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ARTICLE TITLE: **Green procurement process model based on blockchain IoT integrated architecture for a sustainable business**

AUTHORS: **Santosh B. Rane and Shivangi Viral Thakker**

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Q9	Please provide issue number and if not a single page article then last page in reference: Fu *et al.* (2018), Francisco and Swanson (2018).
Q10	Please provide the volume number, issue number and page range in references: Rane, Narvel and Bhandarkar (2019), Rane, Potdar and Rane (2019), Dandage *et al.* (2019), Rane and Narvel (2019).
Q11	Please supply the initials for the author name "Tang and Zhou" in reference: Tang and Zhou (2012).

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Q19	Please provided initial name of the author "Abooie" in the reference: Kosar Roshani (2019).

Green procurement process model based on blockchain IoT integrated architecture for a sustainable business

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Abstract

Q1

Purpose – Blockchain and IoT are recently developed technologies for the database creation and smooth functioning of supply chain activities. The purpose of this paper is to analyse the use of blockchain and IoT for green procurement activities. The integration of blockchain and IoT interface can solve many challenges faced by industries having green procurement.

Design/methodology/approach – Through a literature survey and interviews with procurement managers from different industries, challenges in green procurement were identified. Elements of blockchain and IoT were analysed to overcome the green procurement challenges. Architecture for blockchain and IoT is developed to be implemented in the green supply chain for a sustainable business.

Findings – The challenges of green procurement are categorised and ranked as per the industry survey results. The architecture shows the tasks of blockchain and IoT in green procurement activities.

Research limitations/implications – Green procurement is still at developing stages in India as compared to Europe and many other countries. There is a requirement for more government involvement and participation from industry and customers to implement such methods. Environment issues and challenges faced by industries are addressed.

Practical implications – Blockchain–IoT integration can transform a green supply chain. This research helps industries planning to incorporate blockchain and IoT in identifying the areas to focus and better planning of resources for the successful implementation of smart technologies in their supply chains. Green initiatives ensure global competitiveness as well as recognition at the global level. Green procurement ensures the minimal usage of energy and efficient waste disposal.

Originality/value – The implementation of green procurement and challenges associated with it are addressed in this research. This will work as a framework for industries looking forward to implementing blockchain and IoT in their supply chains for solving green procurement challenges.

Q2

Keywords Sustainability, Internet of Things, Green procurement, Blockchain technology, Block chain–IoT-integrated architecture

Paper type Research paper

1. Introduction

Sustainable and green supply chain is a major concern for all industries worldwide. Protecting the environment with process innovations, new strategies and international certifications like ISO 14000 are goals of many businesses (Song and Gao, 2017). Green procurement ensures high efficiency and low pollution levels by addressing issues such as waste management, carbon footprints, energy management, packaging and transportation, etc. For most of the industries involved in assembling or similar operations, it is the suppliers who will have majority of the environmental impact (Sinha Neena and Garg, 2016).

Blockchain and IoT are nascent technologies for incorporation in supply chains. Although they have got the potential to change the dynamics of the green supply chain, there are certain challenges associated with them. Security and transparency are major

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concerns for green procurement activities that involve various parties and processes such as supplier selection, logistics, packaging and distribution, to name a few.

There are many challenges faced by green procurement and green purchasing in the industries (Liobikienė *et al.*, 2017). This paper analyses the challenges and categorises them for better addressing. Incorporation of new disruptive technologies such as blockchain and IoT has many benefits to overcome the challenges. These technologies are studied in depth and an integrated architecture is developed for handling green procurement in an organisation.

2. Literature survey

2.1 Green procurement and purchasing

The industries and organisations across the world have started considering sustainability as an important factor for green procurement (Lozano, 2012). Dawson and Probert (2007) suggested taking practical actions for sustainable procurement. Vachon and Klassen (2008) have emphasised on the examination of impact of collaboration in the supply chain like joint environment policies and plans to reduce pollution. Cooperation and attitude of suppliers for green practices minimise the procurement cost and ensure social and economic benefits to organisations.

Hollos *et al.* (2011) discussed about a UK-based company that has started joint venture with suppliers to implement green procurement policies so as to have minimum impact on environment. Kalubanga (2012) gave the benefits of linking sustainability to procurement specifically for developing countries. Tate *et al.* (2012) discussed that when the majority of material and components are outsourced by the firm, the environmental impact of the firm will be based on the suppliers it selects and the requirements it gives to the suppliers. Involvement of suppliers become essential in such cases rather than just giving them guidelines. Appolloni *et al.* (2014) conducted a literature review to find requirements for green procurement in the private sector.

Q3 ISO 140001 certification is increasing worldwide which is a representative of environmental concern by industries. Appendix 1 shows that East Asia and Pacific Regions have highest number of ISO certifications registered. The Central and South Asia are at very low level with India being the top country in that region (Appendix 1).

2.2 Blockchain for supply chains

Blockchain technology is majorly used in finance sectors but recently real estate, supply chains and energy sectors have also realised the potential of this disruptive technology (Abeyratne and Monfared, 2016). Blockchain uses data structure techniques to store and link the data for every transactions created by the users (Rane, Narvel, Bhandarkar, 2019; Rane, Potdar. and Rane, 2019).

2.2.1 Purpose. The purpose of using blockchain for green procurement is to track the product right from its raw material stage till its end of life, and even after it gets recycled or reused (Fu *et al.*, 2018). The tracking of items from suppliers to customer with the information about its processing, location, quality, etc., gives better visibility and control over the processes; hence, the company can improve its compliance.

2.2.2 Applications. There are many applications of blockchain for green procurement. Some of them are listed below:

(1) Supplier data for the selection and development of suppliers can be stored and analysed for quality, performance and long-term associations using blockchain database.

(2) Investments done for supplier development programmes may be monitored and information can be used to track the performance measurement of suppliers.

By comparing before and after training performance of suppliers, benchmarking is possible for green suppliers.

(3) Green packaging and logistics information tracking helps evaluating the green impact of the firm.

(4) Waste management and energy utilisation are also areas that can be monitored in blockchain for minimising the environmental impact of firm.

