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Article

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Abstract

The Automotive Industry has been one of the sunrise industries in India and is poised to enhance its contribution from 5 per cent of GDP in 2006 to 10 per cent by 2016. With the liberalization and globalization process which started in 1991, the industry is in the process of transforming itself from being a 'Job order fulfiller' to being an 'Integrated Organisation'. Most automobile and auto-component players in India have chosen the path of attempting to progress on operational/manufacturing capabilities. For advancing on technology capability dimension, they mostly relied on international collaborations. Without a holistic framework of Strategic Technology Management (STM), most of the collaboration has been of limited help and many players are progressing very slowly on technology capability. The key objective of this article is to review the situation related to STM in the industry and evolve a macro level conceptual framework for STM. For this purpose, we did extensive fieldwork and used the methodologies like Interpretive Structural Modeling (ISM) and MICMAC, as they help in identifying the linkages, hierarchies and levels of various enablers of STM and thus provide insights into the complex issue. Factors for STM were evolved from literature survey and expert opinion. A key contribution of the article is evolving a conceptual framework for STM in emerging economy context. The conceptual framework can act as a valuable guide for leaders of the automotive and other industries to think and decide about the future path they need to take to succeed in the emerging era.

Keywords

Automotive industry in India; auto component industry; Strategic Technology Management (STM); competitiveness; collaborations; ISM; MICMAC

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Introduction

In the dynamics of transition of the Indian economy, the automotive industry has emerged as a leading growth driver. The automotive industry's strong linkages with the capital equipment and the services industry and the potential for earning foreign exchange through exports also acted as an impetus for its growth. The automotive industry in India has gone through a lot of transformation since inception and in particular in the last decade. With the liberalization and globalization process started in 1991, the industry saw the entry of international automotive majors in India. Along with the automobile manufacturers, auto component industry has transformed itself from a traditional job fulfiller role to a partnership role. Changing customer preferences, regulations, concern for safety and environment have impacted the product and process technology. In line with the changes happening in the global automobile and auto component industry, the industry in India has also gone in for Technological Alliances (TA)/Joint ventures (JV) with global auto component manufacturers. To remain competitive and improve its competitiveness in the global automotive industry, the auto industry in India needs to align its business strategy and technology development. In this study, we have developed a conceptual framework for STM using widely used ISM and MICMAC methodology, which can act as a valuable guide for industry leaders, practitioners and academicians.

This article is organized in the following manner. This section gives a brief introduction to the automotive industry in India. The following section explains the methodology of this research. The third section is devoted to study of literature related to STM, competitiveness and automotive industry. In this section, we also examine the role and relevance of STM and the study of competitiveness of automotive industry in India. The fourth section describes the development of a conceptual framework for STM using ISM and MICMAC methodology. In the fifth section we discuss the key findings and managerial implications of the study and conclude in the last section.

Automotive Industry in India

The Automotive Industry in India is now working in terms of the dynamics of an open market. Many joint ventures have been set up with leading global automobile manufacturers. In addition, a very large number of joint ventures have been set up in the auto-components sector and the pace is expected to pick up even further. The Government of India is keen to provide a suitable economic and business environment conducive to the success of the established and prospective foreign partnership ventures.

The new liberal economic regime with growing GDP, the immense market potential and the presence of stable and cost competitive manufacturing base has resulted in CAGR of approx 17 per cent from 2002–03 to 2006–07. As per the industry statistics from Society of Indian Automobile Manufacturers (SIAM, 2008), the total automobile production was 11.0 million units in 2006–07 with a turnover of approx. US$ 34 billion. The sector contributes 17 per cent to the kitty of indirect taxes and provides direct and indirect employment to 13.1 million persons. The exports from the automobile sector have grown at 30 per cent annually in last 5 years, with its exports earning close to US$ 4.08 billion.

The large volumes of investment including foreign direct investment in the automobile manufacturing ventures and technical collaboration are propelling a quantum jump in upgradation of technology. As per the Automotive Mission Plan 2006–16 (Government of India, 2006), released by Ministry of Heavy Industries and Public Enterprises, the turnover of the industry is expected to increase to US$ 145 billion by 2016 and exports are expected to touch US$ 35 billion by that time. The increased production and capacity creation in the automobile sector specifically passenger cars is going to accelerate the continuous growth of the auto-component industry as well.

Auto Component Industry

The origin of the Indian auto component industry dates back to 1953, when the Indian government decided to develop its own manufacturing base with the principal aim of import substitution. The principal feature of the Indian auto component industry is that it is a high investment sector of the economy with state-of-the-art technology, and serving a large number of vehicle models. As per the Automotive Component Manufacturer's Association, there are over 550 key players in the auto component sector with a total turnover of US$ 15 billion in 2006–07 (ACMA, 2008).

The Indian auto component industry produces a comprehensive range of components which include engine parts, drive transmission and steering parts, suspension and braking parts, electrical parts, equipment and other parts. Over the years, the industry is successfully working on the path to fulfill its mandate of localization and is moving towards being global suppliers. As per industry statistics (ACMA, 2008), the auto component exports has risen from US$ 760 million in 2002–03 to US$ 2873 million in 2006–07, amounting to 19 per cent of total output.

Technology development in the auto component industry worldwide has been primarily driven by the automobile manufacturers, regulations and changing customer preferences. In India, the technology development has followed the developments in the developed world and thus technology acquisition through collaborations and alliances has been one of the preferred routes.

Challenges before the Automotive Industry

In the fast changing global scenario the automotive industry in India faces many challenges. Some of the major challenges are greater competition in domestic as well as export markets, integrating into the global supply chain, Quality level, Low over all technology level: Product design/ Manufacturing / Other technologies in the value chain, WTO and FTA, etc.

The Indian Industry has responded to the challenges in a major way by going in for technical collaborations/ joint venture and upgrading the product development and manufacturing capability. The concept of attaining competitiveness on the basis of abundant and cheap labour, favourable exchange rates and concessional duty structure is becoming inadequate and therefore, not sustainable. The key question is how quickly the industry is able adapt to the challenges of the fast changing environment and how well the industry is able to integrate the technology management with the business strategies of the firms.

Methodology

The methodology employed for this research work is a combination of fieldwork, literature survey, analysis of secondary data, expert opinion assimilation and application of flexible systems methodologies like ISM and MICMAC. Extensive and interactive fieldwork helped get better view of ground reality, evolve positive view and a more pragmatic conceptual framework that literature (e.g., Burgelman et al., 2004; Husain and Sushil, 1997; Momaya et al., 2004) failed to provide. A literature survey was done keeping in mind the relevance of the topic under study. Emphasis has been given to opinions of experts from the field keeping the practical application and usability of the study in mind. The methodology followed for development of the conceptual framework is graphically represented in Figure 1.

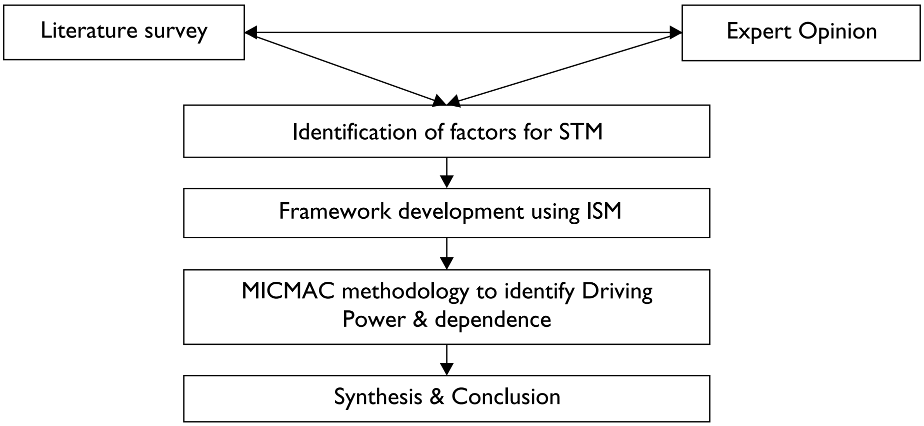

Figure 1. Research Methodology

Source: Adapted based on Kumar et al. (2009).

