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ORIGINAL RESEARCH

Analyzing the Determinants Affecting the Industrial Competitiveness of Electronics Manufacturing in India by Using TISM and AHP

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Abstract *In today's world, the manufacturing organizations have to plan their strategies differently in order to attain competitiveness. The changing consumer demand, demographic priorities, new technologies, and changing attitudes pose threats to existing business strategies and curtails life cycle of electronics goods. With the emergence of new technologies, most of the organizations are feeling the pressure to deliver the latest technology goods and services in short span of time. This study focuses on the determinants which form the basis for the competitiveness of electronics-manufacturing industries (EMI) in India. Extensive literature studies have been performed to identify such determinants. These determinants are discussed with a group of experts to make the finalized set. The total interpretive structural modeling (TISM) is applied to interpret the complexity of inter-relationships among the determinants. Along with this, the weight of each determinant has been calculated using analytic hierarchy process (AHP). The paper will serve the dual value; first, it explores the EMI competitiveness and second, it prescribes usage of ranking of determinants by TISM–AHP method, a unified approach that can be used in ranking for multi-criteria problems in an interpretive manner. The findings suggest that the determinants such as market demand, government support policies, capital investments with higher driving power have higher weights in AHP model, which are further validated by the findings of TISM. Determinants with high driving power obtained from TISM and AHP draw almost same conclusions in terms of importance and rankings. The study will benefit policy makers, stakeholders, and manufacturing industries to gain competitive advantage by learning and implementing the suggested findings.*

Keywords AHP · Competitiveness · Electronics-manufacturing industries · TISM

Introduction

The electronics-manufacturing industries (EMI) are growing at high pace worldwide over the last two decades. Global production has reached to 2 trillion USD in 2014, and it has been projected that it would be 2.4 trillion USD by 2020 (NPE 2012). In India, the fast growth rate of the electronics industry is because of high consumption, production, and trade. Globally, the electronics industry is facing high competition with fast changing new technologies and consumer choices (Prakash and Barua 2016). Over the years, the demand for the electronics goods in the country has significantly increased due to rise in per capita income and growth in information communication technology (ICT)-related industries and usage. In India, the demand for electronics goods is expected to be around 400 Billion USD by 2020 (Meity 2017). The domestic manufacturing of electronics goods is expected to reach 104

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billion USD which would create a gap of 296 billion USD by 2020 (Meity 2017). Hence, big opportunities are available for electronics-manufacturing industries in the country to grow and compete (Singh et al. 2016).

In order to make EMI more competitive, the government must be smart (Kumar et al. 2016) to accomplish smart manufacturing and should take various initiatives. In order to achieve this, the government has worked on various frontiers of EMI like designing national policy for electronics industry in 2012, 100% FDI through automatic route, priority to domestic manufacturing, land availability, attractive financial investment, building high-end human resources, etc. Apart from this, electronics manufacturing cluster scheme has been implemented to develop and improve the infrastructure. Recently, Make-in-India, Skill India, and Digital India campaigns are started by Indian government to improve the performance of the manufacturing sector which will positively impact competitiveness of the electronics industry (Meity 2017). The competitiveness could be considered as a multidimensional construct, and different weights could be assigned to factors which affect these construct, depending upon the firms or industries. The competitiveness of EMI could be measured by using both tangible and intangible indicators. For the EMI both in 'ex ante' and 'ex post' analyses can be applied, depending on the 'process assessment' or 'outcome assessment.' Lall (2001) has measured observable realities of EMI via process (structural drivers) and outcome (competitive industrial performance). Earlier, the performance of the industries mainly depended on the financial parameters, but due to the advent of monopolistic competition, some other influencers also have important role to play like: research and development, innovation, quality, productivity, raw material along with management skills. 'The capabilities are often conceptualized as a business unit's intended or realized competitive performance or operational strengths' (Ferdows and De Meyer 1990; Noble 1995; Koufteros et al. 2002; Größler and Grübner 2006). The competitiveness is a time-based evolutionary construct for which the measurement indicators may have different weights and relevance to the competitiveness. The present research attempts to fill this void and takes the macroview of the electronics industry to identify the determinants of industrial competitiveness. The industrial competitiveness is multi-faceted notion and depends on various factors, which can be viewed as industrial ability to produce its goods and export the same at competitive prices considering the firms collective performance (Reinaud 2005; Sirikrai and Tang 2006).

The article utilizes the multifactor comprehensive evaluation approach to identify the determinants of industrial competitiveness for the electronics-manufacturing industries based on the existing gaps in the literature. This research tries to contribute to make the better understanding of industrial competitiveness of electronics industry in the country. To identify the determinants of electronics industries is important because rising consumption would further put pressure for more imports and weaken the prospects of in-house production and other long-term perspectives for electronics industry. The research helps in achieving following objectives:

- To identify the determinants of industrial competitiveness of EMI.
- To provide the managerial insights for the industry.
- To compare the driving power and the weights obtained by using the TISM and AHP techniques, respectively, to draw insight from the techniques used.

The MCDM approach, which is used in identifying the weights of the determinants, utilizes the TISM and AHP, a dual approach of ranking of the determinants. On methodological front, the paper compares the driving power and weights obtained from the AHP. It was found that ranks of determinates were comparable. This not only validates the results of the findings but also builds the strong model and therefore proposes that the driving power obtained from TISM and weights obtained from the AHP can be used for ranking purposes. Subsequently, the dual and integrated approach would resolve and mitigate the complexity of the real-life problems and will provide the simple, practical, and effective solution in making the decision. Hence, the research integrates the TISM and the AHP to draw robust solution. The research would help the stakeholders and policy makers of electronics industry to identify the problems and focus on the determinants to draw the conclusions.

The article begins with introduction of EMI which explains the concept overview and need to focus on the competitiveness of manufacturing industries. The literature review section throws light on previously discussed concepts and works done by various authors. The methodology section comprises of selection of indicators, and the methodological approaches. The findings are discussed in results section. Some implications are also put forth before concluding remarks.

Literature Review

The concept of the competitiveness has appealed the policy makers and industrialists in many aspects. The notion of competitiveness is applied to firm, industry, region, economies, nation and international comparisons, and even at product/service level (Moon and Peery 1986). Grant (1991) has thrown a different light on firm's resources and capabilities in order to frame its strategy (Wernerfelt 1984; Amit and Schoemaker 1993) and further emphasized on relationships among the resources, capabilities, competitiveness advantage and profitability.