2.2.3 Limitations. Blockchains and bitcoins face hurdle in widespread adoption by organisations as its government regulation status is uncertain. Blockchain requires all stakeholders of a supply chain to join hands and be a part of blockchain-enabled supply chain (Rane, Narvel, Bhandarkar, 2019; Rane, Potdar and Rane, 2019). Resolving crucial technological aspects such as transaction speed, data limits and verification process are some of the challenges for blockchain. The technologies developed today are yet to be proven. Blockchain technology is effective in securing transactions, but can be limited in performance, scalability and confidentiality (Kim and Laskowski, 2018). There are cybersecurity concerns that need to be addressed before general public can entrust their data to a blockchain solution.

Q4

2.3 IoT for supply chain

IoT can give tremendous advantages in the various activities of the supply chain (Banerjee, 2015). RFID-enabled items and smart shelves can track the real time location of products based on which the retailer can optimise the operations. Logistics can be managed efficiently by tracking the trucks and pallets, and carbon footprints may be optimised accordingly.

RFID tags create unique identity of the product and material which can be transmitted in real time across the supply chain network. This helps in the examination of past demand data and forecasting the demand for future.

2.3.1 Purpose. Usage of IoT sensors and monitoring technology is increasing in industries, showing a general shift towards technologically advanced solutions. The data boom in supply chains has led to the use of IoT devices for data collection. Internet of Things gives immediate information about real world objects through internet-based servers which lead to more productivity and high efficiency.

2.3.2 Applications. IoT and wireless technologies improve the effectiveness of environmental programmes that may include monitoring the trucks and vehicles for emission, reuse and recycle of materials, collection and disposal of waste to name a few. RFID provides high visibility in procurement process by helping manage the logistics and relation with the suppliers. Fuel usage, emissions levels and distance travelled by trucks may be tracked to improve the route and efficiency of transport facilities. Information related to green procurement is generated in real time and is accessible to buyer and suppliers.

2.3.3 Limitations. IoT technology needs to prove that the entire IoT infrastructure is effective, efficient, secure and resilient. Because it is a combination of many technologies, standards will have to be defined and accepted so that they can work together. Mobility, scalability and manageability are some of the hurdles described by researchers while using IoT architecture. Large volume of data is generated which requires connectivity and accessibility for longer periods. Heterogeneous environment makes the architecture of IoT even more difficult to manage.

3. Research gaps

Even though great amount of research is done for green supplier development, a complete study on green procurement is not addressed so far (Babbar and Amin, 2018; Lo *et al.*, 2018). Green procurement as a component of green supply chain is studied in parts but the overall challenges and processes related to green procurement need attention of researchers.

The use of recently developed technologies for green procurement needs to be studied. There is no architecture developed for incorporating technologies such as blockchain and IoT in a supply chain. This research work attempts to address few of the research gaps.

4. Research objectives

This paper presents conceptual work for investigating green procurement challenges and providing solutions by developing architecture based on latest technologies such as blockchain and IoT. The research considers all aspects of green procurement starting from vendor selection to the reverse logistics and end of life of products. Specific objectives of the research are as follows:

(1) investigate challenges faced by green procurement model of the supply chain;

(2) categorise the challenges and identify the areas for mitigating the challenges;

(3) study the architecture of blockchain and IoT in the context of supply chain management; and

(4) develop an integrated architecture incorporating blockchain and IoT to make green procurement process transparent, efficient and more reliable (Figure 1).

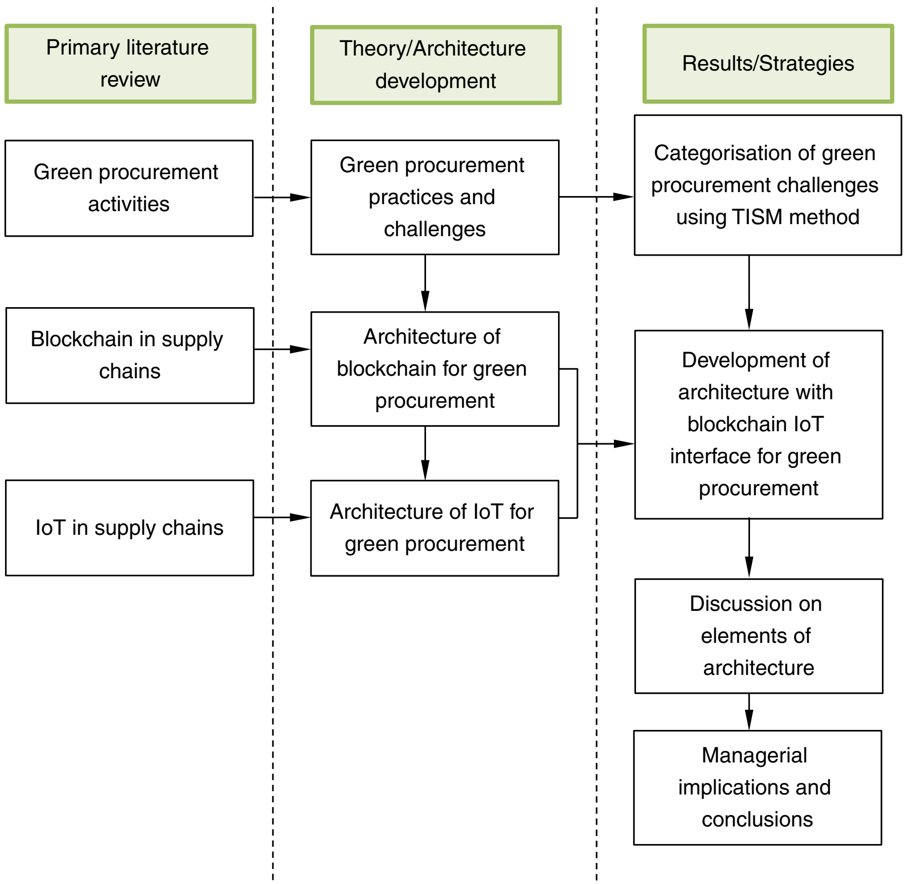

Figure 1.
Research methodology flowchart

5. Research methodology flowchart

The research is divided into three sections as follows: literature survey, development of architecture and analysis and finally strategies development and conclusions. Literature survey was done starting from 2000 to 2019 for the keywords such as green procurement, blockchain and Internet of Things. The search was further narrowed by using secondary keywords like architecture, challenges and total interpretive structural modelling (TISM). While literature survey covers the work done by researchers in the area of green procurement and technologies such as blockchain and IoT, architectures were analysed in the second section. Challenges faced by industries aiming for green procurement were identified by the survey method and analysed using the TISM method. Final section shows the integrated architecture developed for mitigating the challenges using disruptive technologies such as blockchain and IoT. Strategies were developed for mangers and practitioners and conclusion and limitations are explained in final sections.

