An MCDM Approach to Smart Contract Adoption in Indian Electronic Industry

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Abstract

Remember internet boom of 1990s and how its usage changed the way we look at world? Blockchain technology (BT) is the Internet of present time. Studies highlighting ways to leverage the benefits of BT are being carried out aggressively and it's of keen interest for major industries and industrialists. Every new research in the area indicate various benefits of BT related to performance improvements. Therefore, to evaluate the enablers of blockchain adoption in smart contracts becomes essential and of great importance. For consumer driven economy like India, where implementation and adoption of BT has been sluggish, BT implementation can give strategic advantage to any industry, making it relevant to evaluate the feasibility and the importance of blockchain smart contracts in the electronic industry, which occupy a large share of the market. There are different enablers for BT adoption in different industries, and this study focuses on identifying and establishing the relationships between the enabler in the electronic supply chain. Eight enablers were considered after conducting a survey of the literature before applying the Interpretive Structural Modelling (ISM) technique to understand the complex relationships between the identified enablers. The result of the detailed analysis, highlighted traceability as the most significant enabler among others for BT-related smart contract adoption for the electronic industry. This result is of immense importance for managers in identifying and developing policies and strategies related to BT implementation for the firm.

Keywords
Interpretive Structural Modelling, MCDM, Smart Contract, and Blockchain Implementation.

1. Introduction
With the ever-increasing pace of development in technology and trends, the product life cycle is getting shorter every passing day. Products facing short-life cycle (SLC), like consumer electronics, fashion goods, seasonal products, etc., contribute significantly to trade transactions. To bridge the difference in the demand and supply of short life cycle products, flexible policies regarding inventory and order management need to be placed. Under order management method, supply chain contract is widely used to balance demand-supply and many studies have highlighted the use of various forms of supply chain contract in the literature, some of which include wholesale prices contract, two-part tariff contract, revenue sharing contract, buy-back contact, quantity discount contract, quantity flexibility contract, and option contracts.

Recently, blockchain technology (BT) has been creating a buzz (Gupta, 2017) similar to the time when the usage of the Internet was popularized. It has been gaining interest from many industry sectors including but not limited to financial, food processing, and power and energy markets. Researchers have been studying the use of BT for various applications such as supply chain management, transactive industry (both financial and energy), device cybersecurity, identity management, etc. (Gourisetti et al., 2020). One of the unique elements of blockchain technology that made it such a captivating technology to researchers is its features. Blockchain has a plethora of features, and some of the features that have been gaining importance include smart contracts, cryptocurrency, immutable distributed ledger, cryptographic hashing, and digital signature. Among the features, one important feature of blockchain technology that is of interest is smart contracts. Smart contracts are executable codes that run on top of the blockchain to facilitate an agreement between untrusted parties (Nelaturu et al., 2020) Blockchain databases are continuously designed to support the development of decentralized applications for application in the development of smart contracts (Adkins et al., 2020)

Blockchain technology (BT) is expected to bring substantial improvements in the level of accountability, transparency, and traceability by maintaining information symmetry among the supply chain partners of short life products (Bronson & Knezevic, 2016; Carbonell, 2016). BT database management systems can act as a significant boost to manage records, purchase details & use of inventory, traceability, and financial transactions across the entire supply chain (Maru et al., 2018). Few studies have focused on the behavioural dimensions affecting blockchain adoption in supply chain (Francisco & Swanson, 2018; Kamble et al., 2019). As is the case, supply chain managers are usually not provided with the decision-making framework on blockchain adoption the enablers of BT. BT is an emerging technology in the Indian context, and relatively new, and the supply chain managers need to identify the enablers of BT, their relationship with each other, and the above-stated problems they can address. In this study, we identified some factors that enable BT adoption in supply chain based on literature review and bibliometric analysis. Followed by and Interpretive Structural Modelling (ISM) for establishing hierarchical levels of the selected enablers. The remainder of the paper is organized as follows. Section 2 provides a review of relevant literature. Section 3 describes the methodology used in the study. Section 4 presents the results and discussion. The fifth section concludes this paper with future research directions.

