

# **ANALYSIS OF BARRIERS AND RISKS IN GREEN TEXTILE AND CLOTHING SUPPLY CHAIN**

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INDIAN INSTITUTE OF TECHNOLOGY DELHI**

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# **ANALYSIS OF BARRIERS AND RISKS IN GREEN TEXTILE AND CLOTHING SUPPLY CHAIN**

*by*

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**Submitted**

**in fulfilment of the requirements of the degree of Doctor of Philosophy**

*to the*



**INDIAN INSTITUTE OF TECHNOLOGY DELHI**

**JUNE 2020**

*Dedicated to my family*

## **CERTIFICATE**

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This is to certify that the thesis titled '**Analysis of Barriers and Risks in Green Textile and Clothing Supply Chain**', being submitted by Mr. Sanjib Kumar Sinha to the Indian Institute of Technology Delhi, for the award of the degree of Doctor of Philosophy, is a record of bonafide research work carried out by him. He has worked under my guidance and supervision and fulfilled the requirements for submission of the thesis which has attained the standard required for a Ph.D. degree of this Institute.

The results contained in this thesis have not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.

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## ABSTRACT

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Textile and clothing supply chain is one of the most important supply chains in developing economies like India as it provides huge employment generation opportunities. Textile and clothing industry consumes huge amount of resources (air, water and energy) and creates environmental pollution. Therefore, sustainable and green aspects of textile and clothing supply chain have attracted the attention of researchers, practitioners and policy makers. This research focusses on the two related aspects, namely barriers and risks of green supply chain management (GSCM) in Indian textile and clothing industry.

Interpretive structural modelling, fuzzy Analytic Hierarchy Process and fuzzy TOPSIS have been used as decision making tools for analysis of barriers, quantification of risks and prioritisation of risk mitigation strategies. First, an attempt has been made to identify and analyse the important barriers of GSCM in textile and clothing industry. For organised sector, lack of consumer support and encouragement, lack of guidance and support from regulatory authorities, and high implementation and maintenance cost are the major inhibiting barriers. Lack of green suppliers is the most dependent barrier which is influenced by most of the other barriers. In the unorganised sector, complexity of green process and system design along with lack of support from regulatory authorities are found to be the barriers having the maximum driving power. Lack of consumer support and high investment and low economic benefits are also found to be important inhibiting barriers. It is observed that the driver barriers are similar for organised and unorganised textile and clothing supply chains.

Then, an effort has been made to quantify various risks related to GSCM in textile and clothing industry based on their severity of impact and probability of occurrence. Business environment and financial risks have higher impact and their combined impact is around 60%, while remaining 40% is contributed by supply, demand and process risks. Among the specific risks, sourcing of funds, change in legislation, natural disaster and exchange rate fluctuation are having high impact on green clothing supply chain performance. In terms of probability of occurrence, the scenario is quite different as supply, demand and process risks dominate over the business environment and financial risks. Uncertainty of demand, cost of green materials, supplier failure and technological changes are the specific risks having high probability of occurrence. In terms of

integrated score, which combines severity of impact and probability of risk, sourcing of funds, change in legislation, fluctuation of exchange rate and key customer failure are the top four specific risks. A portfolio of risk mitigation strategies for GSCM in textile and clothing industry has been developed. It is found that developing agility in supply chain is the most potent strategy for risk mitigation. Multiple green sourcing with flexible capacities is the second dominant risk mitigation strategy, followed by adoption of the green initiatives (3<sup>rd</sup>), trust building and collaboration (4<sup>th</sup>) and alignment of economic incentives and revenue sharing (5<sup>th</sup>).

In the last part of this research, a case study of textile wastewater treatment plant installed in a vertically integrated textile unit located in Gujarat, India has been presented. Net present value (NPV) method has been used to analyse the investment economics considering different rates of discount. It is found that unless the capacity of waste water treatment plant is utilised fully, it becomes unviable in economic terms.