6. Green procurement challenges

The implementation of green procurement is still in its introduction phase and faces various challenges. The low level of understanding and knowledge among people working in public client organisation and stakeholder's organisation is obstructing the implementation of green procurement. In addition, the enforcement by the government in implementing green procurement is still poor and causes hesitancy among clients and developers to adopt green practices (Parikka-Alhola, 2008). As studied by Wong *et al.* (2003), in China, green procurement is not mandatory and their government only provides a macro level of control for construction projects to reduce the environmental effects. Besides, there are insufficiencies in terms of policies and regulation to promote green procurement. In order to mitigate this issue, more mandatory requirements are needed to provide better sustainability (Jadhav *et al.*, 2018; Kirkire *et al.*, 2018).

The existing tools are not comprehensive to evaluate the criteria of sustainability (Sarkis and Zhu, 2018). Thus, there is a need to create more comprehensive tools for a situation where sustainability is prime concern. Other contributing challenges include the poor market demand for recyclable construction materials and a limited supply of green products that hinder the implementation of green procurement (Table II).

6.1 Data collection

In the present study, barriers in green procurement are considered as elements for modelling. In all, 15 barriers were finalised after a thorough literature survey and interviews with the experts. The experts were from different backgrounds relevant to the study to balance the industry and academics perspectives. The questionnaire was prepared for ranking the criteria by doing comparative analysis of criteria.

6.1.1 Delphi method. Delphi method was used for survey as suggested by many researchers for data collection (Mishra and Rane, 2018). The experts from industry and academics were consulted for the opinion. Delphi method is used by many researchers for survey as it maintains the anonymity of participants and considers individual opinions of the experts (Kirkire *et al.*, 2018). To finalise and do pairwise ranking of the criteria, 50 experts were considered including supply chain managers, procurement managers and suppliers at Tier 1 and Tier 2 levels. Experts was asked to give pairwise rating for 15 barriers. Delphi score is proposed by Listone and Turoff (2002) as given below:

$$\text{Delphi Score} = [(\text{Lowest Score} + \text{Highest Score} + 4) \times \text{Average Score})]/6.$$

For the 30 shortlisted challenges in green procurement, the experts were asked to score them based on their understanding and experince in the field of green supply chain. Based on the Delphi score received from experts, top 15 barriers were identified and given code as B1–B15. These barriers were analysed further using fuzzy interpretive structural modelling to find their contextual relationship with each other and to rank them so that managers and practitioners may focus on them for their eradication from the green procurement process.

6.1.2 Validation of questionnaire. A reliability test is usually conducted for the validation of questionnaire. Cronbach's α, also known as α coefficient, is used to evaluate the internal consistency (and hence reliability) of the questions asked in the survey. Its value generally lies between 0 and 1 and is considered as acceptable when it is higher than 0.70. We have found the value of Cronbach's α as 0.8803 from Excel sheet analysis of the answers given by the participants (Table I)

7. Modelling of challenges using TISM

The TISM methodology is adopted to analyse barriers in the implementation of green procurement and then to develop a relationship among the barriers. TISM model uses reachability matrix and level partitioning same as the one used in the ISM method (Jadhav *et al.*, 2015a, b). The basic steps of TISM methodology are described in following sub-section.

7.1 Interpretation of relationship

Interpretive knowledge base is formed by doing comparative study of barriers; e.g., by simply studying whether barrier B1 will enhance or influence barrier B2 (Ravi and Shankar, 2005; Kosar Roshani *et al.*, 2019). Similarly, a pairwise comparison of all 15 barriers is done for knowledge base generation.

7.2 Initial and final reachability matrix

The interpretive knowledge base is used for forming reachability matrix with the rule that if the entry in initial matrix is *Y* then it is replaced by 1 and if it is *N* then it is replaced by 0. After replacing all codes with appropriate digits, they are checked for transitivity rule (Table II).

7.3 Level partitions

The level partition is carried out, similar to ISM, to know the placement of elements level-wise (Saxena *et al.*, 2006). The levels are determined by finding reachability set and antecedent set. The intersection of both sets gives the first level. Similarly, next levels are determined by following the same process. Six iterations were done to cover all challenges (Table III).

7.4 Formation of the TISM-based model

The TISM-based model was developed as per level partitions in Figure 2. The transitive links are shown by dotted lines and direct relations are shown by solid arrows. Level 1 barriers are placed at the topmost position in the TISM model and Level 6 at the bottom. The direction of arrows help in the identification of relationship between the barriers, and complete structural model gives the interpretation of relationship between all barriers (Rane and Kirkire, 2017). Significant transitive links are shown with dotetd line where the weightage of the link is more than 50 per cent as per experts.

7.5 MICMAC analysis

MICMAC analysis is done to analyse the driving power and dependence of the barriers (Figure 3). The barriers are represented in four clusters based on driving powers and dependence of each barrier (Wakchaure and Jha, 2011; Rane and Kirkire, 2016).