2. Literature review

Blockchain has been gaining interest from industry sectors such as financial, food processing, and power and energy markets (Gourisetti et al, 2020). Wang et al. (2019) asserts that blockchain technology not only is useful in financial applications but also has the potential to streamline the supply chain systems. Recently, supply chain literature aims at new approaches for improving the real-time capabilities of supply chain (Oliveira and Handfield, 2019). In this regard, smart contracts and Blockchain applications in supply chain is in the early phase of development and has been mainly studied in the areas of engineering and information technology (Dolgui et al, 2019). Smart contracts using blockchain (Yue et al., 2016; Ouaddah et al., 2017), implemented between different parties on a decentralized network, are self-enforceable and self-executable contracts (Drummer D. and Neumann D., 2020), and blockchain technology promotes traceable execution of business processes using smart contracts in business process management (Ladleif, J. and Weske, M., 2020). Business processes can be redesigned for adopting blockchain technology to bring about benefits in organizations. Some redesign aspects include changing from intra-to inter-organizational process views using shared data ledgers, using it as means for data communication, and using tokens to manage digital transactions (Tosh et al., 2017; Milani et al., 2020). Business processes also envelopes multiple organizations that require extensive information sharing between them. Insights in both its control flow and data model can achieve a holistic overview through a single source blockchain-based smart contracts (van Wingerde, M. E. M. and Weigand, H., 2020). Thus various aspects of blockchain need to be analyzed for adoption of smart contract in the short life product industry.

Blockchain databases combines properties of blockchain and databases and is a critical emerging technology for developing non-trivial smart contracts, distributed applications and decentralized marketplaces (Adkins et al., 2020). Blockchain enables information to be stored in shared databases using a distributed ledger technology also protects information from removal, corruption or alteration through cryptography and a consensus mechanism (Zheng et al., 2017; Morabito, 2017; Van Rijmenam & Ryan, 2018). Blockchain is used with the same level of certainty in a decentralized system with fully shared and unchangeable information (Casion et al., 2019, Yu et al., 2019). In other words, blockchain consists of a list of systematic blocks that are structured and immutable making it a distributed database (Casion et al., 2019). Some industry experts like Goldman Sachs (2016), stated that transaction costs in insurance could reduce by $2–4 billion (USA), Banco Santander, Oliver Wyman, and Anthemis Group (2015) suggested that banks' infrastructure costs related to cross-border payments and trading of securities could reduce by $15–$20 billion, and World Economic Forum (2015) estimated that up to 10% of the value of the global GDP will be stored on blockchains by 2027. Yu et al. (2019) argues that by distributing the transactions and information to a peer-to-peer network, distributed ledger technology has introduced various disruption to conventional business processes. Such disruptions are argued to have direct or indirect economic, social and political consequences (Kshetri, 2017). It is also argued that with the availability of distributed database, settlements of trade is possible instantaneously without having to worry about failure of payments or delays (Gokhale 2016; Wang et al., 2019). Therefore, with adoption of blockchain technology, decisions on investments also can be taken quickly unlike traditional long-term processes (Morini, 2016).

One of the most important issues the traditional centralized data storage and processing solutions have is regard to tracking the access of data by different people along the supply chain, and how the data has been manipulated over time. Cydon, an example of blockchain platform, employs a smart distributed ledger that provides immutable audit trail and transaction history of data access and modification through the SC. It was observed that Cydon provides authorized and fast access to secure distributed data, avoids failure by distributing encrypted data across different nodes and maintains a track of who has the access to the data in real time (Epiphaniou et al., 2020). Information flow to each block of the blockchain is traceable in real-time through the timestamp of information addition and transmission (Sharples & Domingue, 2016).

Blockchain aspect like transparency makes collaboration possible among different stakeholders like governments, businesses and citizens (Abeyratne & Monfared, 2016). The consensus among the channel members while adopting blockchain leads to high level of authenticity which increases the transparency and efficiency (Kamble et al., 2019). The transparency of transactions on the Blockchain among all the members also increases auditability and trust (Fanning & Centers, 2016).It also leads to positive impact on asset turnover rate and reduces sales expense (Pan et al., 2020). Initial investments are required for initial implementation of blockchains, in time, working on a blockchain platform can remove all risks over the supply chain which in turn will lead to savings in transaction costs and increases visibility, transparency, and security (Giovanni, 2020). Authentication and access control for system security is managed through greater data and rule confidentiality and integrity of blockchain (Ghaffari et al., 2020). Blockchain also prevents data deletion once the transaction occurs (Adkins et al., 2020).

Blockchain is used for coordinating firms' relationships and negotiations through various contracts like smart wholesale price contract and a smart revenue sharing contract (Giovanni, 2020). Digital technology is widely adopted to strengthen supply chain resilience. In this regard, adoption of smart contract through blockchain technology, a promising innovative technology, enables a transparent, secure, and timely data exchange and automation. Blockchain adoption in the supply chain for risk-management leads to substantial reduction in propagation of disruptions, network recovery time, and total costs (Lohmer et al., 2020). Smart contract transactions also help a multi-supplier base development and leads to reduction in transaction costs (Hofmann et al., 2018).