The combination of ISM and MICMAC provides a sound approach and valuable insights while developing conceptual framework. These methodologies have been widely used by researchers (Ilyas et al., 2005; Faisal et al., 2006; Kumar et al., 2009; Saxena et al., 1992; Singh et al., 2003) Detailed steps of ISM and content of each step are given in the Appendix B. Fourteen experts from industry and academia were consulted for the research work. The profile of experts consulted for this study is summarized in Table 1.

Table 1. Length of Experience and Domain Area of Experts

Length of Experience	Number of Respondents	Domain	Number of Respondents
15 years and above	7	Industry	8
10 to 15 years	4	Academia	4
7 to 10 years	3	Industry Associations	2

Source: Developed by authors.

Strategic Technology Management and Global Competitiveness

The review of literature hints at a significant relationship between STM and competitiveness. During the 1980s, strategic management scholars began to recognize technology as an important element of business definition and competitive strategy. Technology was identified as one of three principal dimensions of business definition, noting 'technology adds a dynamic character to the task of business definition, as one technology may more or less rapidly displace another over time' (Burgelman and Wheelwright, 2001). Porter (1983) observes that technology is among the most prominent factors that determine the rules of competition. Friar and Horwitch (1985) explain the growing prominence of technology as the result of historical forces; disenchantment with strategic planning, the success of high-technology firms in emerging industries, the surge of Japanese competition, recognition of the competitive significance of manufacturing and the emergence of an academic interest in technology management. Betz (1994) has proposed that technology strategy is realized in practice through the enactment of several key tasks such as internal and external technology sourcing, deploying technology in product and process development, and using technology in technical support activities. In turn, performing these activities provides change in the firm's technical competencies and capabilities.

Technology is considered to be a major competitive factor for the countries at macro level and for individual firms at micro level. The Global Competitiveness Report (World Economic Forum, 2000) introduces a new focus: *Technology* as one of the key drivers of sustained economic growth. The Automotive Mission Plan (Government of India, 2006), gives due prominence to technology development and has identified several initiatives to enhance competitiveness in manufacturing and technology development. The twenty-first century is expected to be driven by technology and technological competitiveness. A study conducted by Momaya and Ajitabh (2005) on the importance of technology for business success and competitiveness showed a high correlation between technology management and competitiveness in select firms.

Ohmae (1989) had pointed out that technology has almost dismantled the political boundaries of the world for a business, and information and awareness regarding products and solutions flows across countries without any time lag. The point emphasized in this is that to go global, a firm has to be strong in technology and market locally.

The example of Japan is cited in many works as a successful case of establishing global competitiveness through technology management. The success has been brought through a national policy framework. The Economic Survey of Japan (1987–88) describes five phases for globalization (Table 2). Yamanouchi (1995) has enumerated this policy framework followed by Japanese companies to attain global competitiveness in different areas.

As per the United Nations report (2003), experience in South-East Asia suggests that it is possible to achieve impressive competitive success in manufactured exports (refer phase 1 of Japanese policy) by

Table 2. A Japanese Policy Framework for Global Competitiveness

Phases	Broad Activity	Explanation
Phase 1	Export-orientation	Production takes place domestically, and foreign sales are primarily through designated agencies
Phase 2	Direct Sales	Production takes place domestically, and foreign sales companies are established
Phase 3	Direct overseas production	Transfer of manufacturing and production technology
Phase 4	Fully independent foreign businesses	The foreign location of R&D function begins in this phase—Technology development
Phase 5	Global integration	Integration of all functions globally

Source: Yamanouchi (1995).

attracting export-oriented FDI on the back of good location, well-managed macroeconomic policy and moderate levels of skills and capabilities. Another study by Lall (2004) points out that providing a suitable policy framework by the government can attain industrial competitiveness of nations. Examples of China, Korea, Singapore have been given in this study.

In light of the above, STM can be defined as strategic management of technology (MOT), keeping strategic business objectives in mind. It involves key activities from linking technology strategy to business strategies to effective management of innovation, technology transfer, adoption, adaptation, absorption, R&D, design and commercialization.

In the Indian context, studies suggest that the pace of improving competitiveness has been very slow (Momaya, 2001, 2008). India lags behind when compared with the developed or even some emerging countries on macroeconomic indicators of technology, technology management and technology capability (Momaya et al., 2004). Therefore, there is a strong need to create awareness among top leaders about awakening, importance and application of technological capabilities for competitive advantage.

Technology Management and Automotive Industry

The automotive Industry world over has been an important component of industrial and economic progress and its development has characterized global competitiveness of leading industrialized economies. The automotive industry is a fairly developed one and involves huge investments in research and development and technology and is seen as an indicator of the economic progress of the country. The success story of Toyota becoming the world's number one automobile company established the leadership of Japanese automobile manufacturers in the world market. Developing products of exceptional quality with appropriate value proposition has been the key to success of Japanese companies in the US market. Japanese manufacturers have largely followed the policy framework explained above.

Globalization is having a major impact on the automotive industry. The demand for automobiles has changed its international structure. Due to changes in the dynamics of the industry worldwide, automobile manufacturers have considered modular design of auto components and rolling out world cars in different markets simultaneously, a study by Camuffo (2002) suggests. A study of the automotive industry in emerging economics by Mukherjee and Sastry (1996) explains that in the case of Asia other than Japan, countries like South Korea, China and India adopted different paths for technology development in the automobile sector. In case of Korea, the technology development has focused to become world class and global and the Korean companies invest heavily on R&D. The emphasis of Chinese policy has been to meet domestic demand and JV route has been widely adopted. On the other hand, facilitation of growth has been a key driver of technology policy in case of India.

A benchmarking study of auto component supply chain in India and China by Sutton (2004) reveals that automotive industry supply chain has proceeded very rapidly in both the countries at the level of automobile manufacturers and Tier-1 suppliers. The main weakness of the supply chain however lies in the fact that best practice techniques are transferred very slowly to the Tier-2 suppliers. TA / JV's have been the preferred routes of the Indian auto component suppliers for technology developments. Jain and Jain (2003) suggest that while forming collaborations, the needs of both local and foreign partners are required to be clearly understood. Collaborative strategies for innovation have proved to be beneficial and a framework has been suggested by Momaya (2008), taking into consideration the organizational boundary and the geographic scope. The framework developed by Momaya can be generally applied to other industries as well including automotive industry and is found to be very relevant for this purpose.

Case studies of technology management in automobile and auto component industry in India explain the technology management practices in select organizations. Select case studies have been carried out by Husain and Sushil (1997), Husain et al. (2002), Sahoo (2004) and Sahoo et al. (2010a, 2010b, 2011 forthcoming). It has been observed through the case studies that organizations have followed different approaches for technology capability building in India. Also, there is a linkage between OEM technology requirement and auto component manufacturer technology acquisition and development. Based on requirement of automobile manufacturers, auto component manufacturers have acquired technology through international collaborations.

Role and Relevance of Strategic Technology Management

To put the broad picture in a simple framework, the evolution of firms in the automotive industry can be broadly explained with the following Technology Capability to Manufacturing Capability matrix (Figure 2). When we examined the evolution of the industry, we find that many of the automobile and auto component manufacturers in India started from the quadrant I (i.e., job order fulfiller) and preferred to focus on manufacturing capability axis (e.g., path a) and move to the quadrant II (i.e., Manufacturing hubs). The prime focus of the industry as a whole has been to improve indigenization levels and improve on operational efficiency. The journey and popularity of TPM, TQM and Deming awards in the last decade is a testimony of this. However, we find very few examples of organizations moving from quadrant I to quadrant IV (along path b or path c via technological focus). This is because the path on the vertical axis is presumably more difficult and there are issues with respect to investment and gestation period and hence associated risk management.