Porter (1979) highlighted the significance of the five forces: the threat of new entrants, the bargaining power of customers, the bargaining power of suppliers, the threat of substitute products or services, and the jockeying for the position among current contestants for profitability of an industry. To develop competitive strategy according to the prevailing environment depends on the state of maturity, industry concentration, and exposure to international competition (Porter 1980). Porter (1990a, b) in his seminal work has focused on the contribution of industrial organisations on strategic management while formulating the competitive strategy. The countries' huge market can be seen as competitive advantage for high-tech electronics goods manufacturers. These manufacturers due to globalization and open market for ICT goods are competing internationally. The international competition is shaped by various forces like factor cost, foreign market, government role, and management of foreign competitors (Porter 1985). Further, the industries success depends on forward-looking, dynamic, and challenging environmental condition (Porter 1990a, b). The firms need to focus on driving the competitive advantage posed due to stability of market demand, expanding internally, and replication by competitors (Teece et al. 1997).

The main findings of the literature review are presented in two sections. The first part deals with the concept of industrial competitiveness. In the second part, literature on electronics manufacturing is explored in view of pressure due to competition and challenges faced by the electronics industry to improve the competitiveness.

Concept of Industrial Competitiveness

The industrial competitiveness is referred as the ability of sector to sell in foreign market (Meleo 2014). Industrial competitiveness can be analyzed from different perspectives. Industrial competitiveness can be achieved by combination of technological, economic and social factors (Bowonder and Miyake 1990). Haake (2002) has proposed the relation of national business systems to industrial competitiveness. Generally, the competitive environment could be considered by making a comparative analysis of an industry among different countries (Porter 1990a, b; Huggins and Izushi 2015). According to Kudrle (1996), an industry could be considered competitive if it attains a steady or growing market share. Denny et al. (1992) have studied the productivity and growth factors at industry level to measure industrial competitiveness. Rugman (1992) defended to see the industry in an international context rather than local. Hatsopoulos et al. (1988) have considered the trade balance with rising real income as a measure of competitiveness.

Competitiveness of Electronics Manufacturing Sector in India

In long run, the electronics industry requires investment in infrastructure, specialized skills, and capabilities (Ernst 2005, 2014; DIPP 2016). The electronics-manufacturing industry is facing different competitiveness scenarios. These industries are facing the challenges due to imports and giant MNCs existing globally. The challenges are in areas of infrastructure, ease of foreign investment procedures prevailing, tariff structure for domestics and foreign manufactured goods, and ease of doing business. Apart from these, the R&D investment is poor in case of India.

The taxes and domestic tariff paid on input should not be more on domestic goods and must be balanced by levying countervailing duty on imported goods. India should make more free trade agreements or preferential trading agreements with other countries. High level of taxation, uncertainty in tax regime, strict labor laws, high cost of power, infrastructural challenges, and transportation cost are some of the major issues in India restraining growth of EMI. Singh et al. (2017) have performed a competitiveness study between India and China and found that the supply of products from manufacturing unit to market location generally takes more time as compared to countries like China. These factors limit the domestic producers to foreign access, hence confining to domestic market. In addition, the domestic firms are inhibited from forming network at home. The domestic production raises the cost of goods by 8–12% depending on the feature and quality addition. The low-cost manufacturing advantage is only in terms of wages, but overall manufacturing cost increases due to various barriers. Apart from this, the "local needs of the customers" is taken care by the determinants like market demand, user satisfaction, and the product quality and reliability.

The present environment is consumer-focused and market-oriented. The competition is in terms of improved quality, improved performance, wide range, better service quality, and high volume of production. EMI and the government have focused on various initiatives to enhance competitiveness to harness the potential gain of growing market. The competitiveness within an industry could be achieved through an adequate use of management practices, competitive advantage, and organizational modes of a country (Oral 1986).

Measurement is like a barometer that highlights the work done and at the same time motivates to perform better (Najmi and Kehoe 2001). Measurement is required to understand, monitor, control, and manage things properly for the better performance management (Taticchi et al. 2010). The measurement of competitiveness depends on various conditions. The conditions can vary from one country to other or from one case to other. The competitiveness could be influenced by qualitative as well as quantitative factors. The competitiveness can also be evaluated financially based on cost. The cost–benefit analysis is a parametric approach that can be used for evaluation of competitiveness (Oral 1986; Li 2000). Recently, resource-based model incorporating management practices, best practices of manufacturing, marketing approaches, and environmental consideration are used for evaluating the competitiveness.

The implementation of high-end technology (Gupta and Jana 2003) usually makes significant changes in manufacturing industries. According to Porter (1997), industries that compete must have a competitive strategy. Thakkar et al. (2006) focused on management system to relate competitive strategy to its performance indicators. The comparison of business environment such as the world competitiveness index assigns ranks for a country for the business conditions. This ranking can be useful for the investors and policy makers, who can draw better conclusions about the prevailing business environment.

Research Methodology

In order to identify the appropriate determinants of competitiveness, an organized technique was implemented and carried out in a sequential manner. The literature review was based on research articles published in reputed journals. The articles related to electronic manufacturing, industrial competitiveness, manufacturing competitiveness, resources and industrial competitiveness, performance and industrial competitiveness, user perspectives, semiconductor manufacturing government and industrial competitiveness, serendipity and industrial competitiveness, and capabilities and industrial competitiveness were considered while reviewing the literature. The data base of SCOPUS, Emerald, Web of Science, EBSCO, and Science Direct were rigorously searched. Simultaneously, the Google Scholar search engine was also explored for the terms like electronics manufacturing, high-technology manufacturing, research and innovation in electronics manufacturing, electronics manufacturing clusters, electronics-manufacturing industries, competitiveness and global supply networks. Various context research papers were also found which were not considered in the research study. Also, papers from conferences, working papers, and book chapters were excluded in order to sustain the quality.

Overall, the search results gave collection of more than 180 meaningful research papers. After carefully going through the abstracts of the research articles, 78 papers belonging to different journals of the relevant field were selected for the study. Initially, 17 key determinants for evaluating the industrial competitiveness of EMI were chosen. After taking the experts' opinion on these determinants, 12 key determinants were chosen. The expert opinion was taken to group the factors and assign the weightage in pair-wise comparison for AHP technique, used in the study. The experts were chosen based on their experiences in the relevant field. The group of experts was of different background and was not homogenous, but chosen deliberately. Expert's availability for the study too have been a challenging task because of suitable experience and representatives from different backgrounds.