The blockchain enablers identified from the literature are summarized in Table 1 below. The identified key enablers will drive the implementation of blockchain in the supply chain.

Table 1. Key enablers of blockchain technology

Blockchain enablers	**Definition**	**Reference**
Decentralized database (E1)	The data is stored on multiple server across different nodes.	Morabito, 2017; Zheng et al., 2016.
Improved risk management (E2)	Instantaneously trade settlement without worry about failure of payments or delays	Morini, 2016; Wang et al., 2019
Traceability (E3)	Product and transaction traceability is available from the source of origin till final product delivery	Sharples & Domingue, 2016
Transparency (E4)	All the concerned parties have access to in real-time data and carries out consensus base transaction mechanism.	Abeyratne & Monfared, 2016; Kamble et al., 2019
Provenance (E5)	Unique digital token are generated at each transaction point	Tosh et al., 2017; Wang et al. 2019
Reduced transaction cost (E6)	Removal of intermediaries leads to reduced transaction costs of the supply chain	Kshetri, 2017; Hofmann et al., 2018
Auditability (E7)	Data is visible across the supply chain and is error free making it auditable	Fanning & Centers, 2016; Wang et al., 2019
Data privacy and network security (E8)	Cryptographic private key are used in blockchain ensuring data privacy and anonymity.	Ouaddah et al., 2017; Yue et al., 2016

3. Application methodology

Feasibility evaluation of blockchain should include both quantitative and qualitative analysis. In this aspect, Multi Criteria Decision Making (MCDM) techniques are widely used. MCDM techniques helps in identifying the most suitable criteria or alternatives when many different decision criteria need to be considered simultaneously (Cifci & Buyukozkan, 2011). The evaluation procedures of the MCMD techniques are different from one another, and therefore, appropriate techniques need to be chosen depending on the study. This study proposes an integrated MCDM framework for evaluating the enablers of blockchain technology. Thus, this study provides a useful evaluation model to help decision makers in the adoption and implementation process of the blockchain technology in short life cycle industry. The enablers or factors that influence the adoption of blockchain technologies in smart contract adoption have been collated from the available literature and a co-occurrence analysis of keywords from 369 documents extracted from Scopus database.

The aim of this study is to establish interrelationships between the identified enablers and categorize them based on driving and dependence powers using the Interpretive Structural Modelling (ISM) technique (Lim et al. 2017). The steps followed in this study is graphically represented in Figure 1.

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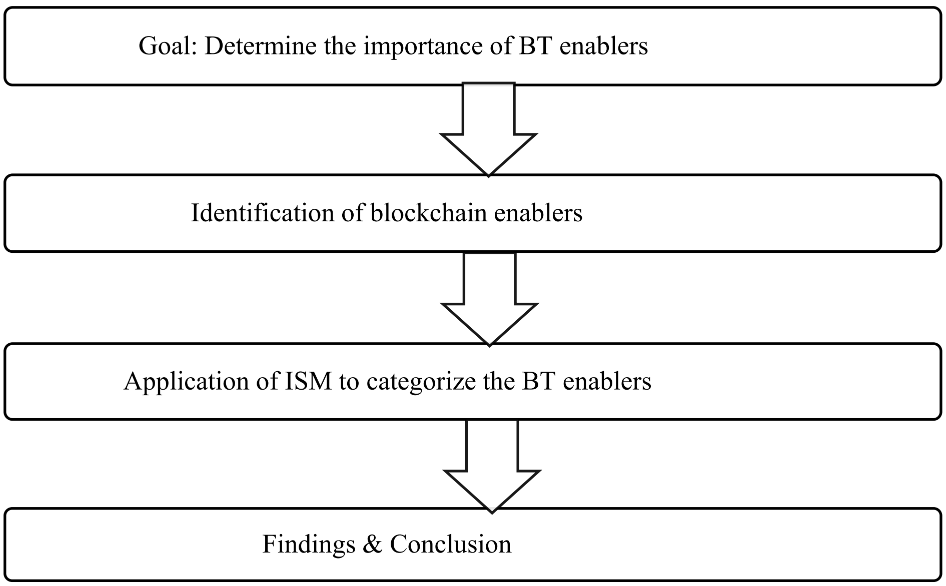


Figure 1. Steps followed in this study

Application of ISM methodology

ISM methodology (Warfield, 1974) is an interactive technique used for assessing complex problems by analysing the inter-relationships among the different elements of a problem. It is a method used to transform mental models into well-defined hierarchical models which makes resolving real life situations easier (Alawamleh and Popplewell, 2011). It provides better insights into both the direct and indirect relationships among the criteria evaluated (Thirupathi and Vinodh, 2016). ISM requires experts with practical experience and knowledge in the field for building multi-level hierarchical model and classifying the elements.