Table I.
Delphi score for challenges in green procurement

S. No.	Category	Challenges for green procurement	Sources	Description and application of blockchain–IoT	Delphi score	Code
1	Material and products	Lack of sustainable products and processes	Tang and Zhou (2012), Rane and Mishra (2018)	Though the technologies do not have direct contribution on availability of sustainable products, the firm can use the database of blockchain to locate the suppliers and industries offering sustainable products	21.5	B1
2		High usage of chemicals and non-recyclable material	Appolloni *et al.* (2014)	Tracking of raw material used in terms of composition and quality may be monitored on blockchains. Life cycle analysis is possible with the use of RFID tags on the components	22	B2
3		High cost of alternative and green material	Appolloni *et al.* (2014)	Replacing plastics with recyclable materials is being researched extensively. Global sourcing on blockchain platforms by having smart contracts for parties from different continents could serve the purpose	24	B3
4		Unavailability of green labelled products	Tang and Zhou (2012)	Green label certified products ensure that there is no adverse impact of business on environment. It is difficult to find such products easily as the norms for green label are stringent	19.6	B4
5		Low end of life reuse of products	Wu and Pagell (2011)	Green supply chain includes reverse logistics and reuse/recycle of components. This needs to be considered while implementing IoT for the tracking of components or material which needs to be done till the recycle point	18.8	B5
6		Low product life span	Meehan and Bryde (2011)	Green products usually have low life span and hence not preferred by many industries. Life cycle of green products could be tracked by IoT devices	14	–
7		High maintenance cost of products	Meehan and Bryde (2011)	Green products require more maintenance in terms of customer service, repair, etc. Blockchain-based customer app could be used for the ease of tracking and maintenance	13.7	–
8		High wastage for packaging	Zsidisin and Siferd (2001)	Packaging of products causes high material wastage as once the product is opened, the packaging is wastage but many green products require high amount of packaging to avoid contact with water and dust	14.7	–
9		Perception that green product would be more expensive	Tang and Zhou (2012)	Green materials are finding their way in industries and daily usage but it is the perception that they will be costlier. Suppliers are hesitant in making products with green material with the notion that final price may go high and buyers may not accept the change	15.2	–
10		Low usage of backhauling of trucks	Tang and Zhou (2012)	Careful route planning and backhauling are not given importance while deciding logistics. This increases logistics cost and requires more fuel. Blockchain and IoT tracking helps finding best routes for trucks and can save fuel and reduce logistics cost	13.2	–

(continued)

S. No.	Category	Challenges for green procurement	Sources	Description and application of blockchain–IoT	Delphi score	Code
11		Lack of logistics strategy in place	Kalubanga (2012)	Logistics costs are increasing with supplier network spread across the country. Importance should be given to logistics planning to ensure efficient costing and route for transportation	12.5	–
12		No tracking of logistics carbon footprints	Appolloni *et al.* (2014)	Tracking of carbon footprints by trucks and other vehicles is not done by most of the industries. The tracking can be done easily with RFID tags and IoT cloud server	12.8	–
13		No legal provision for safe disposal of products	Chaudhuri *et al.* (2018)	Disposal of products after end of life is a big task for industries which leads to open supply chains. There are no legal provisions made by government for safe disposal	13.6	–
14		Use of hazardous products	Chaudhuri *et al.* (2018)	Chemicals and many hazardous materials are used by some industries for manufacturing which leads to lower green index and needs alternatives to be found	14.9	–
15		Poor market demand for recyclable material	Chaudhuri *et al.* (2018)	Recyclable materials may have lesser strength and properties as compared to traditional material and hence are not preferred by product developers	12.7	–
16	Energy and waste management	Lack of awareness for using renewable energy	Dawson and Probert (2007)	Implementation of renewable sources of energy to replace traditional methods needs awareness and strategic planning. IoT-based solutions and sensors are used by industries for managing wind farms and solar fields	20.8	B6
17		Lack of provision for waste management	Dawson and Probert (2007)	Smart waste management can be done using blockchain Crypto coins and digital token. E-waste management is possible by incorporating blockchain and smart contracts	21.4	B7
18		High water and energy usage during processes	Walker and Phillips (2009)	For all processes, the usage of electricity, water and other resources can be monitored. A mechanism for internal operations can be managed by transparency and information sharing offered by blockchain and IoT	30.9	B8
19		Lack of tracking of greenhouse emissions	Walker and Phillips (2009), Sarkar B *et al.* (2008)	There are very less technologies adapted by industries for tracking greenhouse emissions. The tracking is possible with IoT smart devices for entire supply chain	15.7	–
20		No tracking of carbon footprints	Sarkar *et al.* (2008)	Tracking of carbon footprints of the industry requires lot of efforts in terms of data generation and tracking mechanisms so that the industries do not go for it as its not mandatory	16.5	–
21		Low efforts for minimising energy consumptions	Bergendahl *et al.* (2018)	Energy consumption is very high for manufacturing process and also the efforts are not taken for minimising it by adjusting process and designs.	15.5	–

(*continued*)

Table I.

S. No.	Category	Challenges for green procurement	Sources	Description and application of blockchain–IoT	Delphi score	Code
				Dedicated efforts are required with smart device usage to minimise electricity consumption		
22	Organisational	Lack of incentive for companies to implement green procurement	Ahmed and Sarkar (2018)	There are not many incentives given by government for implementing green supply chain. Companies are reluctant to spend large amount on new processes and technologies as the benefits are also not very clear	24.9	B9
23		Lack of top management commitment including money and time	Bergendahl *et al.* (2018)	Top management support and involvement and availability of organisational resources play an important role while implementing new technology	28.6	B10
24		Insufficient integration at industry level	Walker and Phillips (2009), Daniel Jiménez *et al.* (2015)	Green procurement requires integration in industry for involving all the parties. Blockchain and IoT helps in the process of integration by ensuring the smooth information and material flow in supply chain	18.5	B11
25		Lack of awareness on the green procurement concept	Rajkumar *et al.* (2008), Groening *et al.* (2018)	Green procurement is a new term for Indian industries as most supplier selection criteria do not include environment sustainability. Awareness level of industries to foster green procurement practices needs to be enhanced with global exposure and case studies	15.8	–
26	Supplier related	Lack of commitment from suppliers to go green	Lemos and Giacomucci (2002)	In most cases of failure in green procurement, it is the commitment of both parties that play important role. Suppliers should be self-motivated and guided for taking green initiatives	23.8	B12
27		Lack of buyer supplier interface	Igarashi *et al.* (2015)	Blockchain and IoT make supply chain transparent and accessible to all partners, hence the industry need to collaborate with suppliers and other stakeholders for data sharing and information processing	17.6	B13
28		Lack of procedure for supplier selection and development	Igarashi *et al.* (2015), Thakker and Rane (2018)	There are no standard metrics available for supplier selection and development. Standardised and automated processes offered by blockchain enable industries to manage their vendors and track the performance of vendors along with their green scores	19.8	B14
29		Lack of database of green suppliers	Amindoust *et al.*, (2012), Bai and Sarkis (2010), Thakker and Rane (2018)	Industries require many varieties of raw and semi-finished materials and products. A global database creation on blockchain enables the buyers to identify and contact the suppliers as per environment criteria	28.3	B15
30		Lack of training of suppliers	Azadnia *et al.* (2014)	Suppliers are not trained to apply green principles and lack the technology and understanding required. Global exposure with central supply chain database may be helpful in conducting online training and giving solutions to suppliers	16.6	–