This research introduces the total interpretive structural modeling and AHP technique to systematically and comprehensively analyze the industrial competitiveness of EMI. The competitiveness measurement is complex task aiming at enhancing the performance of EMI. Multi-criteria decision analysis (MCDA) is suitable technique for solving such kind of problems. The approach of choosing the appropriate methodology depends on the objectives and the nature of problem. The mixed approach of research methods are used in the study. The relevant literature review is carried out to identify the determinants of competitiveness for EMIs. Such determinants were discussed and validated by a group of experts. The TISM is used to analyze the relation complexity among the determinants and to get the different levels of the determinants based on the complexity and inter-relationships. Finally, the AHP is employed to find out the weights for each determinant and to rank hierarchically.

Selection of Indicators for EMI Competitiveness

While analyzing the competitiveness of the EMI, the focal point of analysis must be those factors that influence the yield of EMI in a country. The extensive literature study was carried out to identify the multi-facet performance characteristics of EMI which are indicated by the 10 determinants along with the symbols (Table 1) used in analysis in the study. The determinants were discussed and finalized by a group of experts ("Appendix 1" Table 5).

Questionnaire Survey and Construct Validation

To validate the determinants of competitiveness for EMI from the literature, a questionnaire was developed for pilot testing of construct validation. The questionnaire was e-mailed to people ranging from highly experienced senior advisors, managing directors, consultants, academicians, government officials, and policy makers in the field of manufacturing in India to get the opinion on the importance of selected determinants on a five-point Likert scale (1—not important, 5—extremely important). Initially, questionnaire was sent to 167 people. However, 29 responses

Table 1 The selected determinants for EMI competitiveness

Determinants	Authors	Description based on literature and experts' views
Adequate infrastructure (V1)	Khan (1998), Porter (1998, 1999, 2000), Prakash and Barua (2016) and Awasthi and Li (2017)	The infrastructure is backbone for industrial development. It includes basic facilities to run industries, semiconductor wafer fabrication, manufacturing capabilities, and electronics-manufacturing clusters
User satisfaction (V2)	Mashhadi et al. (2016) and Marakanon and Panjakajornsak (2017)	The products must meet the customer demands. The producers must be aware about product quality, variety and effective price
Training and skill development (V3)	Grant (1996), Khan (1998), Porter (2000) and Ernst (2014)	The quality of training and skills programs matters a lot while designing and developing the electronics products. A hands-on experience on high-end technology would make employee and workers capable of producing high quality products with knowledge base
Government support policies (V4)	Agarwal (1985), Guhathakurta (1994), Khan (1998), Porter (1999) and Srinivasan and Krueger (2005)	The government role is critical in developing legal framework and supporting the sector's investment opportunities, which is significant for encouraging and protecting foreign companies investing in country. Apart from this, a government plays a role fostering the environment for the business
Capital Investment (V5)	Porter (2004) and DIPP (2016)	The electronics manufacturing requires high capital spending (both International and domestic), because of high expenditure in research and setup cost
Access to raw material (V6)	Massari and Ruberti (2013), DIPP (2016) and Awasthi and Li (2017)	India requires raw materials for electronics manufacturing at competitive prices. The cost of raw material is high in the country. Any change in supply and demand for electronics raw materials alters their prices which fluctuate financial stability of the manufacturing firm and product manufacturing cost
Markets demand and internal environment (V7)	Porter (1990a, b) and Teece et al. (1997), Liu (2005), DIPP (2016) and Rajesh and Ravi (2017)	The electronics-manufacturing industry is expected to reach demand of worth US$ 112–130 billion in India by 2018 because of huge demand in domestic market, which is linked to the internal environment. The internal environment of nation refers to the conditions of the economy in which the interest rate, currency value and the production cost is stable and favorable to the industry
Research and innovation and technology acquisition (V8)	Lall (1987), Rosenberg and Steinmueller (1988), Teece et al. (1997), Khan (1998), Porter (2004), Porter et al. (2007), Lau et al. (2013), Ernst (2014), Dewangan et al. (2015) and Cui and Wu (2016)	Major technological innovations are the source of productivity improvement in industrial development. It determines the technological capability and improvement in firms' competitiveness. The technology transfer agreements and joint ventures are also drivers of competitiveness of EMIs, which helps in technology acquisition
Firm competition (V9)	Porter (1980), Porter (1990a, b), Ernst and O'Connor (2014), Matsuo (2015), Fu et al. (2015) and Kamps et al. (2017)	Electronics industry is changing rapidly and highly dynamic in nature. It is highly competitive and influenced by technological advancements which further drives the benefits of economies of scale because of operational efficiencies and synergies to gain increased output of a product. Industries are under enormous pressure to bring differentiated and unique products to compete in market.
Product quality and reliability (V10)	Agarwal (1985), Bahinipati et al. (2009) and Prakash and Barua (2016)	The quality and reliability in electronics goods are serious issues, for the electronics goods because it is the consumer centric in nature

were obtained in first round. The reminder was sent to those people who did not respond in first round. In second round also, hardly 23 responses were received after a strong follow-up process through e-mail and personal meetings. So finally, a cumulative of 52 responses (six were found incomplete or not suitable) are brought into consideration for the study. The data obtained from the survey were analyzed by single-sample t test. Results of

Table 2 Determinants validation through single-sample *t* test

Factors	*N*	Mean	SD	*t* value
Adequate infrastructure (V1)	46	4.17	0.926	29.830
User satisfaction (V2)	46	2.48	1.206	13.372
Training and skill development (V3)	46	3.78	1.281	19.500
Government support policies (V4)	46	3.83	1.198	21.091
Capital investment (V5)	46	4.41	0.777	37.659
Access to raw material (V6)	46	3.72	0.834	29.405
Markets demand and internal environment (V7)	46	4.13	0.806	33.925
Research and innovation and technology acquisition (V8)	46	3.93	0.929	28.008
Firm competition (V9)	46	2.72	0.720	24.657
Product quality and reliability (V10)	46	2.85	1.192	15.635

this analysis are provided in Table 2. All the determinants are significant at $p < 0.01$. The above analysis was performed using the SYSTAT 13.1 software.

Total Interpretive Structural Modeling

The total interpretive structural modeling (TISM) can be used to interpret the nodes (representing 'what') and link (representing 'how' and 'why') to deal with ill-defined and unstructured problems. The TISM technique utilizes systematic iterative application of graph theory and overcomes practical interpretations of structural models (Sushil 2012, 2016, 2017a, b). The TISM process facilitate the pair-wise multiple comparisons in the form of a hierarchical model based on interpretive structural modeling (ISM) proposed by Warfield (1974) (Sushil 2012). The TISM, an extension of ISM, has been applied in various applications involving neighborhood design (Kumar et al. 2017), supply chain management, higher technical education, marketing and sales, strategy performance management, manufacturing systems, throughput accounting, waste management, telecom service sector, etc. Apart from this, the TISM methodology has more explanatory power than ISM (Dubey et al. 2015; Jayalakshmi and Pramod 2015; Yadav and Barve 2016).