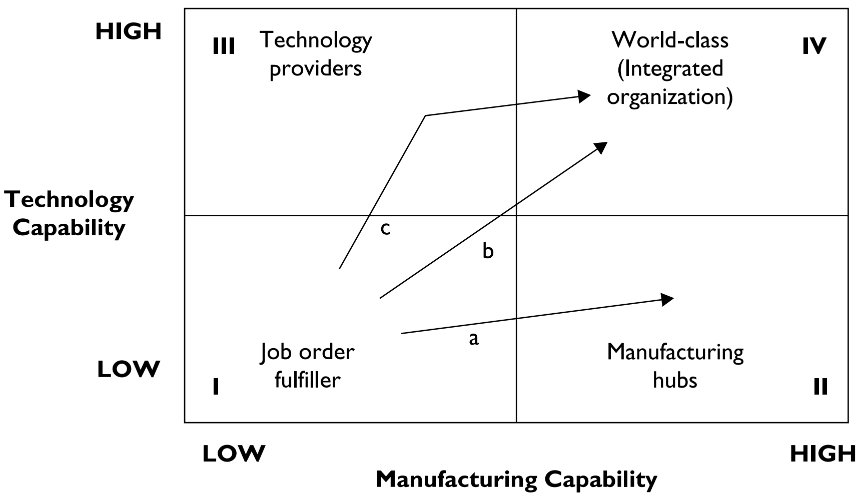

Figure 2. Technology Capability and Manufacturing Capability Matrix

Source: Sahoo (2004).

However, with the changes taking place globally and the change pressures of local market scenario in India, automobile and auto component manufacturers are trying to move in the upward direction. The long term survival, growth and success of the automobile and auto component manufacturers would depend on how well they perform their technology management function and how well they are able to integrate their technology strategy with business strategy. Ultimately, the success lies if they are able to become 'World Class'. This goal of moving into the quadrant IV can be achieved by successful 'Strategic Technology management'.

Analysis of secondary data was carried out to map the current situation of automotive industry in India based on the above framework. In order to map the manufacturing capability, the popularly used 'Trade Competitiveness Index' (TCI) was considered. TCI is an excellent measure of manufacturing competitiveness as it directly and indirectly indicates value addition within the country and the manufacturing technology proliferation (Momaya and Goyal, 2007).

TCI is defined as,
TCI = (Exports – Imports)/(Exports + Imports)

A longitudinal analysis (1998–2007) of the TCI for Top 10 automobile producing countries in the world (based on data sourced from UN Comtrade) shows that Japan and South Korea have very strong TCI followed by India and Germany (see Figure 3). USA has the lowest TCI due to the inherent nature of domestic consumption of automobiles. China, on the other hand has gradually moved up, which is also reflected in the exports thrust being given by Chinese government. Relatively stronger performance of India reflects the actual situation of India becoming the 'Small car manufacturing and export hub' for global automobile manufacturers like Hyundai and Suzuki. The downward trend in the last two years can be explained by the fact that the actual vehicle exports have reduced in the last two years due to strategic intents of manufacturers like Maruti Suzuki.

For assessment of Technology capability, R&D investment has been taken as a simple measure since no direct measure of technology capability could be found from secondary data sources. The R&D scoreboard, 2007, data was used as the base for the mapping of the countries of relevance to our study, i.e., India, Japan, Korea, China and Germany. The data has been analyzed and R&D investment index (RII) has been used to map the automobile and component manufacturers. The details of the compiled data is given in Appendix A.

RII is defined as:
RII (%) = (R&D Investments)/(Sales Turnover) × 100

Using the TCI and RII as indices for 'Manufacturing capability' and 'Technology capability' respectively, we have mapped the position of countries of relevance in Figure 4. Representative sample of Automobile manufacturers and Component manufacturers is mapped in the framework (as shown in Figure 4) for a better understanding of the relative position of each country.

The mapping of the five major countries relevant to our study suggests that Japanese companies have established strong manufacturing and technology capability and thus has been successful in the global automotive landscape. German companies have stronger technology capability and also get mapped in the same quadrant as Japan. Whereas China has progressed on manufacturing front as well as now moving in technology dimension, Korea seems stronger in manufacturing capability. Compared to this,

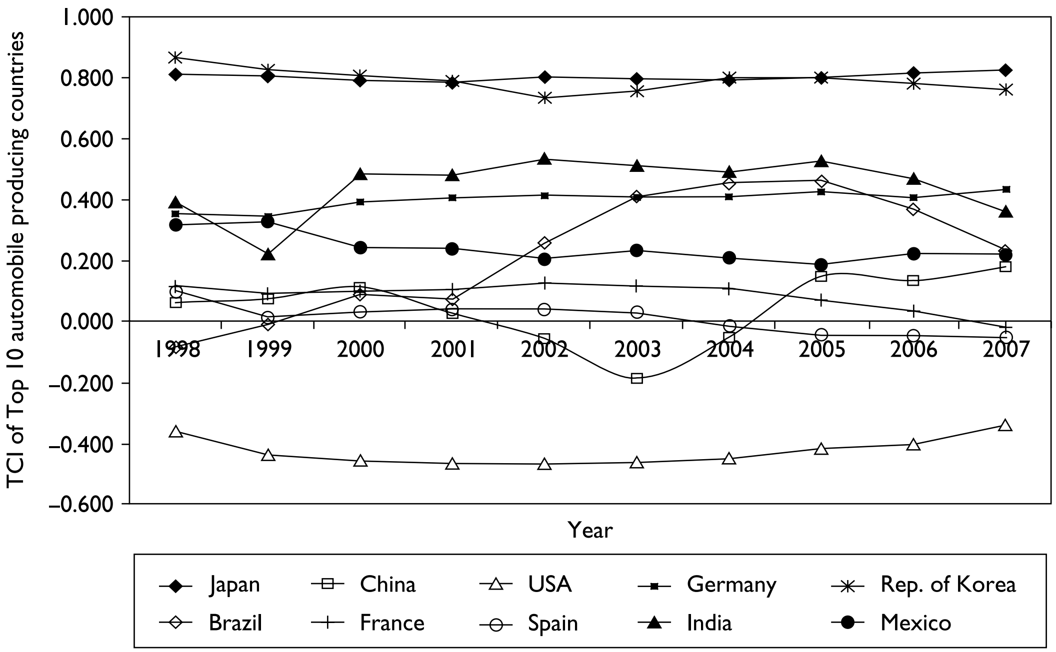

Figure 3. TCI of World's Top 10 Automobile Producing Countries

Source: Developed based on data from UNCOMTRADE, 2008.

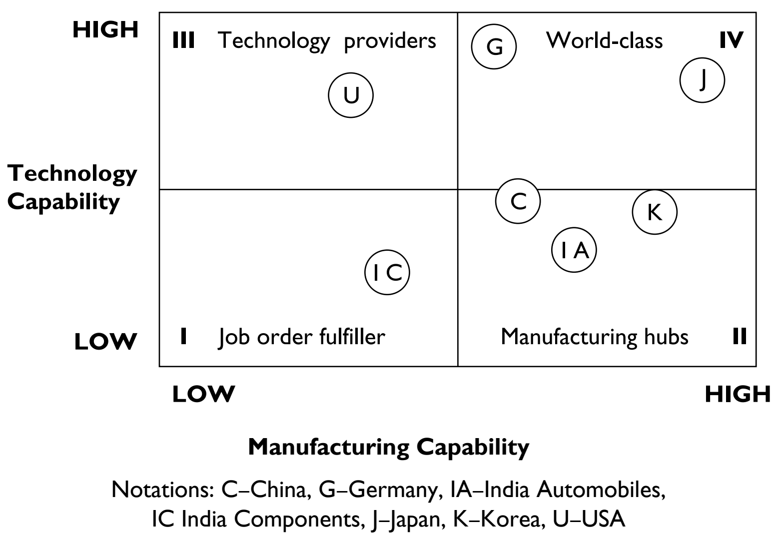

Figure 4. Mapping of Countries on Technology Capability ~ Manufacturing Capability Matrix

Source: Developed by authors.