Table I.

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	DP
1	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0	6
2	0	1	0	1	1	1	1	0	1	1	1	0	0	0	1	9
3	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0	6
4	0	1	0	1	1	1	1	0	1	1	1	1	1	0	1	11
5	0	1	1	1	1	1	1	0	1	1	1	0	0	0	1	10
6	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	12
7	0	1	1	1	1	1	1	0	1	1	1	1	1	0	1	12
8	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	14
9	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0	6
10	0	1	1	1	1	1	1	0	1	1	0	0	0	0	0	8
11	0	0	1	1	1	1	1	0	1	0	1	0	0	0	0	7
12	1	1	1	1	1	1	1	0	1	1	1	1	1	0	0	12
13	0	1	0	1	1	1	1	0	1	1	0	0	1	0	0	8
14	0	0	0	1	1	1	1	0	0	0	0	0	0	1	0	5
15	0	1	1	1	1	1	1	0	1	1	0	0	0	0	1	9
Dependence	4	10	11	15	15	15	14	1	13	10	8	5	6	1	7	

Table II.
Final reachability matrix of ISM

B3 (high cost of alternative and green material), B9 (lack of incentive for companies to implement green procurement) and B10 (lack of top management commitment including money and time) were found to be dependent barriers. B8 (high water and energy usage during processes), B12 (lack of commitment from suppliers to go green) and B15 (lack of database of green suppliers) were identified as independent barriers.

8. Discussion and applications

The results obtained by total interpretive structural analysis (TISM) shows the six levels of barriers. Commitment from suppliers to go green is Level 6 barrier and it leads to other barriers such as lack of interface between buyer and supplier and low response from buyers. Top-level barriers are the unavailability of green products, low rate of reuse of products, lack of awareness for using renewable energy and no incentives for companies for implementing green procurement. The linkages are shown to mark direct effect of one barrier on other. For instance, high usage of energy and resources leads to non-sustainable products and processes.

These barriers could be mitigated by developing roadmap for green procurement process. Next sub-section shows the architecture developed for green procurement process using the blockchain and IoT-integrated architecture.

8.1 Architecture for green procurement based on blockchain–IoT

Green procurement process starts with the careful selection and management of suppliers (Figure 4). Development of suppliers for sustainability in supply chain can be done by using the information network of blockchain. Historic performance of suppliers along with its green impact can be monitored on blockchain and IoT network. Smart contracts and IoT ensure that the suppliers are involved in taking green initiatives and their environment performance is tracked for the long-term association (Awasthi *et al.*, 2010).

Next in the green procurement comes the management of material and products. Characteristics of the products along with historic data can be saved in blockchain. This will allow users to identify the origin, quality and time requirement of the product (Aquilani *et al.*, 2017). The information helps tracking green quality, recyclability and carbon footprints of products. Safe disposal of product can be carried out with this information specifically for products containing lead batteries and other materials which may be harmful after their end of life.

Table III.
Level partitioning

Variables	Reachability set	Antecedent set	Intersection set	Level
Iteration 1				
1	1, 3, 4, 5, 6, 7	1, 6, 8, 12	1, 6	
2	2, 4, 5, 6, 7, 9, 10, 11, 15	2, 4, 5, 6, 7, 8, 10, 12, 13, 15	2, 4, 5, 6, 7, 10, 15	
3	3, 4, 5, 6, 7, 9	1, 3, 5, 6, 7, 8, 9, 10, 11, 12, 15	3, 5, 6, 7, 9	
4	*2, 4, 5, 6, 7, 9, 10, 11, 12, 13, 15*	*1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15*	*2, 4, 5, 6, 9, 10, 11, 12, 13, 15*	*I*
5	*2, 3, 4, 5, 6, 7, 9, 10, 11, 15*	*1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15*	*2, 3, 4, 5, 6, 7, 9, 10, 11, 15*	*I*
6	*1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 15*	*1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15*	*1, 2, 3, 4, 5, 6, 9, 10, 11, 12, 13, 15*	*I*
7	2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 15	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15	2, 3, 4, 5, 7, 9, 10, 11, 12, 13, 15	
8	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15	8	8	
9	*3, 4, 5, 6, 7, 9*	*2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15*	*3, 4, 5, 6, 7, 9*	*I*
10	2, 4, 5, 6, 7, 9, 10	2, 4, 5, 6, 7, 8, 10, 12, 13, 15	2, 4, 5, 6, 7, 10	
11	3, 4, 5, 6, 7, 9, 11	2, 4, 5, 6, 7, 8, 11, 12	4, 5, 6, 7, 11	
12	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13	4, 6, 7, 8, 12	4, 6, 7, 12	
13	2, 4, 5, 6, 7, 8, 9, 10, 13	4, 6, 7, 8, 12, 13	4, 6, 7, 8, 13	
14	4, 5, 6, 7, 14	14	14	
15	2, 3, 4, 5, 6, 7, 9, 10, 15	2, 4, 5, 6, 7, 8, 15	2, 4, 5, 6, 7, 15	
Iteration 2				
1	1, 3, 7	1, 8, 12	1	
2	2, 7, 10, 11, 15	2, 7, 8, 10, 12, 13, 15	2, 7, 10, 15	
3	*3, 7*	*1, 3, 7, 8, 10, 11, 12, 15*	*3, 7*	*II*
7	*2, 3, 7, 10, 11, 12, 13, 15*	*1, 2, 3, 7, 8, 10, 11, 12, 13, 14, 15*	*2, 3, 7, 10, 11, 12, 13, 15*	*II*
8	1, 2, 3, 7, 8, 10, 11, 12, 13, 15	8	8	
10	*2, 7, 10*	*2, 7, 8, 10, 12, 13, 15*	*2, 7, 10*	*II*
11	3, 7, 11	2, 7, 8, 11, 12	7, 11	
12	1, 2, 3, 7, 10, 11, 12, 13	7, 8, 12	7, 12	
13	2, 7, 8, 10, 13	7, 8, 12, 13	7, 8, 13	
14	7, 14	14	14	
15	2, 3, 7, 10, 15	2, 7, 8, 15	2, 7, 15	