Step wise explanations of TISM modeling are as following:

1. Identification of the factors significant in addressing the problem. The factors identification can be done through literature studies, survey, experts opinion, or group problem-solving techniques like brain storming.
2. Make the contextual relationships among factors by pair-wise comparison.
3. Form a structural self-interaction matrix (SSIM) through expert opinion or survey method to indicate the pair-wise relationships among all the factors.
4. Develop an initial reachability matrix (IRM) from SSIM. This matrix should be checked for transitivity and thereafter final reachability matrix (FRM) must be developed from IRM.
5. Carry out the factors partitions exercise from final reachability matrix (FRM) into different levels.
6. Form a conical matrix from the level partition exercise.
7. Develop a digraph based on the relationship given in conical matrix and remove transitive links except those which have distinct interpretation.
8. Make a TISM model by replacing element nodes with the statements and links as interpretation relations in the digraph.

The complete procedure employed to perform TISM exercise for this study is explained in "Appendix 2" section.

Analytic Hierarchy Process

The competitiveness can be evaluated through MCDA technique under the assumption of independence of criteria. The AHP (Saaty 1977, 1990) has been applied to get the relative importance of the factors based on the weights assignment. AHP is considered as the powerful and effective tool for setting priorities and getting informed decisions. The eigen vector method of AHP is preferred for deriving the priority vector for the pair-wise comparison. Also, it helps in understanding a rationale behind the decision.

The following are the steps for MCDA technique using AHP (Hong 2009).

Step 1: Define the problem and its objectives.
Step 2: Configure the hierarchy from top to bottom.
Step 3: Construct the pair-wise matrix of size $n \times n$ for each of the levels for the comparison.
The expert can opt for his/her choice on a preference of nine-point scale. If two criteria of equal importance are compared, then a value of 1 is assigned; on the other hand, if one is absolutely important, then the value of 9 is assigned. Apart from this, the intermediate value (e.g., 2, 4, 6 and 8) can be assigned on the basis of importance.

Table 3 Pairwise weights (based on the principal eigenvector of the decision matrix)

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1	1.00	4.00	3.00	0.20	0.50	3.00	0.17	3.00	2.00	1.00
V2	0.25	1.00	0.33	0.20	0.25	0.33	0.17	0.33	2.00	1.00
V3	0.33	3.00	1.00	0.20	0.25	0.50	0.17	0.50	2.00	0.50
V4	5.00	5.00	5.00	1.00	2.00	2.00	0.50	5.00	4.00	3.00
V5	2.00	4.00	4.00	0.50	1.00	2.00	0.33	3.00	3.00	4.00
V6	0.33	3.00	2.00	0.50	0.50	1.00	0.25	2.00	2.00	2.00
V7	6.00	6.00	6.00	2.00	3.00	4.00	1.00	5.00	4.00	4.00
V8	0.33	3.00	2.00	0.20	0.33	0.50	0.20	1.00	2.00	2.00
V9	0.50	0.50	0.50	0.25	0.33	0.50	0.25	0.50	1.00	0.50
V10	1.00	1.00	2.00	0.33	0.25	0.50	0.25	0.50	2.00	1.00

Step 4: Compute the eigenvalue by using the relative weights of criteria and add them all to the weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.

Step 5: Consistency and consequence weights analysis must be applied.

Steps 3–5 are performed for all levels in the hierarchy. Fortunately, professional commercial software is available to perform such exercise. For solving the research problem, BPMSG AHP priority calculator has been used to simplify the implementation of the AHP's steps and to automate its computations (Table 3).

Results and Discussion

Digraph Formation

A digraph consisting of nodes and edges is a visual representation of the factors and their interdependencies. A digraph containing transitive links was also evolved from the conical matrix ("Appendix 2"). After removing the indirect links, a final digraph (Fig. 1) was developed. Only significant transitive links are shown in final TISM digraph.

The market demand (Fig. 1) is the principal driver of electronic goods in the country and specifically the same industry development trends are seen globally. All stake holders including manufacturing industries, manufacturing associations, and government must give the highest weight to market demand before formalizing the strategies and policies, respectively. By gauging the market demand, successful strategy can be formulated. The government policies and capital investments should be altered based on market demand. The government role is quite significant particularly in formulating and designing the business policies, excise regulations such as tariff rates, etc. The government's policies create the legal framework to implement, strengthen, and support the sector conditions. The EMI requires huge amount of capital investment for setting up the sophisticated plant. The investments further strengthen the market position of an industry and raise the competition.

The government must emphasize on framing flexible policies for capital investment so that such policies in turn develop better environment for investments in future. The government should implement policies to support smooth investment in electronics manufacturing. The change in locus of manufacturing for country like India would build up the employability. The policies can support building core infrastructure and facilitate with basic requirement in the manufacturing domain. Simultaneously, the government should promote training and skill development through the training centers. Apart from this, the policies strengthen the supply chain to access of electronics components and other necessary raw material for production. The infrastructure has cascading effects on society and enhances economic vitality.

The research and innovations can produce cutting-edge solutions for advanced technological developments and would produce high-level products and services. This can be supplemented by training and skill development. The quality and customized products would provide more satisfaction to the users. The customer satisfaction is an important criterion for retaining the market position in competitive business environment. The customer satisfaction seems to be influenced by various factors, thus having high dependence.

Implications of TISM Findings

This study determined the influential variables of competitiveness of EMI and indicates that market demand is an important determinant. The market demand motivates the government to form new policies and create the ecosystem for capital investment. The government policies and capital investment are correlated. The same is supported by the Caselet 1 given below.