Automobile manufacturers in India (IA) still lie in the quadrant of 'Manufacturing Hub' and the extent of technology capability is low compared to other countries. The relative position of India, China and Korea on the horizontal axis is based on TCI and thus explains the exports from these countries.

Another important outcome of the RII study is that, the RII for auto component firms is higher than the same for OEMs for most countries, may be due to leading auto component manufacturers like Bosch and Denso whose RII is substantially higher compared to automobile manufacturers. For the sake of bringing clarity, the position of auto component manufacturers in India (IC) was also mapped. On the basis of data collected from private sources and ACMA, the component manufacturers in India still lie in the 1st quadrant. This essentially means that auto component manufacturers today focus on aggregate assembly rather than focusing on increasing value addition.

Gaps Identified

Through the literature survey and secondary data analysis, the following gaps have been identified in the area of Strategic Technology Management in automotive industry in India:

1. Strategic Technology Management is an embryonic field of study, particularly in emerging countries. Some literature is available on strategy, technology management, different areas pertaining to technology management (such as product development, innovation management, technology transfer, etc). However, enough cases of strategic technology management in the Indian context could not be found in literature. Also, a comprehensive macro level framework for showing a path for firms for carrying out 'Strategic Technology Management' could not be found, though there are many frameworks covering specific aspects of STM.
2. The automotive industry in India has improved its manufacturing capability and quality over the years. This is supported by the largest number of Deming Award winners outside Japan, expert opinion from the industry and secondary data analysis. However, the focus on technology capability development, which is important and of higher level is lacking, as is evident from the simple yet powerful analysis carried out in this study.

These results provide the motivation for developing a framework for STM in automotive industry in India, which is covered in the scope of this study. The research can be further strengthened in future by carrying out case studies and empirical research in future to assess the status of STM in automotive industry in India.

Developing a Conceptual Framework for STM

The literature reviewed provided a broad understanding of various factors of Strategic Technology Management. However, no single framework could be found in literature suggested for Strategic Technology Management. Thus, it was proposed to develop a conceptual framework for STM using the ISM methodology.

Interpretive Structural Modeling (ISM)

Interpretive Structural Modeling (ISM) is an effective methodology for dealing with complex issues. It has been used for over 25 years by specially trained consultants to help their clients understand complex situations and find solutions to complex problems. First proposed by J. Warfield (1973), Interpretive Structural Modeling (ISM) is a learning process that enables individuals or groups to develop a map of the complex relationships between the many elements involved in a complex situation. Various researchers (Faisal et al., 2006; Ilyas et al., 2005; Kumar et al., 2009; Saxena et al., 1992; Singh et al., 2003) strongly advocate of the utility of ISM. They have deployed this technique successfully for analyzing complex problems and developing frameworks. The various procedural steps of ISM are well documented in literature.

MICMAC Analysis

The MICMAC methodology, a system of multiplication of matrices applied to structural analysis was developed by Duperrin and Godet (1973) to study the diffusion of impacts through reaction paths and loops for developing hierarchy of variables. MICMAC analysis has been widely used by researchers in various studies and modelling of complex issues. The objective of this analysis is to categorize the variables according to their driving power and dependence (Saxena et al., 2006). Based on the driving power and dependence, factors are classified into four clusters, as explained below. This classification helps in better understanding and clarifies the broader issues.

1. Cluster I: Weak driver and weak dependent factors (points near the origin), a group of so-called *autonomous* factors. These factors are relatively disconnected from the system—they have only a few links, though these links could be very strong.
2. Cluster II: Weak driver and strong dependent factors. These factors are mainly *dependent*.
3. Cluster III: Strong driver and strong dependent factors. These *linkage* factors should be studied more carefully. Any action on these factors will impact others.
4. Cluster IV: Strong driver and weak dependent factors. They condition the rest of the system and are called 'Independent'.

Modeling Approach Used in this Research

The modeling approach in this research using ISM and MICMAC methodologies consists of nine steps as described in the Table 3.

Factors Identified for Developing Framework

An extensive study of literature was carried out and expert opinion was taken to identify the various factors for developing the conceptual framework. The expert's view (five Executive Directors/Vice Presidents/General Managers, three Manager/Senior Managers in automobile and auto component

Table 3. Modelling Approach

Steps	Description
Step 1	Identification of factors relevant for STM, with help from literature and expert opinion
Step 2	Establishment a contextual relationships among the elements by which it is possible to establish their pair-wise comparison.
Step 3	Developing a structural self interaction metrics (SSIM) of elements using pair-wise relationship
Step 4	Developing a reachability metrics from SSIM and by incorporating transitivity of elements
Step 5	Transitivity is established by the assumption that if element A is related to B and B is related to C, then A is related to C
Step 6	Partitioning reachability metrics into different levels
Step 7	Draw a digraph based on relationships as defined in Step 2
Step 8	Convert the resultant digraph to final digraph by removing indirect links
Step 9	MICMAC analysis to categorize the factors into various clusters based on their Driving Power and Dependence

Source: Developed by authors.
Note: The step wise explanation and detailed working is annexed as Appendix B.

industry, two senior officials from industry associations and four academicians) was assimilated for this purpose. The various factors identified through literature review and expert opinion are listed and elaborated below:

- Strategic Business Objective
- Government Policy and Regulations
- Technology Strategy
- In-house development
- Technical agreement
- Joint Venture
- Technology Capability
- Technology performance
- Business Performance
- Other factors

1. **Strategic Business Objective**
   Strategic Business Objective defines the key objectives of the organization based on Vision and key directions of Top Management. As outlined by scholars Friar and Horwitch (1985) and Betz (1994), the strategic objectives pave the way for the organization to formulate the required technology strategy. The top leadership involvement in formulating the strategic objectives ensures the involvement of key personnel of the organization and help providing the direction in technology strategy formulation.
2. **Government Policy and Regulations**
   Government Policy is defined as the extent to which top management views government policies to be restrictive or liberal. With government policies becoming more and more liberal and government providing incentives for R&D investments (Finance bill, 2005, Government of India), it is

expected to have a significant impact on the way organizations formulate their technology strategy. Though similar incentives were given by Government of India in the 1970s, at that point of time the technology level of firms was low and the sourcing of technology from foreign partners was difficult. In the globalized environment when there is no restriction for technology transfer and when technology development is encouraged through such steps by the government, they will have a positive bearing on the industry. The Automotive Mission Plan (Government of India, 2006) also outlines the key initiatives to be taken by Government of India to promote technology development in Indian automotive industry.