## सारांश

कपड़ा और वस्त्र आपूर्ति श्रृंखला भारत जैसी विकासशील अर्थव्यवस्थाओं में सबसे महत्वपूर्ण आपूर्ति श्रृंखलाओं में से एक है क्योंकि यह रोजगार के बड़े अवसर प्रदान करती है। कपड़ा और वस्त्र उद्योग भारी मात्रा में संसाधनों (वायु, जल और ऊर्जा) का उपभोग करता है और पर्यावरण प्रदूषण पैदा करता है। इसलिए, कपड़ा और वस्त्र आपूर्ति श्रृंखला के टिकाऊ और हरित प्रक्रिया के पहलुओं ने शोधकर्ताओं, अभ्यासियों और नीति निर्माताओं का ध्यान आकर्षित किया है। यह शोध भारतीय कपड़ा और वस्त्र उद्योग में दो संबंधित पहलुओं, हरित आपूर्ति श्रृंखला प्रबंधन (GSCM) की बाधाओं और जोखिमों पर ध्यान केंद्रित करता है।

इंटिग्रेटिव स्ट्रक्चरल मॉडलिंग (ISM), फजी एनालिटिक हायरार्की प्रोसेस (AHP) और टॉपसिस (TOPSIS) का उपयोग बाधाओं के विश्लेषण, जोखिमों की योग्यता और जोखिम शमन रणनीतियों के प्राथमिकताकरण से सम्बंधित निर्णय लेने के उपकरण के रूप में किया गया है। अनुसंधान के पहले भाग में कपड़ा और वस्त्र उद्योग में GSCM की महत्वपूर्ण बाधाओं को पहचानने और उनका विश्लेषण करने का प्रयास किया गया है। संगठित क्षेत्र के लिए, उपभोक्ता की सहायता और प्रोत्साहन में कमी, नियामक प्राधिकारी से सहायता और मार्गदर्शन में कमी तथा उच्च कार्यान्वयन और रखरखाव लागत प्रमुख अवरोधक व बाधाएं हैं। हरित आपूर्तिकर्ताओं की कमी सबसे अधिक आश्रित बाधा है जो अधिकांश अन्य अवरोधों से प्रभावित होती है। असंगठित क्षेत्र में, नियामक प्राधिकारी से सहायता की कमी तथा हरित प्रक्रिया और प्रणाली के डिजाइन की जटिलता अत्यंत शक्तिशाली बाधाओं के रूप में पाई गई हैं। उपभोक्ता सहायता का अभाव, उच्च निवेश और कम आर्थिक लाभ भी महत्वपूर्ण अवरोधक पाए गए हैं। यह देखा गया है कि संगठित व असंगठित कपड़ा और वस्त्र आपूर्ति श्रृंखलाओं की मुख्य बाधाएं एक जैसी ही हैं।

इस शोध के दूसरे भाग में, कपड़ा और वस्त्र उद्योग में GSCM से संबंधित विभिन्न जोखिमों को उनके प्रभाव की गंभीरता और घटना की संभावना के आधार पर निर्धारित करने का प्रयास किया गया है। व्यावसायिक वातावरण और वित्तीय जोखिमों का प्रभाव अधिक है, उनका संयुक्त प्रभाव लगभग 60% है जबकि शेष 40% योगदान आपूर्ति, मांग और प्रक्रिया जोखिमों द्वारा है। विशिष्ट जोखिमों में, धन के स्रोत, कानून में बदलाव, प्राकृतिक आपदा और विनिमय दर में उतार-चढ़ाव का हरित वस्त्र आपूर्ति श्रृंखला प्रदर्शन पर उच्च प्रभाव पड़ रहा है। घटना की संभावना के संदर्भ में परिदृश्य काफी अलग है क्योंकि आपूर्ति, मांग और प्रक्रिया के जोखिम व्यावसायिक वातावरण और

वित्तीय जोखिमों पर हावी है। मांग की अनिश्चितता, हरित सामग्रियों की लागत, आपूर्तिकर्ता की विफलता और तकनीकी परिवर्तन विशिष्ट जोखिम होते हैं जो घटना की उच्च संभावना रखते हैं। प्रभाव की गंभीरता और जोखिम की संभावना के समन्वित संदर्भ में धन के स्रोत, कानून में बदलाव, विनिमय दर में उतार-चढ़ाव और प्रमुख ग्राहक विफलता चार सर्वोच्च विशिष्ट जोखिम हैं। इस शोध में कपड़ा और वस्त्र उद्योग में GSCM के लिए जोखिम शमन रणनीतियों का एक पोर्टफोलियो विकसित किया गया है। यह पाया गया है कि आपूर्ति श्रृंखला में चपलता विकसित करना जोखिम शमन के लिए सबसे शक्तिशाली रणनीति है। लचीली क्षमताओं के साथ विभिन्न हरित स्रोत दूसरी प्रमुख जोखिम शमन रणनीति है, इसके पश्चात हरित पहलों को अपनाना (3<sup>rd</sup>), विश्वास निर्माण और सहकार्यता (4<sup>th</sup>) और आर्थिक प्रोत्साहन व राजस्व साझाकरण का संरक्षण (5<sup>th</sup>) आते हैं।