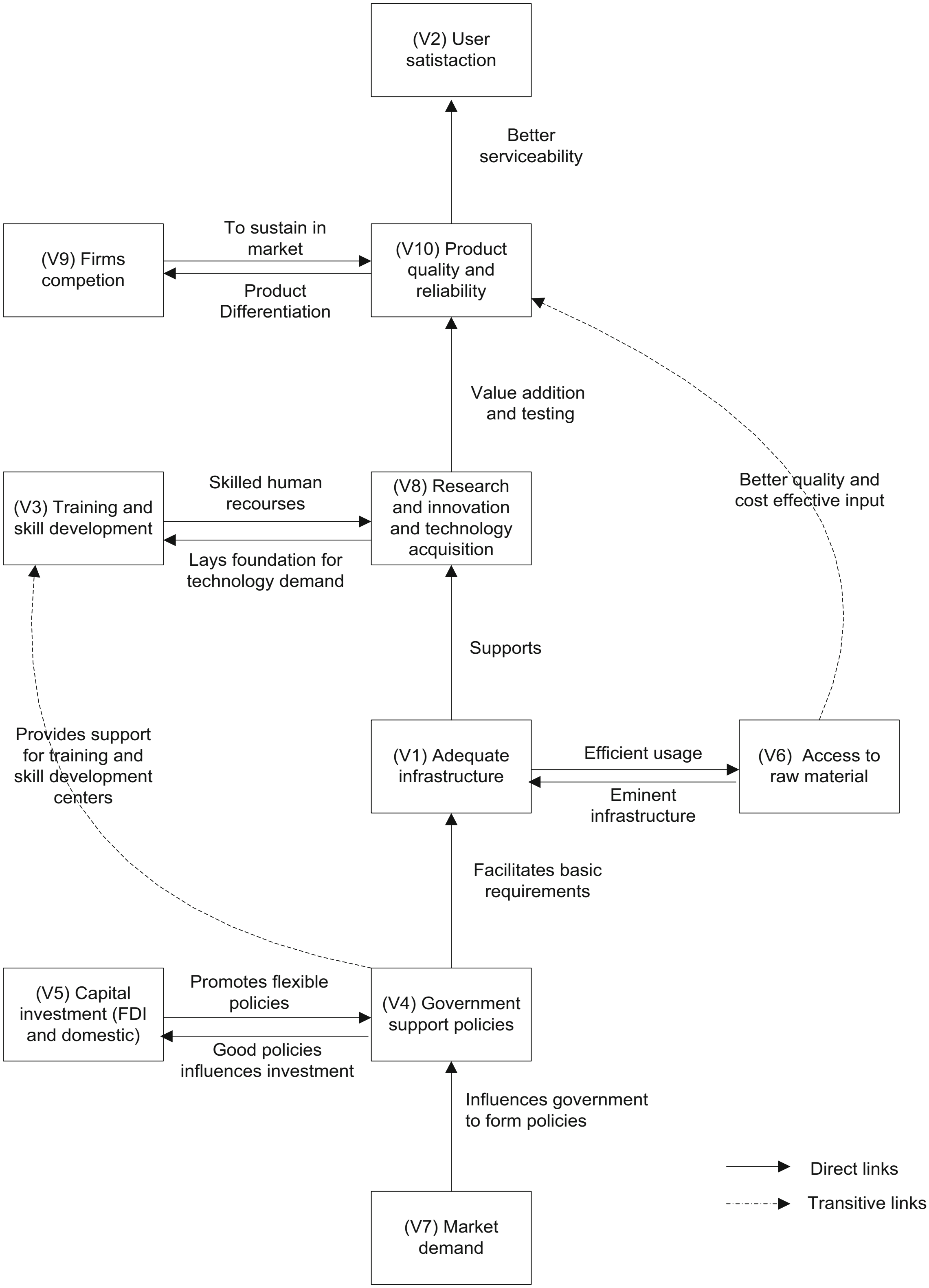

Fig. 1 A TISM model representing the hierarchical relationships among the determinants of EMIs competitiveness

Caselet1: The demand of EMI has touched the 100 USD mark across all sub-sectors and the domestic manufacturing and accounts to one-third of the total demand in 2014. In view of above, the "Make in India" initiatives were launched by the government to promote electronics manufacturing in the country in 2014. This includes the policies for smoothening the manufacturing ecosystem, cutting down the procedural delay, tax sops and focus on innovation, skill development and thrust on education, reforms in the labor laws, demographic dividend, investment in human resources, stimulating manufacturing economics, and streamlining the standards. Apart from this, government formulated short-, medium-, and long-term plans for boosting the manufacturing industries. These policy frameworks build up the environment for capital investment for domestic and foreign investors such as Modified Special Incentive Package Scheme (MSIPS) under which the subsidy ranges from 20 to 25% (Meity 2017). The Fig. 2 demonstrates and validates the finding of the TISM model.

Caselet 2: The Government Support Policies make the government to develop better infrastructure and other common facilities. For this the government took initiatives in 2012 for providing the land to the existing and new electronics-manufacturing clusters (EMC). The government targets to create 200 EMCs by 2020. Along with this, the government has made a tough target of setting up two fabrication-manufacturing facilities in the country. The findings of the TISM model are validated and shown in Fig. 3.

Caselet 3: Vetril Electronics Private Limited, a reputed company established in year 1978, attains quality products from in-house research and innovation. The company has worldwide customers, which includes: ABB, GE, L&T, BEL, BHEL, Alstom, MROTEK, and CENTUM. The company aims at acquiring the technology for its vertical segments to serve its customers. Simultaneously, the company looks after its human resources and technocrats who are highly qualified and have wide experience in the field. The Fig. 4 exhibits and condescends the TISM findings.

AHP Modeling

In AHP model, the expert ("Appendix 1" section) opinions were collected for pair-wise comparison and relative importance of the determinants to identify the