(*continued*)

Table III.

Variables	Reachability set	Antecedent set	Intersection set	Level
Iteration 3				
1	*1*	*1, 8, 12*	*1*	*III*
2	2, 11, 15	2, 8, 12, 13, 15	2, 15	
8	1, 2, 8, 11, 12, 13, 15	8	8	
11	*11*	*2, 8, 11, 12*	*11*	*III*
12	1, 2, 11, 12, 13	8, 12	12	
13	2, 8, 13	8, 12, 13	8, 13	
14	*14*	*14*	*14*	*III*
15	*2, 15*	*2, 8, 15*	*2, 15*	*III*
Iteration 4				
2	*2*	*2, 8, 12, 13*	*2*	*IV*
8	2, 8, 12, 13	8	8	
12	2, 12, 13	8, 12	12	
13	2, 8, 13	8, 12, 13	8, 13	
Iteration 5				
8	8, 12, 13	8	8	
12	12, 13	8, 12	12	
13	*8, 13*	*8, 12, 13*	*8, 13*	*V*
Iteration 6				
8	8, 12	8	8	
12	*12*	*8, 12*	*12*	*VI*

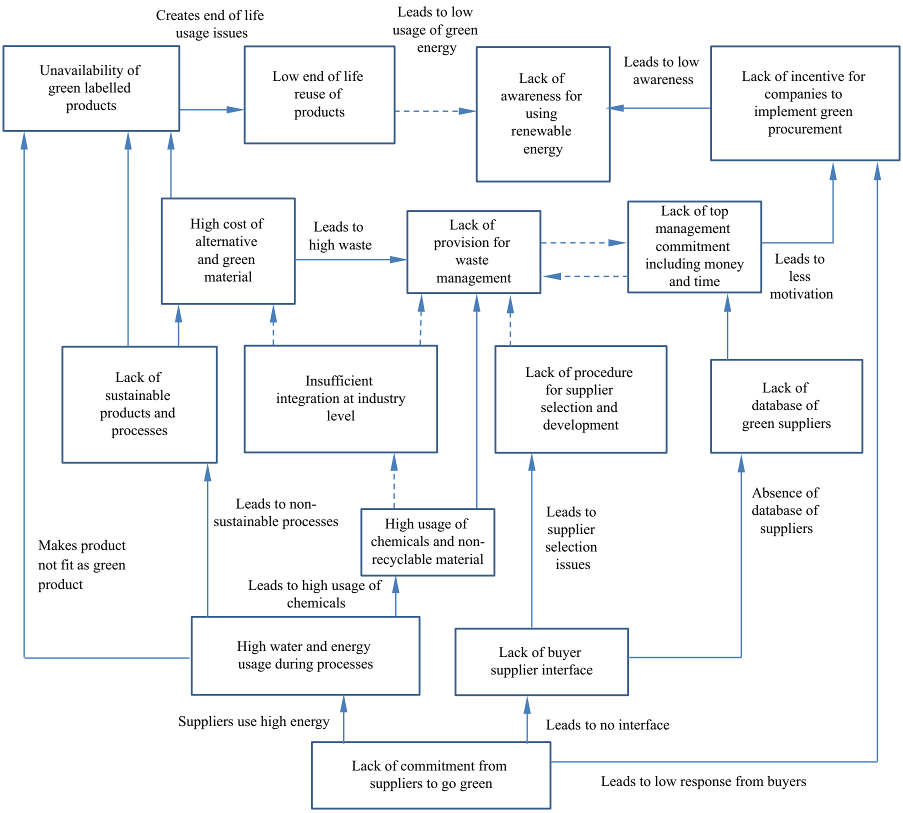

Figure 2.
TISM model for barriers

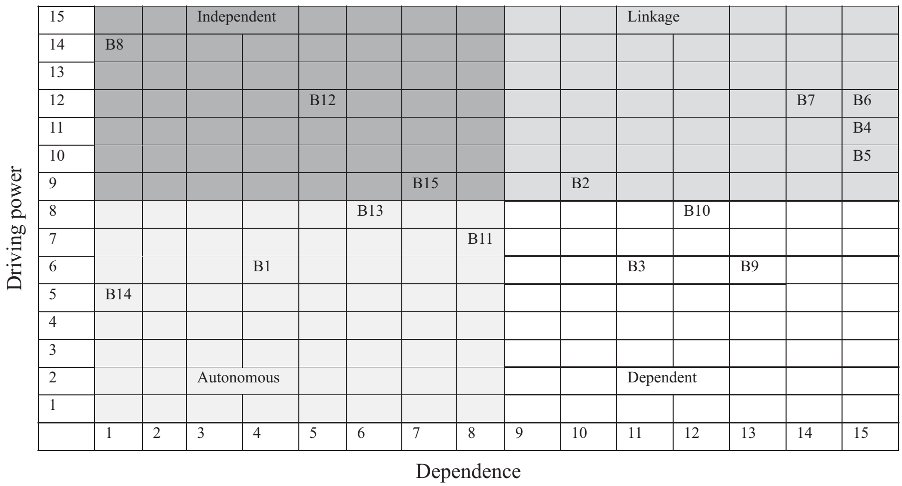

Figure 3.
MICMAC analysis of barriers

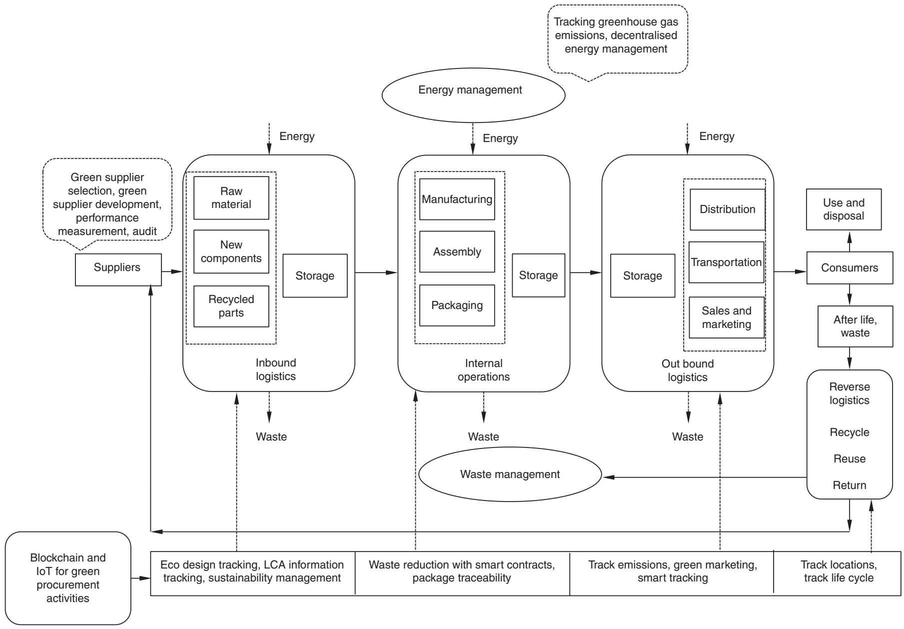

Figure 4. Blockchain–IoT-integrated architecture for green procurement activities

Sustainability in logistics network is difficult to gain as in most of the businesses, logistics is handled by the third party. Scheduling and planning of transport facilities is tedious task if done manually. The use of blockchain and IoT eases vehicle tracking, emissions and compliance monitoring, and allows firm to develop policies for logistics. Choice of warehouse and transport medium are major factors for reducing pollution. Rewarding drivers and logistics companies for safer and green practices can be done using cryptocurrencies.

Blockchain enables eco-design by enabling information and design sharing with multiple parties involved. Data can be managed in a controlled environment for all to develop the innovative products considering environment criteria. Recycling of packaging material may be monitored by the use of RFID tags and blockchain.

Waste management is critical process in green procurement. The reduction of waste by suppliers and reuse of material after end of life may be considered while selecting suppliers. Including waste reduction metrics in performance measurement ensures that suppliers do not over utilise the material. Tracking the amount of energy usage by firm can also be done with blockchains. For all processes, the usage of electricity, water and other resources can be monitored. Emission trading mechanism for internal operations can be managed by transparency and information sharing offered by blockchain and IoT.

8.2 Strategies for managers and practitioners

The emergent disruptive technologies such as blockchain and IoT can increase collective responsibility of the employees and organisation. The guidelines are developed for the practitioners and managers who will be having key roles in the implementation of blockchain–IoT-integrated architecture in the organisations to address green procurement challenges for green and sustainable business:

(1) Every industry/organisation will have different requirement in terms of tracking of transactions and supply chain analysis. It is advisable to first understand

the blockchain–IoT application in the industry and make an implementation plan for the same.

(2) Blockchain–IoT-integrated architecture is complex in nature with the involvement of many participants within and outside the organisation. It is essential for practitioners to make a detailed layout of implementation to know about information and material flow in the system.

