase via contracts. Setting up a collection system for retail consumers, who are not their primary revenue generators, is not profitable for such firms. Also, there are no penalties for not collecting the required percentage.

(c) The technology-based and performance-based standards involve a sophisticated fool-proof reporting system. Also, administrative costs for the government to monitor and enforce this policy are high. The SPCBs need not be aware of the existence of an informal recycler in a remote corner of their states. As there is no traceability of forward and reverse supply chains, with man-made errors (and manipulation) in auditing, it is easy for firms to provide incorrect reports of compliance to the government. It could also happen that the expensive technology/equipment is installed (hired on rent) for the purpose of registration and is uninstalled after obtaining the registration. The costs are high for the government to periodically inspect recyclers.

There are other problems with this type of a policy. If a recycler gets herself registered, then she has to incur high recycling costs that would make her business less profitable than her competitors who have not registered. This situation is similar to what Sen (2006) says: '*there are high pay-offs for successful non-co-operating rule-breaking*' and '*significant losses for those who follow the rules while other do not*'. Due to the lack of scale in end-of-pipe pollution control, smaller firms could end up facing higher costs of compliance. These firms might also have lower financial capacity to install necessary process technology. Also, if competing firms do not invest in similar technologies, smaller firms which lack market power would hardly be able to invest to reduce pollution. Probability of detection and the amount of penalty also play an important role in firms deciding to comply with the rules or not. Over and above these, lack of effective monitoring mechanism, despite other suitable conditions, leads to non-compliance, causing the environmental regulations ineffective. This is particularly true in markets where firms have unassailable advantage through non-compliance, given the high cost of compliance and smaller market sizes.

We also attempt to study the essence of previous environmental policies as they might throw more light on this issue. Priyadarshini and Gupta (2003) mention that most of the Environmental Acts and Rules in India are based on certain procedures and discrete having extreme low punitive measures (token measure) or extreme high punitive measures like closure of the facility. Curmally (2002) called the approaches adopted by the government for pollution control as command-and-control in nature. The 'command' being the laying down of technology-based and performance-based standards, while 'control' being the power to disrupt power or water supply of erring units, imposition of fines or even imprisonment of people responsible. The author warns that for the command-and-control approach to be effective in controlling pollution, certain criteria need to be met by the SPCBs and CPCB. These include having infrastructure facilities such as laboratories for testing of samples, an in-depth understanding of environmental problems, and above all, effective and efficient monitoring and enforcement capabilities. The author also pointed that the effectiveness of the command-and-control approach in controlling pollution is minimal because the working of pollution control boards in India does not fulfil the above criteria. With the perspective provided by Curmally (2002), it is interesting to note that the Batteries Rules 2001 had only 'command' and no 'control'!

10.6 The Institutional Arrangement for Policy Implementation

The important institutions actively involved in environmental policy implementation are the CPCB and SPCBs. In this section, we attempt to study the relation between CPCB and SPCBs and its impact on the policy implementation.

The Water (Prevention & Control of Pollution) Act 1974, enacted under Article 252 of the Constitution, made provision for the establishment of Pollution Control Boards in the Centre (CPCB) and at the State levels (SPCBs). Following this, in 1981, the Air (Prevention and Control of Pollution) Act was passed. The CPCB had to implement both Water and Air Act. Subsequently, the Environment Protection Act (EPA) was passed in 1986 as an Umbrella Act to solve the issues in the Water and Air Act, and later more responsibility was given to CPCB under this.

As said by Mishra and Sahu (2009), in India, the state regulatory authorities do not frame, implement and/or enforce independent environmental policy of their own but rather adopt the policies formulated by regulatory bodies at the centre making necessary changes to suit to the local conditions. It is also a precedence that the central government issues guidelines to various state bodies on environmental matters and the sectoral policies and programmes put forth by the states are usually formulated within the broad framework of national policies and guidelines. These policies and programmes under environment policy are usually implemented through SPCBs which are required to enforce important environmental legislations for the protection of the environment under the overall guidance of CPCB. The structure of environment policymaking and implementation is as follows:

(a) The MoEF is the policymaking body. The state governments have to adopt these policies.

(b) CPCB monitors the adoption and implementation of policies at state level.
(c) SPCBs ensure compliance of various actors, involved in creating externalities, with the policies. It also penalises actors for non-compliance, as stated by the policies.

Three reports available in the public domain are used to understand the relationship between CPCB and SPCBs. The reports are Planning Commission (2001) report on evaluation of SPCBs, 192nd report by Parliamentary Standing Committee on Science and Technology, Environment & Forests (2008) and IIM Lucknow (2010) report on evaluation of CPCB.