Following are the steps used in ISM methodology:

Step 1: Identification of the enablers that influence the adoption of blockchain in smart contracts for short life products. The enablers are identified from the existing literature

Step 2: Establish contextual relationships between the enablers identified in the previous step.

Step 3: Develop a structural self-interaction matrix (SSIM) based on the relationships observed between the pair of enablers in the previous step. The relationships between pairs of enablers are denoted by using the alphabets V, A, O, and X.

Step 4: An initial reachability matrix (IRM) is derived from the SSIM. The alphabets V, A, O, and X are written in binary elements 0 and 1.

Step 5: The IRM is then checked for the presence of transitivity. In this step, if an enabler X affects another enabler Y and the enabler Y affects an enabler Z; then enabler X necessarily affects enabler Z. This leads to the development of the final reachability matrix (FRM).

Step 6: The partitioned levels are obtained through iteration of the FRM and is used to draw a directed graph (DG).
Step 7: The enabler nodes are then replaced with the statements to obtain an ISM model.

The symbols used to represent the contextual relationship between the pair of enablers (k and l), are explained as follows:
V: Enabler k will help achieve enabler l, but not vice versa
A: Enabler l will help achieve enabler k, but not vice versa
X: Enablers (k and l) will help each other to achieve
O: Enablers (k and l) have no relationship with each other

The SSIM is given in Table 2.

Initial reachability matrix (IRM)
The IRM (Table 3) is obtained by binary coding the symbols (V, A, X and O) in SSIM. The rules for substitution (Vasanthakumar, Vinodh, and Ramesh 2016) are as follows:

- If in SSIM the (k, l) entry is V, then (k, l) entry in IRM becomes 1 and (l, k) entry becomes 0.
- If in SSIM the (k, l) entry is A, then (k, l) entry in IRM becomes 0 and (l, k) entry becomes 1.
- If in SSIM the (k, l) entry is X, then both (k, l) and (l, k) entries in IRM becomes 1
- If in SSIM the (k, l) entry is O, then both (k, l) and (l, k) entries in IRM becomes 0

The transitivity rule is applied to obtain the final reachability matrix. It is observed that there is no transitivity links between (k, l). The driving power and the dependence power of the enablers are calculated (Table 4) and the level partition is obtained (Table 5). Here, driving power means the total number of enablers one enabler is able to achieve while dependence power means the total number of all enablers that help to achieve this particular enabler.

Table 2. SSIM matrix

Enablers	**E8**	**E7**	**E6**	**E5**	**E4**	**E3**	**E2**	**E1**
E1	V	V	V	V	V	V	V	
E2	A	V	A	V	A	V		
E3	A	A	A	A	A			
E4	A	V	A	V				
E5	A	X	A					
E6	X	V						
E7	A							
E8								

Table 3. IRM matrix

Enablers	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**
E1	1	1	1	1	1	1	1	1
E2	0	1	1	0	1	0	1	0
E3	0	0	1	0	0	0	0	0
E4	0	1	1	1	1	0	1	0
E5	0	0	1	0	1	0	1	0
E6	0	1	1	1	1	1	1	1
E7	0	0	1	0	1	0	1	0
E8	0	1	1	1	1	1	1	1

Table 4. FRM matrix

Enablers	E1	E2	E3	E4	E5	E6	E7	E8	Driving power
E1	1	1	1	1	1	1	1	1	8
E2	0	1	1	0	1	0	1	0	4
E3	0	0	1	0	0	0	0	0	1
E4	0	1	1	1	1	0	1	0	5
E5	0	0	1	0	1	0	1	0	3
E6	0	1	1	1	1	1	1	1	7
E7	0	0	1	0	1	0	1	0	3
E8	0	1	1	1	1	1	1	1	7
Dependence power	1	5	8	4	7	3	7	3	76