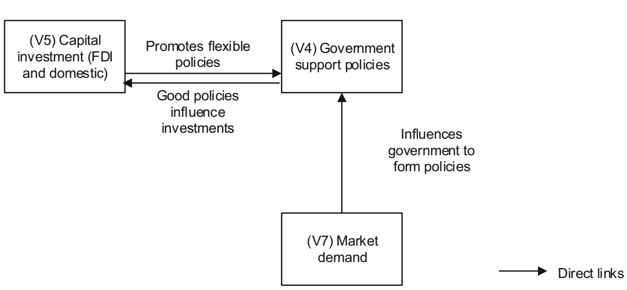

Fig. 2 Validation of partial TISM model by Caselet 1

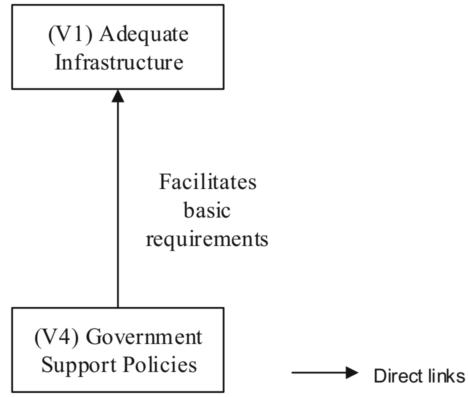

Fig. 3 Validation of partial TISM by Caselet 2

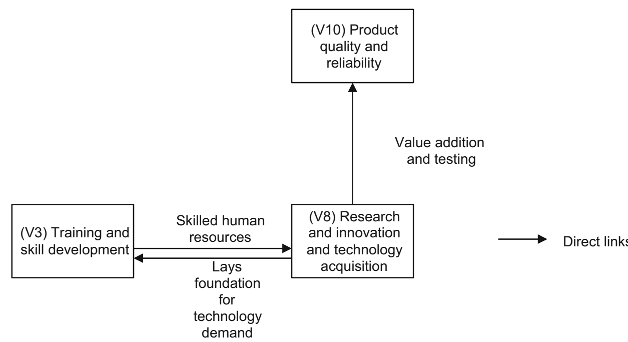

Fig. 4 Validation of partial TISM model by Caselet 3

competitiveness of EMI. If opinion of the experts varies, then independent analysis can be carried for specific group (Basak 1988). Madu and Kuei (1995) have talked about the consistency and reliability of the model based on group decision-making process. The decision matrix (Table 3) is prepared after pair-wise comparison. Table 4 depicts the weights of the determinants obtained after six iterations through the AHP software.

Priorities

The consistency ratio (CR) is less than 0.1, which signifies that the comparisons of matrix are of good consistency. Principal eigenvalue for the matrix is 10.856, eigenvector solution is obtained in six iterations, and Delta is coming out to be 4.6E−9 signifies the convergence of the matrix.

From the results (Table 4), it can be easily stated that market demand is getting highest weightage of 27.9%. Government support policies and capital investments contain 20.1 and 13.3% weights, respectively. The adequate infrastructure and raw material availability come out at fourth and fifth positions, respectively. For country like India, the infrastructure and raw material are the significant determinants because raw material is mainly imported from

Table 4 Resulting weights for the criteria based on pair-wise comparisons

Symbols	Factors	Weight (%)	AHP rank	Weighted DP (%)	DP rank
V1	Adequate infrastructure	9.4	4	12	4
V2	User satisfaction	3.3	10	2	10
V3	Training and skill development	4.2	8	8	6
V4	Government's support policies	20.1	2	15	2
V5	Capital investment	13.3	3	15	2
V6	Access to raw material	7.5	5	12	4
V7	Markets demand and internal environment	27.9	1	17	1
V8	Research and innovation and technology acquisition	5.7	6	8	6
V9	Firms competition	3.5	9	5	8
V10	Product quality and reliability	5.2	7	5	8

DP Driving Power (from TISM)

China and other countries. The infrastructure connotes the importance of necessary conditions like fabrication facility, transport, well-integrated supply chain for smooth flow of goods and clusters. Informatics infrastructure which is the backbone for telecommunications devices plays a leading role in supporting the EMI. Research and innovation along with training and skill development are having lesser driving power and is dependent on other determinants as per TISM digraph.

Implications of AHP Modeling

The principle of AHP lies in solving the larger problem and creation of structural problem. The BPMSG AHP Online System helps to perform the sensitivity analysis and access the resulting ranks of alternatives. The AHP model ranks research and innovation and product quality at sixth and seventh positions, respectively. The technical education and skilled labors are also important for the EMI sector. The training and skill development and firm competition are ranked at eighth and ninth positions, respectively. The sser satisfaction having highest dependence and lowest deriving power is attaining tenth position in AHP model, signifying the importance of customer in the whole process. Through the sensitivity analysis, it was found that the best alternatives are robust enough for weight ranking. The weight ranking obtained from AHP provides the similar results as of TISM, except for two determinants: product quality and training and skill development. The findings of TISM–AHP are similar in terms of importance of ranking.

Conclusions

This study provides the industrial-level analysis using empirical evidence and identifies several specific determinants of industrial competitiveness that are particularly effective in enhancing the electronics industry in India. The research study provides recommendations to improve industrial competitiveness of electronics industry. However, the research is subjective study, which makes it difficult to correlate quantitatively; however, the caselets are being used to validate the digraph. In the present scenario, the usage of electronics goods is taking a steep hike. In this article, firstly, the determinants of competitiveness for EMI are identified, and thereafter, they are analyzed through TISM process to find the direct and indirect relationships. Further, the TISM digraph is plotted to highlight the influence pattern of determinants among each other.

The TISM results show that market demand is highly influential parameter for the successful manufacturing industries. The government support policies and capital investment are important determinants influencing the growth of EMI. The adequate infrastructure and raw material availability are also important to set up a manufacturing plant. Research and innovation and the technology acquisition along with training and skill development required for the improvement of products and services have moderate driving power and dependence. Further, the product quality and user satisfaction are the key parameters which improve the firm competitiveness.

Moreover, findings from AHP process suggest the weights of each determinant contributing to the competitiveness of EMIs.

The study finds the market demand as highest weighted determinant. If market demand is high, chances of firm to grow becomes higher in the market. The government supports policies and capital investment fuel to set up electronics-manufacturing plant in the country. The driving power and the AHP ranking provide the similar results, and hence the findings of the TISM are corroborating with those of AHP. Overall, it could be a key learning for the manufacturing industries, government officials, and business personal to focus on the hierarchy and relative weights of determinants used in this study to make profitable decisions and to attain competitiveness in EMI sector. Our results indicate that when industry and the government build sound infrastructure capability and improve business environment to capture the market demand along with measures like training and skill development, firm's competition, product quality, and reliability, etc., they can directly improve industrial competitiveness.

The research creates numerous contributions to the existing literature. The study examines the relationship between various determinants of industrial competitiveness of electronics industry and ranks the determinants on the basis of driving power using TISM and the weights of AHP, a unique approach of its kind. The driving power in conjunction with AHP weights for ranking the determinants is used for the first time. This is the first study to examine role of determinants of the electronics industry. In this novel approach, there exists high correlation between the driving power and the rank obtained through the AHP. Our focus on industrial competitiveness a significant output is a methodological contribution and the significant determinants.

Limitations of the Study and Future Research

The TISM and AHP techniques are qualitative and perception based models, developed by experts' opinion. The experts were chosen based on relevant background, but if more experts are added to the study, the outcomes may vary. Next, the determinants identified in the study are specific to electronics-manufacturing industry, these determinants may vary if the industry changes. The TISM outcomes and parameters' ranks may alter, if the study is performed in a different market place and geography. The quantitative model can be developed to study the productivity measures of the select industry. The survey can be carried out to analyze the specific context or measure of the electronics industry.