3. **Technology Strategy**
   The Technology Strategy consists of policies, plans and procedures for acquiring knowledge and ability, managing that knowledge and ability within the company and exploiting them for profits. As highlighted by Ford (1988), technology strategy is not the same as R&D strategy which is concerned only with acquiring technology through in-house activities. Sahoo et al. (2004) and Husain et al. (2002) emphasize the relevance of technology strategy in Indian automotive industry context as the same has been taken as the guiding and driving force for technology development. Technology strategy will drive the technology development in-house, through TA or through JV or a combination of the three factors.
4. **Technology Development (In-house, TA, JV)**
   When the macro context is not very favourable and the lag is vast, technology sourcing, transfer and absorption can play a key role in STM to build technological capabilities (e.g., Momaya et al., 2004; Nicholls-Nixon, 1995). As suggested in literature, there are primarily two ways of technology sourcing and development. One way is to develop technology in-house and the other way is to source technology from outside. This can be done either through a technical agreement or by forming a joint venture. Cohen and Levinthal (1990, p. 128) found that an internal R&D capability is also an important determinant of the firm's 'absorptive capacity'; that is the firm's 'ability to recognize the value of new, external information, assimilate it and apply it to commercial ends'. This indicates a close link between internal technology development and the capacity to use external source of technology. However, many important technologies lie outside the technological capabilities of the firms, which need to be acquired through license agreements or strategic alliances. Wesley and Daniel argue that the ability to evaluate and utilize outside knowledge is largely a function of prior related knowledge. In essence, in the Indian context development of in-house capability by auto component manufacturers becomes essential for technology absorption through TA/JV.
5. **Technology Capability**
   Technology capability of the organization determines the technological competitiveness of the organization. Stalk et al. (1992) distinguish core competencies defined by Prahlad and Hamel (1990, p. 65), from strategic capabilities: 'whereas core competence emphasizes technological and production expertise at specific points along with value chain, capabilities are more broadly based, encompassing the entire value chain'. They define a capability as 'a set of business processes strategically understood. The key is to connect them to real customer needs'. Though distinct, technological competencies and capabilities are complementary concepts. The stronger the firm in terms of technology (product, process and management aspects), the better the position of the organization in technology implementation, leading to better technology performance.

6. **Technology Performance**
   Technology performance is the result of implementation of technology strategies in the value chain and encompasses the hardware, software and brainware aspects. Since technology capability and technology performance have a phase lag and may differ in dimension, therefore technology performance is considered to be separate from technology capability.
   Technology implementation results in new product and services development and also helps in improving the operational and cost efficiency of the organization, which can be considered as the parameters to judge technology performance. Burgelman et al. (2004) describe the various team structure, project management and product development process, organizational learning and audit for successful implementation of technology strategy. The better the technology implementation, the more successful the firm will be in terms of technology performance. In the Indian context, this becomes a critical success factor.
7. **Other Factors**
   Business strategy is decided based on several factors besides technology capability of the organizations. It includes domains like Service, marketing, regulatory framework and competitive pressures, etc. For the purpose of this study, these extraneous factors, though relevant in the overall business context, are being termed as 'Other factors' and have been excluded from the scope of this study to keep the study focused.
8. **Business Performance**
   Business Performance is the ultimate measure of success or failure of a firm. The performance in business can be determined in terms of Revenue, Market share growth, Exports, Profits, etc. While evaluating business performance, both short term and long term view of the organization performance is required to be taken. Also, what is relevant to see is the relative performance of the organization in the industry.

The Conceptual Framework Developed Using ISM

Using the ISM methodology (see Appendix B), a conceptual framework has been developed for Strategic Technology Management (Figure 5). The framework developed provides the linkages, hierarchies and levels of the identified factors for STM. This macro level framework, though appear simplistic in nature, provide very valuable insights in the context of automotive industry in India.

The framework identifies 'Strategic Business Objective' and 'Government Policy & Regulations' as the main driver of 'Technology Strategy'. It also identifies 'In house development' as one of the routes for developing 'Technology Capability', beside the TA and JV routes. The other key point to be noted is that 'Technology Performance' being at a distinct level from 'Technology Capability'. This could be explained by the fact that in the context of automotive industry, there is long gestation period involved for translating capability into performance. Based on the developed framework, it is suggested that the Strategic Technology Management can be performed as follows:Organizations need to develop the Technology Strategy based on Strategic Business Objective and Government Policy. Based on the technology strategy, Technology Capability can be developed by In-house development/TA/JV. Technology Capability acquired can be implemented to achieve Technology Performance, which will drive Business Performance.

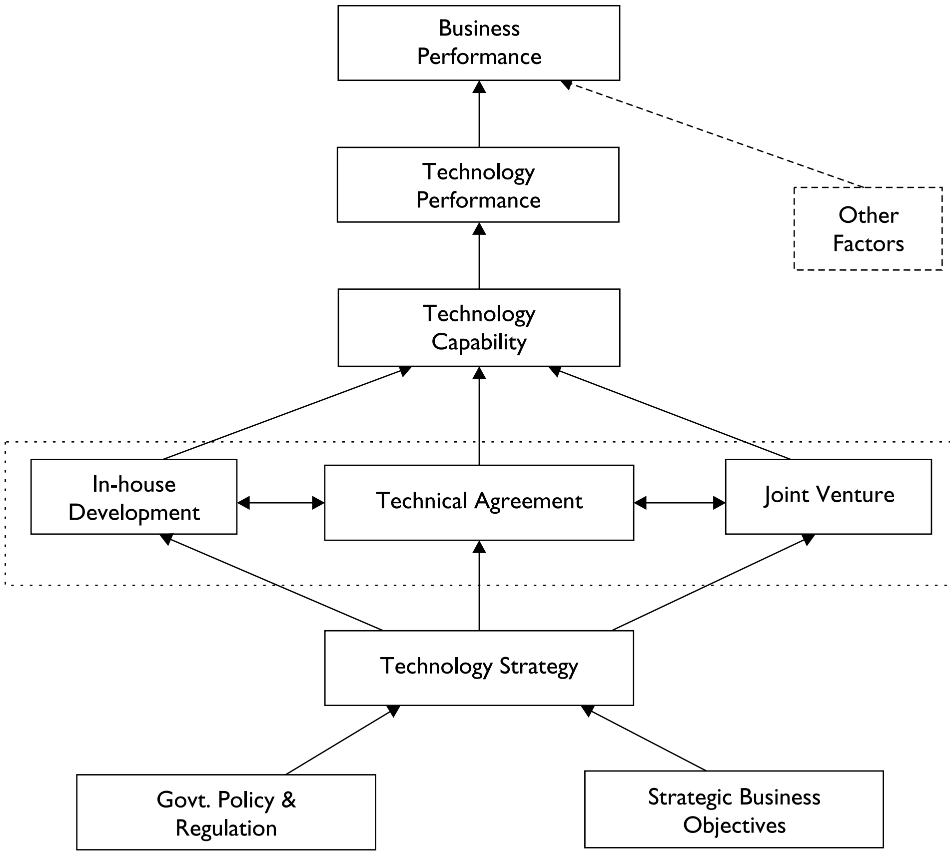

Figure 5. Conceptual Framework for Strategic Technology Management

Source: Developed by authors.

Clustering of Factors Using MICMAC

In this research, MICMAC analysis was carried out and it was observed that the ranks of driving power and dependence of factors for STM get stabilized at 4th iteration M4, with the SSIM of ISM being considered M1. Based on the M1 and M4, the factors for STM were clustered based on their driving power and dependence. The detailed matrices and calculations are appended as Annexure B (Step 9). The key results from MICMAC study (before and after stabilization) are shown in Figure 6 and Figure 7 respectively.

The key finding is that, though initially it appears that driving power is low from the matrix M1, the stabilized matrix M4 reflects that driving power of factor such as 'Strategic Business Objective' (which is dependent on Top Management leadership), is quite high. MICMAC analysis thus proves and substantiates the popular belief that Top Management plays an important role to start any initiative/define the future for the organization.