(3) Finance plays major role while implementing a new technology. A complete transition into blockchain–IoT will require to be planned in terms of investment and return on investment. Case studies of successful implementation and the challenges faced by the companies are helpful to managers for detailed planning.

(4) Blockchain and IoT require vigour training for employees for the successful and smooth functioning of organisations. Practitioners can conduct training sessions and workshops for the employees so as to make them conversant with the technology before implementation.

(5) There could be some legal- and government-related issues as it requires smart contracts and other legal documents from all the parties of the supply chain. The practitioners are required to evaluate the legal documents and verify the government norms.

9. Conclusion

This paper presents the research in the domain of green procurement. The challenges faced by industries while opting for sustainable and green procurement are discussed, and to overcome the challenges, the blockchain and IoT-integrated architecture is suggested for implementation. Based on Delphi score received by the expert survey, 15 challenges are selected out of 31 identified and are categorised in four categories as: material and products, energy and waste management, organisational and supplier related. Total interpretive structural method is used to find the contextual relation between the challenges related to green procurement. MICMAC analysis is done to identify the dependence of barriers on each other. The architecture developed for green procurement based on recent technologies such as blockchain and IoT is helpful in overcoming some of the challenges analysed in this research. The architecture includes energy and waste management in green procurement activities. The green procurement process when combined with blockchain and IoT architecture helps not only in energy and waste minimisation but also ensures that the suppliers and consumers are well connected in the supply chain. This architecture is a roadmap for industries planning to initiate green procurement activities in their organisation. The architecture demonstrates the application of blockchain and IoT in inbound, outbound logistics and internal operations of the supply chain.

10. Limitation and future scope

Green procurement process faces many challenges despite the availability of advanced technologies. Trust, time, transparency and consistency are prime challenges for the supply chain activities. Although blockchain and IoT are potential technologies to overcome many hurdles, the organisations may not be ready to share information on a platform for all parties to view and access. The government norms and regulations are different across the globe and hence international procurement standards and best practices vary across the supply chain partners.

For the technologies and the process to succeed, there is a requirement to develop the standard and practices for the green procurement activities. The research can be done to address the issues such as energy management, waste recycling and minimising carbon footprints. Green procurement challenges needs to be solved for aligning the activities with the green supply chain.