Appendix 1

List of experts who were consulted for the determinants validation and weights assignment for AHP process. The name and affiliation are kept hidden to maintain the data privacy of the experts. The list of experts is shown in Table 5 highlighting their profile with experience.

Table 5 List of experts

Experts	Expert profile/designation	Experience (years)	Category
Expert 1	Professor, international business	> 20	Academician, Delhi, India
Expert 2	Senior adviser (electronics manufacturing firms association)	> 20	Industry association
Expert 3	Managing director (manufacturing unit)	> 20	Industry, India
Expert 4	Politician	> 15	Government of Uttar Pradesh
Expert 5	Seniors advisors (marketing and sales)	> 18	Government Official, India
Expert 6	Consulting enterprise architect (manufacturing plant)	> 15	Industry, India
Expert 7	General manager (supply and distribution)	> 14	Industry, India
Expert 8	Associate research director (manufacturing insights)	> 17	Industry (MNC), India location
Expert 9	Manager-cost reduction and product excellence (manufacturing)	> 13	Industry, India
Expert 10	Trainer (manufacturing and heavy engineering)	> 12	Industry, India
Expert 11	Deputy general manager (research and development)	> 13	Industry, India
Expert 12	Head (production and manufacturing)	> 16	Government Officials, India
Expert 13	Senior executive (marketing and business development)	> 14	Industry, India
Expert 14	Manager (customer relationship management)	> 12	Industry, India
Expert 15	Senior engineer (production)	> 9	Industry, India
Expert 16	Policy maker (industrial setting and development, MSME)	> 12	Government Officials, India
Expert 17	Assistant manager (procurement)	> 10	Government Officials, India
Expert 18	Quality assurance manager	> 11	Industry, India
Expert 19	Manager (digital marketing)	> 8	Industry, India
Expert 20	Associate (customer services)	> 8	Industry, India
Expert 21	Professor, competitive strategy	> 14	Academician, Government, India
Expert 22	Deputy general (infrastructure and planning)	> 11	Industry, India
Expert 23	Senior officer (import/export)	> 13	Government Official, India

Appendix 2

The complete procedure of TISM exercise performed in this study is as following:

Development of Structural Self-Interaction Matrix (SSIM)

SSIM was developed based on the pair-wise relations among the selected factors. A survey was conducted to get the suggestion on 'leads to' or 'influences' type relations. The survey was conducted in spell of 5 months taking the detail expert views from 49 practitioners in India. The average years of experience of the participants is more than 8 years, and they represented 11 industries, seven premier academic institution, and three manufacturing associations. The expertise and experience of practitioners along with vast spread of manufacturing industries helped in making the exercise inclusive and viable. The following four symbols were used to denote the direction of relationship between two factors (*and**j*):

(a) *V* for the relation from factor *i* to factor *j* (i.e., factor *i* influences factor *j*)
(b) *A* for the relation from factor *j* to factor *i* (i.e., factor *i would* be influenced by factor *j*)
(c) *X* for both direction relations (i.e., factors *i and j* influence each other)
(d) O for no relation between the factors (i.e., factors *i and j* are not related).

Based on the consensus on contextual relationships, the SSIM was developed (Table 6).

Development of initial reachability matrix

After making SSIM, an initial reachability matrix was developed (Table 7). For this, symbols *V*, *A*, *X* or *O* of SSIM were substituted by 1 or 0 s by applying following rules-

Table 6 Structural self-interaction matrix (SSIM)

	V10	V9	V8	V7	V6	V5	V4	V3	V2	V1
V1	V	O	V	O	X	A	A	V	O	1
V2	A	A	O	O	O	O	O	O	1	
V3	V	O	X	O	O	A	A	1		
V4	V	O	V	A	V	X	1			
V5	V	O	O	A	O	1				
V6	V	O	O	A	1					
V7	V	O	O	1						
V8	V	O	1							
V9	X	1								
V10	1									

Table 7 Initial reachability matrix (IRM)

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1	1	0	1	0	0	1	0	1	0	1
V2	0	1	0	0	0	0	0	0	0	0
V3	0	0	1	0	0	0	0	1	0	1
V4	1	0	1	1	1	1	0	1	0	1
V5	1	0	1	1	1	0	0	0	0	1
V6	1	0	0	0	0	1	0	0	0	1
V7	0	0	0	1	1	1	1	0	0	1
V8	0	0	1	0	0	0	0	1	0	1
V9	0	1	0	0	0	0	0	0	1	1
V10	0	1	0	0	0	0	0	0	1	1

Table 8 Final reachability matrix

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
V1	1	1*	1	0	0	1	0	1	1*	1
V2	0	1	0	0	0	0	0	0	0	0
V3	0	1*	1	0	0	0	0	1	1*	1
V4	1	1*	1	1	1	1	0	1	1*	1
V5	1	1*	1	1	1	1*	0	1*	1*	1
V6	1	1*	1*	0	0	1	0	1*	1*	1
V7	1*	1*	1*	1	1	1	1	1*	1*	1
V8	0	1*	1	0	0	0	0	1	1*	1
V9	0	1	0	0	0	0	0	0	1	1
V10	0	1	0	0	0	0	0	0	1	1

* Transitive relationship

(a) If the (*i*, *j*) entry in the SSIM is *V*, then the (*i*, *j*) entry in the initial reachability matrix becomes 1 and the (*j*, *i*) entry becomes 0.
(b) If the (*i*, *j*) entry in the SSIM is *A*, then the (*i*, *j*) entry in the initial reachability matrix becomes 0 and the (*j*, *i*) entry becomes 1.

Table 9 Driving power and dependence of determinants

Determinants	Driving power	Dependence
Adequate infrastructure (V1)	7	5
User satisfaction (V2)	3	9
Training and skill development (V3)	5	7
Government support policies (V4)	9	3
Capital investment (V5)	9	3
Access to raw material (V6)	7	5
Markets demand (V7)	10	1
Research and innovation and technology acquisition (V8)	5	7
Firm competition (V9)	3	9
Product quality and reliability (V10)	3	9