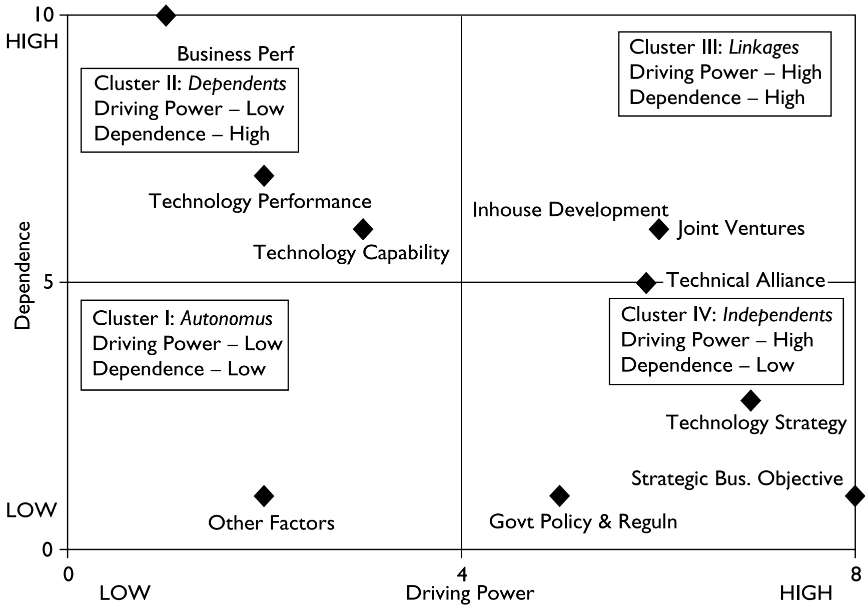

Figure 6. Driving Power and Dependence of Factors for STM (based on M1)

Source: Developed by authors.

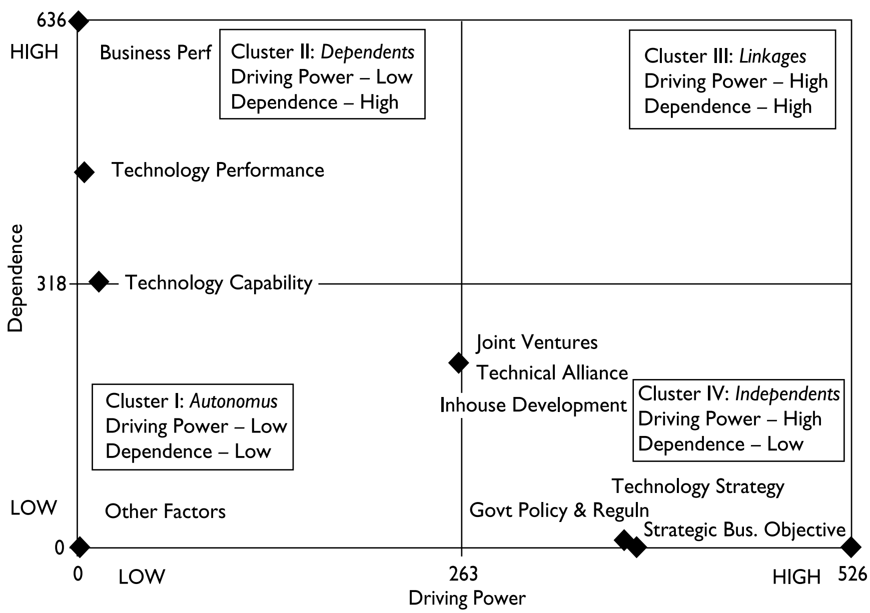

Figure 7. Driving Power and Dependence of Factors for STM (based on M4) after MICMAC

Source: Developed by authors.

The 2nd factor with high driving power and low dependence is 'Technology Strategy'. 'Government Policy & Regulations' is another factor which has high driving power, but very low dependence. This hints at the important role played by government policies for technology capability development.

Through the iterative process, factors such as In-house development and JV have moved from *Linkages* cluster to the *Autonomous* cluster, though with a fairly high degree of dependence. The MICMAC analysis also shows the increasing degree of dependence of 'Technology Capability', 'Technology performance' and 'Business Performance' factors.

MICMAC analysis carried out provides valuable insight and helps interpreting the ISM model from a broader perspective. The conceptual model brings out 'Strategic Business Objective' and 'Technology Strategy' as the most crucial drivers for building technology capability and performance.

Key Findings and Managerial Implications

The concept of STM has been there for a long time, particularly in select developed countries. The study identified several gaps in its understanding, adaptation and implementation in the context in India. Very low share of world production, declining trend in the trade competitiveness index (Figure 1) in automotive industry, hint at huge future challenges for the industry. A more problematic area in terms of STM emerges from comparative view of R&D. Not only are R&D investments low in absolute or percentage terms for a country that wishes to catch-up after losing decades, but data is not available in the public domain for auto component industry. Needless to mention, the stated spending on R&D faces the problem of lack of complete data, hinting at several hidden problems.

Experts opine that technology development in automotive industry in India, particularly in the last decade, has been primarily driven by the regulations that have been promulgated by the Government of India. Most automotive players in India have chosen the path of attempting to progress on operational/manufacturing capabilities to meet market demand. While automotive players in other countries like Japan, Korea and Germany are investing heavily for developing technological capability, the focus on the part of players in India is missing.

For advancing on technology capability dimension, they mostly relied on international collaborations. Without a holistic framework of STM, most collaboration has been of limited help and many players are progressing too slowly on technology capability. While the situation of low and slowly improving technological competitiveness of the players and industry can be partly attributed to strategic gaps in macro policies and their implementation, the gaps in firms may also be the root cause.

The conceptual framework identifies 'In-house R&D development' as one of the ways to develop technology capability. When viewed in conjunction with the theory of 'absorptive capacity' (Cohen and Levinthal, 1990), this provides some insight as to why automotive players in India have really not moved in the technology capability dimension. The other key aspect that has been highlighted during expert interaction is that, quantum of resources required for developing in-house technologies is phenomenal. So far, the industry in general has not displayed any major commitment in this direction. As the gestation period for the projects will be long, this remains a key issue in technology development. This being an important dimension, probably it has not attracted the attention of entrepreneurs/top management, particularly when easier options of sourcing technology through international collaboration are available.

Top leadership involvement is very crucial for any strategic change and the same is required for technology capability development in automotive industry in India. The conceptual framework developed using ISM and MICMAC methodology suggest that the driving power of 'Strategic business objective' led by top management of organizations is quite high and thus will be a key factor to drive the technology strategy of the organization.

At a policy level, the whole focus of Indian auto component industry has been to develop it as a manufacturing hub. There has been little effort in terms of moving into the area of technology development. Of course, this does not mean anyway that the route adopted is wrong. But the case in point is that there has been no major industry wide effort in this direction. It's only in 2006, that the aspect of developing 'design capability' has been included in Automotive Mission Plan 2006–16. While policymakers should review long-term trends in technological competitiveness, (can be reflected in trade competitiveness of the industry, as few firms in India have investments and intellectual property to measure it directly), firms should evolve their matrices to help with critical decisions on STM and their impact. There is need for more bold policies to reverse the negative trends and industry associations can play more useful role. Companies will have to evolve and execute strategies to build dynamic capabilities on technology management and other related fronts to achieve catch-up that has become urgent due to decades lost.

Being focused on developing a conceptual framework based on literature survey and expert opinion, there are limitations of this study and hence scope for lot of further research. This exploratory research does not address empirical testing. ISM and MICMAC methodologies have been used to develop the conceptual framework; however, the same needs to be validated with more in-depth qualitative and empirical research considering the importance in the emerging era.

Concluding Remarks

This research evolves a generic conceptual framework for Strategic Technology Management from the context of growing automotive industry in India, an emerging country. The concepts and the framework evolved can be useful source for leaders and teams of auto component manufacturing sector for accelerating their journey of Strategic Technology Management, which is essential to be competitive and successful in the emerging era. Despite the exploratory nature of the study, the interactions with experts and findings from ISM and MICMAC clearly hint at an urgent need to evolve and implement strategies for a rapid scale-up in overall competitiveness of firms and the industry through strategic management of technology.