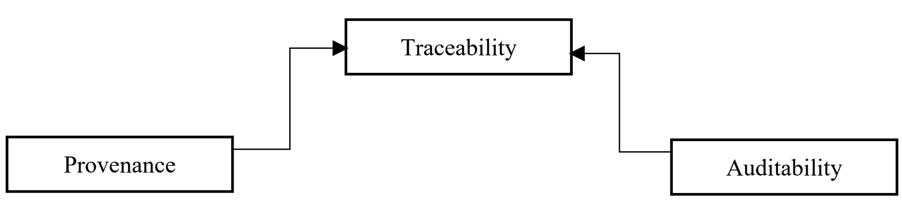
Table 5. Level partition

Enablers	Reachability set	Antecedent set	Intersection set	Level
Decentralized database	E1,E2,E3,E4,E5,E6,E7,E8	E1	E1	6
Improved risk management	E2,E3,E5,E7	E1,E2,E4,E6,E8	E2	3
Traceability	E3	E1,E2,E3,E4,E5,E6,E7,E8	E3	1
Transparency	E2,E3,E4,E5,E7	E1,E4,E6,E8	E4	4
Provenance	E3,E5,E7	E1,E2,E4,E5,E6,E7,E8	E5,E7	2
Reduced transaction cost	E2,E3,E4,E5,E6,E7,E8	E1,E6,E8	E6,E8	5
Auditability	E3,E5,E7	E1,E2,E4,E5,E6,E7,E8	E5,E7	2
Data privacy and network security	E2,E3,E4,E5,E6,E7,E8	E1,E6,E8	E6,E8	5

The digraph is developed based on the level partition obtained through FRM. The nodes are replaced with the blockchain enablers and is converted to ISM hierarchy model (Figure 2). The directional relationships between enablers are marked with directed arrows and enablers with strong driving powers are placed at the bottom of the hierarch while the ones with strong dependence power are located at the top of the hierarchy model.

MICMAC analysis
MICMAC analysis classifies the criteria (enablers) into four categories namely autonomous, dependent, linkage, and independent, based on the driving and dependent powers calculated in the FRM matrix (Ravi and Shankar, 2005). The classification of enablers are as follows based on MICMAC analysis.

1) Autonomous enablers: The enablers with weak driving power and weak dependency falls under this category.
2) Dependent enablers: The enablers with weak driving power but strong dependency falls under this category.
3) Linkage enablers: The enablers with strong driving power and strong dependency falls under this category. They are strongly linked with other enablers
4) Independent enablers: The enablers with strong driving power but weak dependency falls under this category.



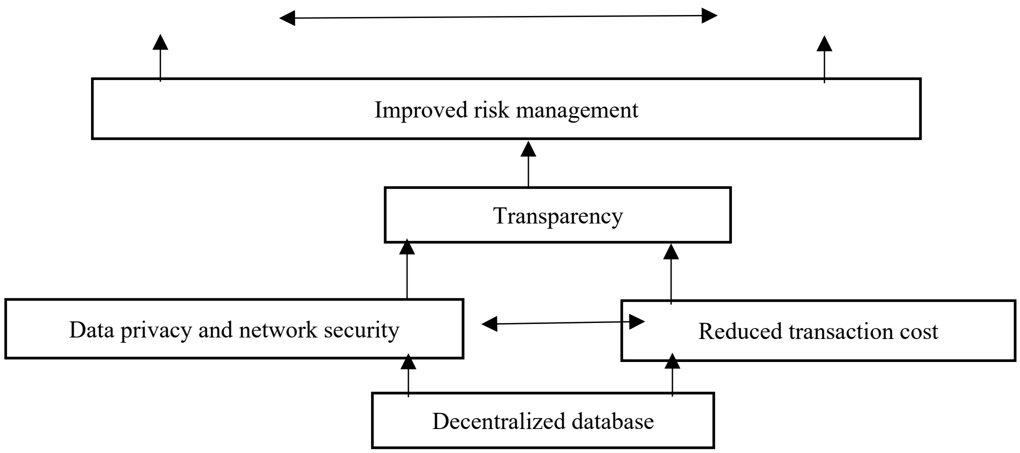


Figure 2. ISM hierarchy model

The driving power – dependency diagram obtained using the MICMAC analysis is shown in Figure 3.