10.6.1 Planning Commission of India (2001) Report

The Planning Commission of India had prepared an evaluation report on the SPCBs by studying them for 6 years, viz., 1992–93 to 1997–98, which covers the entire Eighth Five Year Plan period. Planning Commission (2001) reported several issues that are helpful to analyse the institutional arrangement of pollution control boards. The report highlighted the lack of professional members (and the presence of non-technical members) in most of these boards. These boards also tend not to fill the vacancies corresponding to members representing local bodies. However, it was found that the SPCBs of Assam, Karnataka, Bihar, Manipur, Tripura and Goa were exceptions, and they maintained a balance between professionals and generalists. As the sanctioned strength was not completely filled, there existed a widely varying per unit staff ratios across SPCBs. No particular norm was followed for staffing which might have contributed to this. The workload also varied significantly. For example, while in Andhra Pradesh one technical person had to monitor hundred units, Himachal Pradesh and Kerala had twelve and fourteen resources, respectively, for similar task. Similarly, the SPCBs of the North Eastern States (with exception of Assam) were extremely short-staffed. Some of them were unable to perform basic functions such as cycle count of inventory of polluting units. The ratio of technical to non-technical staff also varied significantly across State Boards. The highest ratios were found with the State Boards of Punjab and Bihar, while critically low ratios were associated with those of Himachal Pradesh, Haryana and Goa. Due to shortage of administrative staff, technical staff belonging to engineering and science departments were being deployed for inspecting the polluting units to meet the norms fixed by the CPCB. It was also found that the chairmen of SPCBs changed frequently.

The financial resources of an SPCB consist of (1) project-based grants from CPCB, external assistance in the form of grants-in-aid from State and Central Governments and other grants and (2) own resources like consent fee collections, reimbursement of water cess, sample testing fees, interest on investments, receipts from sale of forms, consultancy receipts, fines and forfeitures. The report analysed relative positions of 25 SPCBs in terms of financial resources. The report indicated that on one end there were state boards such as Tripura, Manipur, Meghalaya, Jammu and Kashmir and Kerala which were primarily dependent on grants-in-aid and at the other end of the spectrum were states like Uttar Pradesh, Maharashtra, Tamil Nadu, Orissa, Haryana, Punjab, Andhra Pradesh and Karnataka which have a significantly high ratio of own resources to total resources. Reimbursement of water cess constituted an important source of revenue in states such as Punjab, West Bengal, Bihar, Uttar Pradesh, Orissa and Rajasthan. Also, the reimbursement of water cess statistics furnished by the MoEF was different from those provided by the SPCBs, which is a point of concern. Data on expenditure incurred by SPCBs during the Eighth Five Year Plan indicates that 57% of all the funds were spent on administration. Maintenance, depreciation and other expenses also constituted a significant portion of the remaining part. Ironically, the expenditure on essential items like R&D and training and pollution prevention activities was negligible. The resources raised by SPCBs were not fully spent and the surpluses built up by many boards indicate lack of motivation to efficiently carry out monitoring activities. This is despite a dire need for expenditure on pollution control activities, R&D, etc. This could also be because of the lack of autonomy in expenditure decisions.

The report also found that in the states of Punjab, Kerala, Karnataka, Gujarat and Haryana, a significant proportion of manufacturing units discharging effluents to water stream did not have treatment plants. Similarly, a significant proportion of plants emitting air pollutants do not have any air pollution control measures in the states of Punjab, Gujarat, Karnataka and Kerala. It was also observed that significant proportion of plants, which have some treatment mechanism, did not adhere to standards prescribed by the government. The punitive action by SPCBs was tied up with litigation and considerable number of cases were pending for more than a year. The SPCBs were unable to force compliance by disrupting their electricity or water supply because of some powerful pressure groups.

10.6.2 Parliamentary Standing Committee on Science and Technology, Environment & Forests (2008) Report

In its 192nd report, The Parliamentary Standing Committee on Science and Technology, Environment & Forests (2008) on functioning of CPCB mentioned that 77% of Chairpersons and 55% of Member Secretaries in different SPCBs did not meet the requisite qualifications to hold their respective posts. The report also highlighted the concern that adequate representation from all stakeholders including the polluter and victim were not present in these boards. It was also highlighted that independent resources in the board who possess expertise in pollution control and legal areas were necessary. The report indicated that the committee was of the view that with a board composition constituted by Central Government and dominated by Government representatives, the CPCB cannot be expected to perform its duties as a watchdog of environmental protection. Presence of strong lobbies in the industry and other sectoral ministries were also discussed.

10.6.3 IIM Lucknow (2010) Report

The recent report on evaluation of CPCB by IIM Lucknow (2010) questioned the rationale for existence of two parallel structures, i.e. CPCB and SPCBs, each one working as an independent and autonomous entity in its own capacity with no single agency exhibiting adequate command and control. While CPCB is controlled by central government, SPCBs are controlled by state governments resulting in lack of proper coordination. This study also points out the deplorable situation regarding tenure of chairman and member secretaries and their respective qualifications. Neither any advertisement for the post nor any panel of experts for selection of chairman and member secretary of SPCBs or CPCB were found.