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Appendix A

1. Trends in Trade Competitiveness Index (TCI) of Top 10 Automobile Producing Countries

Rank	Country/Year →	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1	Japan	0.813	0.805	0.792	0.786	0.803	0.798	0.794	0.800	0.818	0.826
2	China	0.063	0.074	0.113	0.026	–0.056	–0.186	–0.051	0.148	0.135	0.179
3	USA	–0.362	–0.441	–0.458	–0.468	–0.470	–0.464	–0.452	–0.419	–0.405	–0.342
4	Germany	0.355	0.345	0.394	0.408	0.416	0.409	0.411	0.428	0.408	0.435
5	Rep. of Korea	0.867	0.825	0.807	0.790	0.734	0.758	0.799	0.799	0.781	0.761
6	Brazil	–0.081	–0.009	0.087	0.075	0.259	0.412	0.454	0.462	0.370	0.235
7	France	0.114	0.090	0.100	0.105	0.125	0.118	0.107	0.069	0.034	–0.018
8	Spain	0.099	0.014	0.033	0.040	0.041	0.029	–0.015	–0.045	–0.047	–0.053
9	India	0.392	0.224	0.485	0.479	0.535	0.511	0.491	0.526	0.469	0.364
10	Mexico	0.317	0.328	0.244	0.240	0.204	0.233	0.211	0.186	0.224	0.221

Source: UN Comtrade.
TCI is calculated as TCI = (Exports – Imports)/(Exports + Imports)
Category: Vehicles, HS Classification 87.

2. Trends in Trade Competitiveness Index (TCI) for Automobile and Auto Component Industry in India

Year	2000	2001	2002	2003	2004	2005	2006	2007
Automobiles	0.485	0.479	0.535	0.511	0.491	0.526	0.469	0.364
Auto components	–0.033	–0.039	0.082	–0.078	–0.085	–0.028	–0.091	–0.194

Source: UN Comtrade, ACMA.

3. R&D Investment Index (RII) in Countries of Relevance to the Study

Country	Total No. Companies Surveyed	Automobiles			Components			Grand Total		
		Sales (£M)	R&D Investment (£M)	RII (%)	Sales (£M)	R&D Investment (£M)	RII (%)	Sales (£M)	R&D Investment (£M)	RII (%)
USA	20	190,827	7,161	3.75	89,845	2687.4	2.99	280,672	9,849	3.51
Japan	23	213,295	8,978	4.21	65,329	2879.5	4.41	278,624	11,857	4.26
Germany	15	211,930	8,847	4.17	60,941	3942.4	6.47	272,871	12,789	4.69
France	5	65,447	3,082	4.71	19,483	1000.8	5.14	84,930	4,083	4.81
South Korea	4	34,969	796	2.28	1,134	40.8	3.60	36,103	837	2.32
India	2	5,234	114	2.17	NA	NA	1.50*	5,234	114	2.17

Source: R&D Scoreboard, 2007.

Note: *(Unofficial data, not from R&D Scoreboard); For China, the R&D investment figure is only a reference figure calculated based on several studies.

4. TCI and RII for Countries of Relevance

Index	Japan	China	USA	Germany	Korea	France	India (A)	India (C)
TCI	0.83	0.18	–0.34	0.43	0.76	–0.02	0.36	–0.19
RII (%)	4.26	2.4	3.51	4.69	2.32	4.81	2.17	1.5

Appendix B

Developing a Conceptual Framework for Strategic Technology Management

As outlined in Table 3, a stepwise modeling approach was carried out for developing a macro level conceptual framework for STM relevant to automotive industry in India. The detailed steps and working is explained below.

Step 1: Identification of Factors for STM

Extensive study of literature was carried out and expert opinion was taken to identify the various factors for developing the conceptual framework. Experts from industry and academia were consulted and their views were assimilated for this purpose.

- The objective of the Program is Strategic Technology Management for 'Business Performance'.
- 'Business Performance' is a result of 'Technology Performance' and 'Other Factors'.
- 'Technology Strategy' is strategy to spearhead the technology development activities through 'In-house development', 'TA' or 'JV'.
- 'Technology capability' takes place by carrying out technology development, as per the technology strategy.
- 'In-house capability', 'Technical Agreement' and 'Joint Ventures' are various means of developing technological capability.
- For driving the technology strategy, 'Strategic Business objective' (based on Top Management leadership and vision) needs to be clearly defined.
- 'Government policy and regulations' provides reasons for firms to enhance their technological capability and thus influence the technology strategy.
- 'Other factors': Factors other than technology (e.g. competition, marketing, customer relationship etc.), that affect business performance—however, not included in the scope of this research work.

The various factors identified through literature review and expert opinion for ISM are listed below:

1. Business Performance
2. Strategic Business Objective
3. Technology Performance
4. Technology Strategy
5. Technology Capability
6. In-house Development
7. Technical Agreement (TA)
8. Joint Ventures
9. Government Policy and Regulations
10. Other factors

Step 2: Defining the Contextual Relationships between Factors

Detailed study was conducted and the following contextual relationship was found most appropriate for developing ISM for STM. The relationship and notations used building SSIM are described below:

V – Will help achieve
A – Will be achieved by
X – Will help achieve each other
O – No relation

Step 3: Developing the Structural Self Interaction Matrix (SSIM)

The SSIM was developed by carrying out the pair-wise comparison of elements using the relationship and notations as explained earlier. The SSIM developed is shown below:

SSIM	10	9	8	7	6	5	4	3	2
1	A	A	A	A	A	A	A	A	A
2	O	O	V	V	V	V	V	V	
3	O	O	A	A	A	A	A		
4	O	A	V	V	V	V			
5	O	O	A	A	A				
6	O	A	X	X					
7	O	O	X						
8	O	A							
9	O								

Step 4: Developing the Reachability Matrix

Based on the above SSIM, the reachability matrix is drawn as follows, by replacing the contextual relationships with binary digits as per the following rules:

(1) If the (i, j) entry in the SSIM is V, the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes O.
(2) If the (i, j) entry in the SSIM is A, the (i, j) entry in the reachability matrix becomes 0 and the (j, t) entry becomes 1,
(3) If the (i, j) entry in the SSIM is X, the (i, j) entry in the reachability matrix becomes 1 and the (j, I) entry also becomes 1.
(4) If the (i, j) entry in the SSIM is 0, the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also become 0.

A (Pi)

R (Pi)

Matrix	1	2	3	4	5	6	7	8	9	10
1	1	0	0	0	0	0	0	0	0	0
2	1	1	1	1	1	1	1	1	0	0
3	1	0	1	0	0	0	0	0	0	0
4	1	0	1	1	1	1	1	1	0	0
5	1	0	1	0	1	0	0	0	0	0
6	1	0	1	0	1	1	1	1	0	0
7	1	0	1	0	1	1	1	1	0	0
8	1	0	1	0	1	1	1	1	0	0
9	1	0	0	1	0	1	0	1	1	0
10	1	0	0	0	0	0	0	0	0	1

Step 5: Transitivity check

The transitivity was checked and found to be OK.