Table 10 Iterations of TISM process for partitioning the levels

Iteration 1	Reachability set (RS)	Antecedent set (AS)	AS ∩ RS	Level
V1	1, 2, 3, 6, 8, 9, 10	1, 4, 5, 6, 7	1, 6	
V2	2	1, 2, 3, 4, 5, 6, 8, 9, 10	2	I
V3	2, 3, 8, 9, 10	1, 3, 4, 5, 6, 7, 8	3, 8	
V4	1, 2, 3, 4, 5, 6, 8, 9, 10	4, 5, 6, 7, 10	4, 5, 6, 10	
V5	1, 2, 3, 4, 5, 6, 8, 9, 10	4, 5, 7, 10	4, 5, 10	
V6	1, 2, 3, 6, 8, 9, 10	1, 4, 5, 6, 7, 10	1, 6, 10	
V7	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1, 3, 4, 6, 7, 8, 9, 10	1, 3, 4, 6, 7, 8, 9, 10	
V8	2, 3, 8, 9, 10	1, 3, 4, 5, 6, 7, 8	3, 8	
V9	2, 9, 10	1, 3, 4, 6, 8, 9, 10	9, 10	
V10	2, 9, 10	1, 3, 4, 5, 6, 7, 8, 9, 10	9, 10	
Iteration 2	**Reachability set (RS)**	**Antecedent set (AS)**	**AS ∩ RS**	**Level**
V1	1, 3, 6, 8, 9, 10	1, 4, 5, 6, 7	1, 6	
V3	3, 8, 9, 10	1, 3, 4, 5, 6, 7, 8	3, 8	
V4	1, 3, 4, 5, 6, 8, 9, 10	4, 5, 6, 7, 10	4, 5, 6, 10	
V5	1, 3, 4, 5, 6, 8, 10	4, 5, 7, 10	4, 5, 10	
V6	1, 3, 6, 8, 9, 10	1, 4, 5, 6, 7, 10	1, 6, 10	
V7	1, 3, 4, 5, 6, 7, 8, 10	1, 3, 4, 6, 7, 8, 9, 10	1, 3, 4, 6, 7, 8, 9, 10	
V8	3, 8, 9, 10	1, 3, 4, 5, 6, 7, 8	3, 8	
V9	9, 10	1, 3, 4, 6, 8, 9, 10	9, 10	II
V10	9, 10	1, 3, 4, 5, 6, 7, 8, 9, 10	9, 10	II
Iteration 3	**Reachability set (RS)**	**Antecedent set (AS)**	**AS ∩ RS**	**Level**
V1	1, 3, 6, 8	1, 4, 5, 6, 7	1, 6	
V3	3, 8	1, 3, 4, 5, 6, 7, 8	3, 8	III
V4	1, 3, 4, 5, 6, 8	4, 5, 6, 7	4, 5, 6	
V5	1, 3, 4, 5, 6, 8	4, 5, 7	4, 5	
V6	1, 3, 6, 8	1, 4, 5, 6, 7	1, 6	
V7	1, 3, 4, 5, 6, 7, 8	1, 3, 4, 6, 7, 8	1, 3, 4, 6, 7, 8	
V8	3, 8	1, 3, 4, 5, 6, 7, 8	3, 8	III
Iteration 4	**Reachability set (RS)**	**Antecedent set (AS)**	**AS ∩ RS**	**Level**
V1	1, 6	1, 4, 5, 6, 7	1, 6	IV
V4	1, 4, 5, 6	4, 5, 6, 7	4, 5, 6	
V5	1, 4, 5, 6	4, 5, 7	4, 5	
V6	1, 6	1, 4, 5, 6, 7	1, 6	IV
V7	1, 4, 5, 6, 7	1, 4, 6, 7	1, 4, 6, 7	
Iteration 5	**Reachability set (RS)**	**Antecedent set (AS)**	**AS ∩ RS**	**Level**
V4	4, 5	4, 5, 7	4, 5	V
V5	4, 5	4, 5, 7	4, 5	V
V7	4, 5, 7	4, 7	4, 7	
Iteration 6	**Reachability set (RS)**	**Antecedent set (AS)**	**AS ∩ RS**	**Level**
V7	7	7	7	VI

(c) If the (i, j) entry in the SSIM is X, then the (i, j) entry in the initial reachability matrix becomes 1 and the (j, i) entry also becomes 1.

(d) If the (i, j) entry in the SSIM is O, then the (i, j) entry in the initial reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Table 11 Conical matrix

	V2	V9	V10	V3	V8	V1	V6	V5	V4	V7	Driving power	Rank
V2	*1*	0	0	0	0	0	0	0	0	0	1	6
V9	1	*1*	1	0	0	0	0	0	0	0	3	5
V10	1	1	*1*	0	0	0	0	0	0	0	3	5
V3	1*	1*	1	*1*	1	0	0	0	0	0	5	4
V8	1*	1*	1	1	*1*	0	0	0	0	0	5	4
V1	1*	1*	1	1	1	*1*	1	0	0	0	7	3
V6	1*	1*	1	1*	1*	1	*1*	0	0	0	7	3
V5	1*	1*	1	1	1*	1	1*	*1*	1	0	9	2
V4	1*	1*	1	1	1	1	1	1	*1*	0	9	2
V7	1*	1*	1	1*	1*	1*	1	1	1	*1*	10	1
Dependence	10	9	9	7	7	5	5	3	3	1		

A TISM model (Fig. 1) has been developed based on conical matrix by removing replacing the nodes as factors and edges as comments to illustrate the complexity of inter-relationships among the determinants

Transitive links of the contextual relation also were checked in initial reachability matrix (Table 2) which states that if factor ($A \rightarrow B$) and ($B \rightarrow C$) then necessarily ($A \rightarrow C$). This is called transitivity among the determinants. 1* entries have been filled in initial reachability matrix to incorporate transitivity. As a result, a final reachability matrix (Table 8) was developed.

Driving Power and Dependence

The driving power and dependence have been calculated for each determinant (Table 9) from final reachability matrix. The driving power of a determinant is the sum of ones in the rows, and its dependence is sum of ones in the columns. The ranks of driving and dependence were given based on maximum number of ones in rows and columns, respectively.

Level Partitions

To place the determinants on level wise in a hierarchy, the reachability set and antecedent set were derived for each factor from the final reachability matrix. In case of a factor, if intersection of the reachability set and the antecedent set were same as the reachability set, then the factor was considered at the top level. The top-level factors usually do not lead the other factors. The top-level factors were removed from the iterations. The process goes continued till all the factors get the levels (Table 10).

A conical matrix (Table 11) was formed from the level-partioning process. The factors are arranged from the level one to last level. The values are filled from the final reachability matrix (Table 8).

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Key Questions

1. What are the various determinants of electronics manufacturing at industrial level suitable for Indian context?
2. How electronics manufacturing could be more personalized and customer centric to get more competitive advantages for a longer time period?
3. How the market demand can be fulfilled with electronic products/services with adaptability of technological components and changes in government policies to satisfy the need of users in developing countries like India?

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