इस शोध के अंतिम भाग में भारत के गुजरात में स्थित एक कपड़ा उद्योग में स्थापित अपशिष्ट जल उपचार संयंत्र पर मामले का अध्ययन प्रस्तुत किया गया है। छूट की अलग-अलग दरों को ध्यान में रखते हुए, निवेश अर्थशास्त्र का विश्लेषण करने के लिए शुद्ध वर्तमान मूल्य पद्धति (NPV Method) का उपयोग किया गया है। यह पाया गया है कि जब तक इन अपशिष्ट जल उपचार संयंत्र की क्षमता का पूर्ण उपयोग नहीं किया जाता है, यह आर्थिक रूप से अलाभकारी हो जाते हैं।

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## LIST OF ACRONYMS AND ABBREVIATIONS

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Acronyms and Abbreviations	Full form
AHP	Analytical hierarchy process
ACR	Anaerobic contact reactor
Al	Aluminium
ARI	Aggregative risk index
BOD	Bio-chemical oxygen demand
BSE	Bombay stock exchange
CC	Closeness coefficient
CETP	Common effluent treatment plant
CFAT	Cash flow after tax
CN	Cyanide
CSE	Lack of consumer support and encouragement
CO	Cash outflow
COD	Chemical oxygen demand
CPCB	Central pollution control board
Cr	Chromium
CSR	Corporate social responsibility
CU	Colour units
Cu	Copper
DEMATEL	Decision making trial and evaluation laboratory
DM1	Decision maker 1
DM2	Decision maker 2
DM3	Decision maker 3
EB	Lack of economic benefits
EEM	Lack of effective environmental measures
ELECTRE	Elimination and choice by translating reality
ELT	Lack of eco-literacy and training
EMS	Environmental management system
ESC	Extended supply chain

<b>Acronyms and Abbreviations</b>	<b>Full form</b>
ESER	Energy saving and emission reduction
ETP	Effluent treatment plant
EU	European union
FAHP	Fuzzy analytic hierarchy process
FMEA	Failure mode and effects analysis
FNIS	Fuzzy negative ideal solution
FPIS	Fuzzy positive ideal solution
FSC	Forest stewardship council
FSG	Lack of flexibility to switch over to green system
GIBS	Green international brands
GLM	Green logistic management
GOTS	Global organic textile standard
GPD	Complexity of green process and system design
GS	Lack of green suppliers
GSCM	Green supply chain management
HRSCC	High rate solid content clarifier
IL & FS	Infrastructure leading & financial services limited
IMC	High implementation and maintenance cost
IRP	Interpretive ranking process
IRR	Internal rate of return
ISM	Interpretive structural modelling
ISO	International organisation for standardisation
IT	Information technology
KL	Kilo litres
LCS	Lack of support from consumers
LEB	High investment and low economic benefits
LGM	Lack of green materials, process and technology
M & S	Marks and spencer
MCDM	Multicriteria decision making
MCU	Market competition and uncertainty
MICMAC	Matrix of cross impact multiplication applied to classification

<b>Acronyms and Abbreviations</b>	<b>Full form</b>
MSC	Marine stewardship council
NBV	Net benefit value
NGO	Non-governmental organisation
NPV	Net present value
NSE	National stock exchange
OSHA	Occupational safety and health administration
pH	Potential for hydrogen
PV	Present value
PVA	Polyvinyl alcohol
R & D	Research and development
RO	Reverse osmosis
ROA	Return on assets
ROS	Return on sales
RS	Lack of reward system
RSPO	Round table on sustainable palm oil
SAFS	Small alternative firms
SBR	Sequential batch reactor
SC	Supply Chain
SCM	Supply chain management
SCRM	Supply chain risk management
SEL	Slackness in enforcement of legislation
SME	Small and medium sized enterprise
SRA	Lack of guidance and support from regulatory authorities
SSCM	Sustainable supply chain management
SSIM	Structural self-interaction matrix
TDS	Total dissolved solid
TEP	Lack of trust and environmental partnership among supply chain partners
TFN	Triangular fuzzy number
TMC	Lack of top management commitment
TOPSIS	Technique for order of preference by similarity to ideal solution

<b>Acronyms and Abbreviations</b>	<b>Full form</b>
TSS	Total suspended solid
UGO	Uncertainty of green outcome
UK	United Kingdom
US	United States
USEPA	United states environmental protection agencies
WC	Working capital
ZLD	Zero liquid discharge
Zn	Zinc

## APPENDIX

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