4. Results and discussion

The results from 10 experts, both from the academia and industry, are summarized here. The present study uses ISM for establishing hierarchical interrelationships between the identified enablers and classify them based on their driving and dependence powers into four categories using MICMAC analysis. The graphical display of MICMAC analysis helps in communicating the interrelationships effectively and helps in decision-making processes. The ISM hierarchical model (Fig. 3) and the driving power- dependency diagram (Fig. 4) describes the role of various blockchain enablers and their effect on adoption of smart contract in supply chain. The enablers E1, E6 and E8 have very strong driving power with weak dependency and are therefore positioned at the bottom of the ISM hierarchy and within the independent enabler category in driving power – dependency diagram. The enablers E2 and E4 help achieve other strategies and have strong driving power and dependency and are therefore positioned at the intermediary levels of ISM hierarchy. These enablers are located in the linkage category quadrant and have links with enablers that are above or below them. The enablers E3, E5 and E7 have weak driving power, but have strong dependency. The enablers in this category are classified under dependent category. They are placed at the top in the ISM hierarchy as they are influenced largely by other strategies. There are no enablers in the autonomous category. This indicates that all the enablers are interrelated with each other. The results of MICMAC analysis shows that careful measures should be taken while taking decisions on improving or focusing on various enablers (Figure 3).

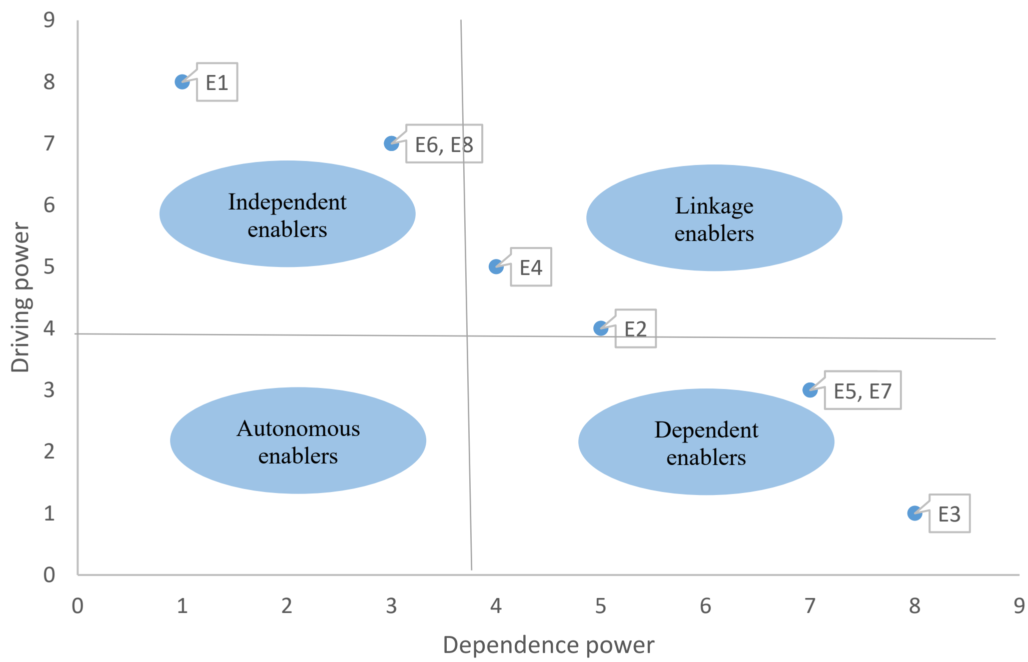


Figure 3. Driving power – dependency diagram

5. Conclusion

Supply chain contracts have been widely adopted by a large number of organisations and industry practitioners to deal with the complexities and uncertainties in the supply chain. The degree of flexibility and the required technologies to be adopted depends on a number of situations. This paper studies the enablers of blockchain to adopt smart contract for the short life cycle products. Eight enablers of blockchain that impacts smart contract adoption in the supply have been identified based on literature review and co-occurrence analysis of the corpus extracted from Scopus database. Various direct and indirect interrelationships between the enablers are identified using ISM and a hierarchical model is developed based on their driving and dependence powers. The MICMAC analysis is used along with ISM for classifying the enablers into four categories viz. autonomous, dependent, linkage and independent. A large number of enablers are positioned in the independent category as well as dependent category indicating that most of the enablers are not highly interlinked with each other.

The results from the ISM can be used to identify which enablers to focus on to help in faster and smoother adoption of smart contract for the short life products. The research framework adopted in this study can be extended to other industries for future research. Different enablers can also be identified for analysing the feasibility and importance of smart contracts in the supply chains. Similar research can also be done using a combination of other MCDM techniques to support the findings of this study.

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