Based on this available evidence and a thorough analysis of the reports, the reason for the policy failure can be summarised as follows:

(a) The command-and-control approach works only in an environment conducive for its implementation, i.e. strict monitoring and enforcement.
(b) Such an environment can be created only by institutions (involved in policy implementation) with a high degree of coordination and purpose.
(c) This institutional arrangement was lacking in the case of CPCB and SPCBs due to which the gap between policy formulation and implementation widened.

It is worth mentioning here about the amendment made to Batteries Rules 2001 in May 2010. The main feature of the amendment is that it imposes penalty for non-compliance by cancelling registration after giving a reasonable opportunity for hearing. Having studied the institutional arrangement, we feel that this amendment may not limit the externalities significantly. This is consistent with the opinion provided by Ayyar (2009) that a policy failure can be due to the '*unwise choice of policy instrument or insufficient provision of inputs to the organisation entrusted with the implementation, or the inadequate capacity of the organisation entrusted with the implementation*'.

10.7 Implications for Similar Policies

The central government had notified E-waste (Management and Handling) Rules 2011 and revised it in 2016.

<u>E-waste (Management and Handling) Rules 2011</u>

The CLSC of e-waste (i.e. discarded electrical and electronic equipment) creates negative production and product externalities. This policy, which came into effect from May 2012, was intended to limit these externalities. Salient features of this policy are listed below:

(a) Manufacturers of electrical and electronic equipment are responsible for collecting their products at the end-of-life and ensuring that it is recycled in a proper way by formal e-waste recyclers. Manufacturers can set up collection centres individually or collectively. The manufacturers are financially responsible for managing the e-waste generated from end-of-life of its own products and historical waste available on the date from the policy come into force.
(b) E-waste recyclers are responsible for obtaining registration from the SPCB. They also need to ensure that the recycling processes are in accordance with the standards laid down in the guidelines published by the CPCB.
(c) Bulk and retail consumers of electrical and electronic equipment should ensure that the e-waste generated by them is channelized to an authorised collection centre or formal recycler, i.e. e-waste recycler registered with the government.
(d) Manufacturers, recyclers and bulk consumer should maintain records pertaining to generation, collection and processing of e-waste and make the records available for government whenever needed.

This policy for e-waste was revised in 2016 by including more clauses. In the revised version, refurbishers are identified as a separate stakeholder that is separate from recyclers. Refurbishers are mandated to get authorization from the respective SPCB. Emphasis is given for skill development of informal e-waste processors and assisting them to set up e-waste processing facility. There are also collection targets set for producers and a mandate to participate in Producer Responsibility Organization for joint e-waste collection. However, *the fundamental nature of* e-waste policy *remains the same*, i.e. the approach based on product take-back and mandating stakeholders to follow rules (command-and-control).

The nature of e-waste policy and the institutions enforcing them are similar to Batteries Rules 2001. These policies are based on command-and-control approach and involve high administration costs for the government in terms of time and money. The parties involved in policymaking (like government, trade associations, affected firms, environmental advocacy groups, etc.) to limit production and product externalities in CLSC seems to favour a command-and-control approach. The reasons for this are described by Stavins (2002). These policies are likely to fail using the typical command-and-control approach. There is a need to frame policies that could work through the market to stimulate cost-effective environmental protection. According to Stavins (2002), such policies encourage behaviour through market signals rather than through explicit directives, i.e. they encourage firms or individuals to undertake efforts that are in their own interests and that collectively meet policy goals in a cost-effective manner. It is not within the scope of this article to cover what kind of market-based policies should be framed. Our intention is to highlight the need for moving away from framing only command-and-control policies, using the case of Batteries Rules 2001. The government and the parties involved may consider market-based policies or a combination of command-and-control and market-based policies to limit the negative environmental externalities. Walls and Palmer (2001) said that as many policy instruments are needed as policy objectives and a mix of policies/policy instruments are likely to be necessary to mitigate the negative environmental externalities of production and product.

10.8 Conclusion

We observe that failure of policy to limit externalities in the CLSC of lead–acid batteries is due to reasons other than poor monitoring by government and lack of penalties for non-compliance. These are only symptoms of the real problems. The problems identified are (1) institutional arrangement for policy implementation and (2) nature of the policy. Given the limitations of the regulatory institutions, we recommend the government to move away from framing policies that are based on command-and-control approach. The emerging literature on impact of government policies on CLSC may consider the two factors (that are not readily observable), i.e. nature of policy and the institutional arrangement, for future research. Many other developing countries like China, Brazil, etc. are formulating or planning to formulate policies to limit the externalities in the CLSC of products like e-waste, plastic items, etc. This suggests that the insights developed in this paper may be extended to other countries or tested in countries that have implemented similar policies. As described above, the insights from this study can also be extended to other environmental regulations like E-waste management rules, Remanufacturing rules etc.

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