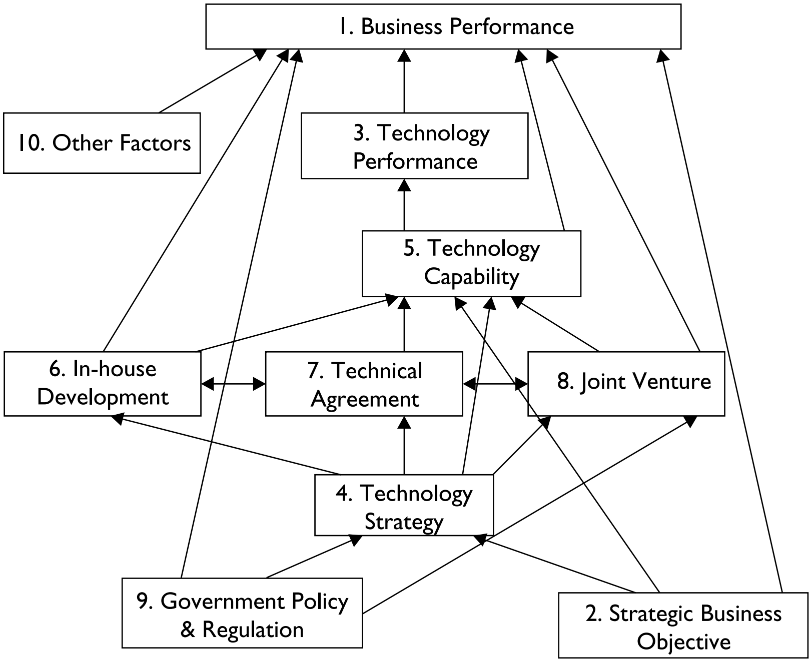
Step 6: Partitioning

Now the partitioning of the SSIM is carried out and the results are summarized below:

Element Pi	Reachability Set R (Pi)	Antecedents Set A (Pi)	Intersection Set R (Pi) n A (Pi)	Levels
1	1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	1	1
2	1, 2, 3, 4, 5, 6, 7, 8	2	2	6
3	1, 3	2, 3, 4, 5, 6, 7, 8, 9	3	2
4	1, 3, 4, 5, 6, 7, 8	2, 4, 9	4	5
5	1, 3, 5	4, 5, 6, 7, 8	5	3
6	1, 3, 5, 6, 7, 8	2, 4, 6, 7, 8, 9	6, 7, 8	4
7	1, 3, 5, 6, 7, 8	2, 4, 6, 7, 8	6, 7, 8	4
8	1, 3, 5, 6, 7, 8	2, 4, 6, 7, 8, 9	6, 7, 8	4
9	1, 4, 8, 9	9	9	6
10	1, 10	10	10	2

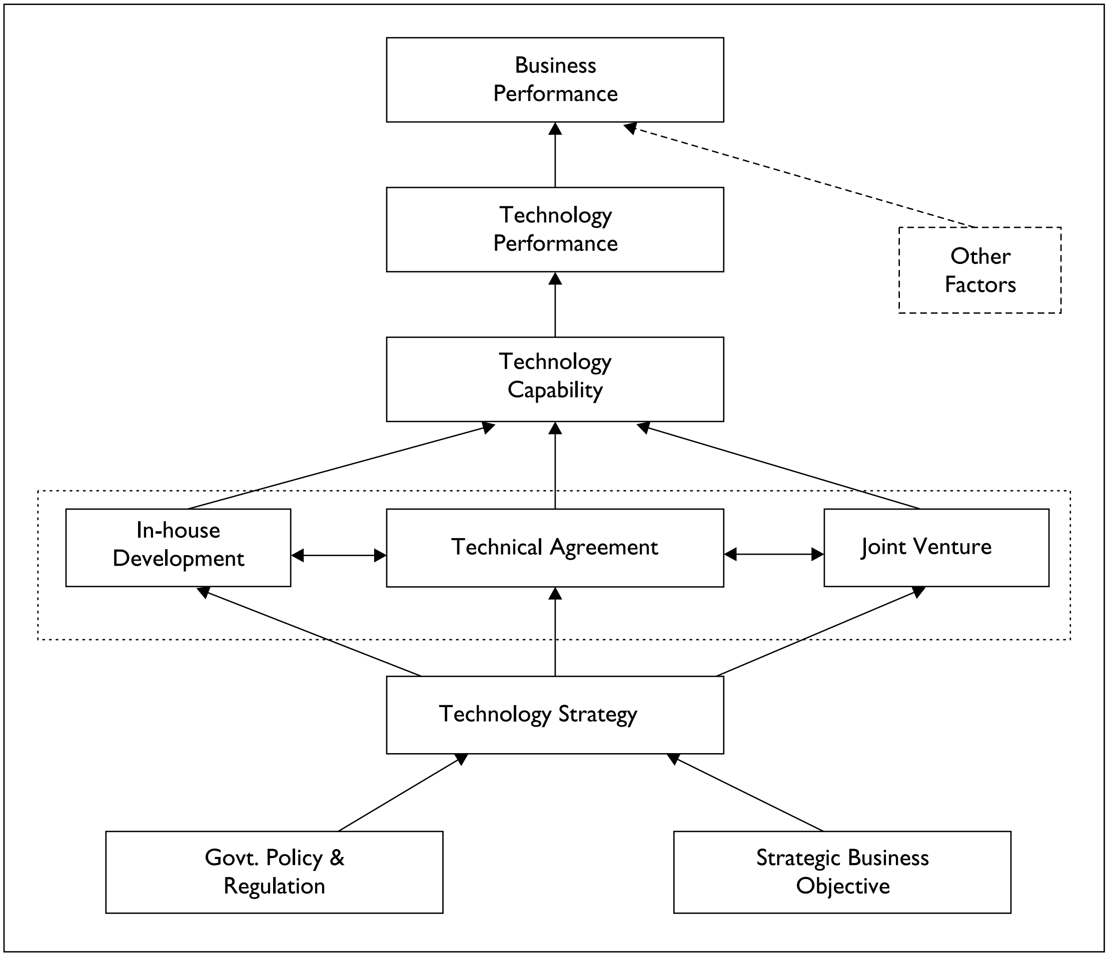
Step 7: Leveling of Elements and Construction of Diagraph

The various elements are levelled and the diagraph is constructed using the relationship from SSIM



Step 8: Drawing of Final Diagraph

By removing the direct links, the final diagraph is made as follows:



Step 9: MICMAC Analysis

MICMAC analysis was carried out starting with the base reachability matrix M1 developed in ISM, based on the contextual relationship in the SSIM. The process of matrix multiplication was continued till the time the ranks of factors based on driving power and dependence becomes stabilized.

It was observed that the stabilization occurs at M4. The Matrices M1, M4 are shown as follows.

Matrix M1

A (Pi)

R (Pi)	Matrix M^1	1	2	3	4	5	6	7	8	9	10	Driver Power	Rank
	1	1	0	0	0	0	0	0	0	0	0	1	7
	2	1	1	1	1	1	1	1	1	0	0	8	1
	3	1	0	1	0	0	0	0	0	0	0	2	6
	4	1	0	1	1	1	1	1	1	0	0	7	2
	5	1	0	1	0	1	0	0	0	0	0	3	5
	6	1	0	1	0	1	1	1	1	0	0	6	3
	7	1	0	1	0	1	1	1	1	0	0	6	3
	8	1	0	1	0	1	1	1	1	0	0	6	3
	9	1	0	0	1	0	1	0	1	1	0	5	4
	10	1	0	0	0	0	0	0	0	0	1	2	6
	Dependence	10	1	7	3	6	6	5	6	1	1		
	Rank	1	6	2	5	3	3	4	3	6	6		

Matrix M4

A (Pi)

R (Pi)	Matrix M^4	1	2	3	4	5	6	7	8	9	10	Driver Power	Rank
	1	1	0	0	0	0	0	0	0	0	0	1	7
	2	152	1	113	4	82	58	58	58	0	0	526	1
	3	4	0	1	0	0	0	0	0	0	0	5	6
	4	113	0	82	1	58	40	40	40	0	0	374	2
	5	10	0	4	0	1	0	0	0	0	0	15	5
	6	82	0	58	0	40	27	27	27	0	0	261	4
	7	82	0	58	0	40	27	27	27	0	0	261	4
	8	82	0	58	0	40	27	27	27	0	0	261	4
	9	105	0	79	4	60	45	44	45	1	0	383	3
	10	4	0	0	0	0	0	0	0	0	1	5	6
	Dependence	635	1	453	9	321	224	223	224	1	1		
	Rank	1	7	2	6	3	5	5	4	7	7		

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