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Appendix 1. ISO Certifications – Worldwide, Central and South Asia

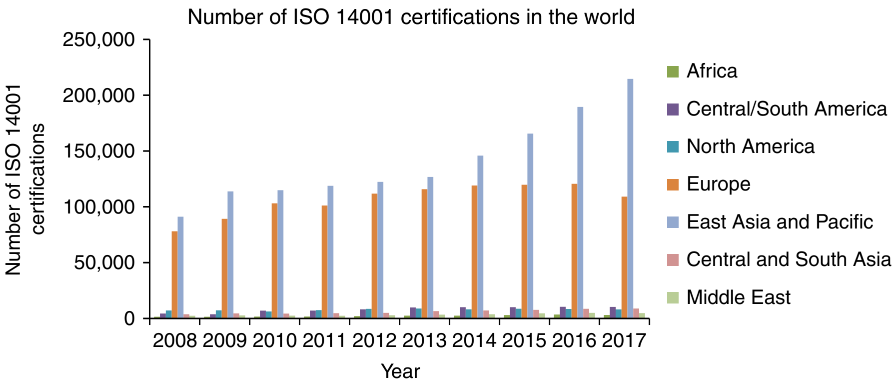

Figure A1.
ISO 14001 certifications worldwide in last 10 years

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Country	*3,770*	*4,517*	*4,380*	*4,725*	*4,969*	*6,577*	*7,187*	*7,708*	*8,612*	*8,896*
Afghanistan	4	9	1		80	0	1	1	1	83
Bangladesh	29	42	4	21	39	57	59	101	119	137
Bhutan	3	3	4	5	4	5	5	6	6	8
India	*3,281*	*3,799*	*3,878*	*4,147*	*4,286*	*5,872*	*6,443*	*6,782*	*7,725*	*7,887*
Kazakhstan	143	294	126	132	122	151	152	136	148	140
Kyrgyzstan	1	4	2	1	1	1	1	0	0	2
Maldives	4	6	5	5	4	4	4	6	7	6
Nepal	8	7	9	10	7	8	15	21	19	21
Pakistan	200	218	258	299	272	275	314	445	343	350
Seychelles	2	5	1	4	3	3	3	4	7	6
Sri Lanka	87	116	83	90	135	185	176	193	215	212
Tajikistan						1	1	2	2	14
Turkmenistan	1	1		0		1	2	1	3	5
Uzbekistan	7	13	9	11	16	14	11	10	17	25

Table AI.
ISO 14001 certifications in Central and South Asia

Appendix 2. Questionnaire for green procurement

Green procurement considers environmental impact while purchasing products or conducting business (Maignan, 2002; Matopoulos *et al.*, 2016). It ensures reduced pollution by industries and hence improves its Green Score.

Table AII lists few questions that address the green procurement activities. The level of green procurement activities of the organisation is assessed based on the score generated using this questionnaire. The experts were asked to mark Yes/No for each question based on six categories. The remarks column explains the categories and assessment basis.

S. No.	Area for green procurement	Questions	Yes/No	Remarks
1	Manufacturing process	The raw material used is eco-friendly? Is the process sustainable? Does the industry comply with legal norms? Does the company use high amount of water and energy? Does the life span of product is high? What are the requirements of process?		This section gives rating for manufacturing processes used for making product. Green procurement practices like water and energy usage are considered
2	Materials	The material is procured in a sustainable way? The material can be reused or recycled? Does the product require harsh chemicals? Any alternative is found for materials? Does it require packaging? Can the packaging be green and sustainable?		The questions are framed for finding the status of green procurement practices with respect to procurement of material from suppliers
3	Transportation	Does the product travels more than 100 miles to reach the firm? Does the truck used confirm with emission standards? Carbon footprints of truck are calculated? Does the firm have logistics strategy?		Logistics-related activities are considered for measuring performance of green procurement
4	Waste management	Does the material or product require additional storage? Does the product comply with recycle and reuse norms? Is there any legal process for waste disposal after use? Is the product hazardous after end of life?		Waste management is integral part of green supply chain. Procurement of waste and reuse of the same are determined here
5	Energy management	Is the greenhouse emissions tracked? Is renewable energy used for power generation? Carbon foot prints are tracked? Efforts for minimising energy consumptions taken?		Assessment of Use of alternative energy sources and minimising consumption of energy by tracking carbon prints is done in this stage
6	Supplier management	Are the suppliers committed to go green? Is there any buyer supplier interface? Is there any procedure for supplier selection and development? Does there exist a database of green suppliers?		The efforts taken by buyer and suppliers for green procurement activities are assessed in this section

Table AII.
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About the authors

Dr Santosh B. Rane, PhD and ME, is Lean Six Sigma Master Black Belt, Reliability Expert and CII Certified Supply Chain Executive. Dr Santosh Rane is working as Dean Academics in Sardar Patel College of Engineering, Mumbai. Dr Rane has over 25 years of quality improvement and problem-solving experience in various industries. He is also Corporate Trainer and Consultant. He has conducted workshops on Lean Six Sigma, JIT, reliability engineering, project management, Kaizen-led innovation, TPM, SMED and other relevant domain. He has driven improvement in the areas of HR, sales and marketing, supply chain, production, reliability, operations, back office, quality and project management, among others. He is Editorial Board Member for *International Journal of Supply Chain and Inventory Management* (Inderscience Publishers). He is Reviewer for *Journal of Production & Manufacturing Research* (Taylor Francis), *International Journal of Supply Chain and Inventory Management* (IJSCIM, Inderscience Publications), *International Journal of Six Sigma & Competitive Advantage* (Inderscience Publications), *Benchmarking: International Journal* (Emerald publication). He has also worked as Advisory Committee Member for many international conferences.

Shivangi Viral Thakker is working as Assistant Professor in KJSCE and is Doctoral Student in the Department of Mechanical Engineering, SPCE, Mumbai, India. Her current areas of research are green procurement, green supply chain management and artificial intelligence. She is CII Certified Supply Chain Executive. She has publications in international journals and conferences and has received research grant from the Mumbai University for her research work. She has completed Master's Degree in Mechanical Engineering. Shivangi Viral Thakker is the corresponding author and can be contacted at: shivangiruparel@somaiya.edu