Chapter No. 3

Research Design and Methodology

3.1 Introduction

In this chapter the research design and the research methodology used, the blueprint for conducting the research, data collection, instrument design, research format, outline plan for data analysis (statistical methods/ tools employed) have been covered. In the previous chapter, the literature review has been conducted, wherein the constructs of strategic sourcing (SS) and risk management (RM) have been covered along with the research gaps identified therein and the research objectives of this study. The literature review has formed the edifice for the architecture of the research, i.e. the research design and methodology. This chapter encompasses the overview of the research framework adopted for the study and the relevant details including implementation, data analysis and inferences have been covered in subsequent chapters.

This chapter is divided into three sections. Section 3.1 covers an overview of the research process. The second section (3.2) and third section (3.3), covers survey, instruments, data collection, and statistical techniques/ tools used for analysis respectively, as well as their appropriateness in meeting our research objectives respectively.

3.2 Overview of the Research Process

Research is a scientific rigorous process that should be undertaken in a structured manner (Chen et al., 2013). Research process entails a series of logically ordered directional choices, running from problem formulation, design and execution of study, analysis and interpretation. The set of choices is systematically circular, i.e. it starts with a problem and gets back to a problem, though, never arrives back at the exact starting point, even if all goes well (McGrath, 1982; Veloso, 2000; Jawahar Babu, 2012). Broadly our research process subscribes to this viewpoint.

Different research designs used by various researchers are divided into three categories, according to AT Kearney, 2013 which include exploratory, descriptive, and experimental. The fact that the strategic sourcing risk management (SSRM) has just received much attention in the recent past and the research in this field has been mainly towards formalization of concepts etc.

and use a positivism approach (SIAM, 2015). The conceptual studies are meant to represent research methodology that describes basic/ fundamental concepts of SSRM. Most papers propose conceptual framework for managing supply network/ sourcing risks, followed by empirical research, which is by far less than the conceptual and exploratory researches (Zsidisn and Ritchie, 2008).

This study has been based on research objectives leading to the development of a conceptual framework and resultant model, the intention being to carry out a quantitative, scientific examination of the proposed relationship paths of the constructs identified and outcomes in the SSRM in Indian automotive industry. The study, uniquely, seeks to ascertain the perspectives of strategic sourcing/ supply management in establishing the tenets of meaningful risk management in the automobile industry in the Indian context. The coverage includes overall research methodology, research design, sampling strategy, measurement of constructs and design, research instrument and the statistical tools employed, i.e. the significant issue about the methodology of data analysis.

In order to prepare a comprehensive strategic sourcing risk management (SSRM) normative framework for the Indian automobile industry a detailed study of the risk sources, risk drivers and a supplier selection model incorporating the cost components and risk factors has been undertaken post literature review and identified research gaps. The data has been collected through both primary (industry practitioners and academicians by means of detailed interactions/ in-depth interviews, surveys etc.) and secondary sources (including online databases, annual reports, third-party data providers, etc.). Both quantitative as well as qualitative statistical tools have been employed, namely Bayesian network modelling for risk sources, exploratory factor analysis for risk drivers (enablers and barriers) and analytical hierarchy process and data envelopment analysis for the risk adjusted model for supplier selection in global sourcing context. The outcomes of these three models/ analysis are 'Risk Assessment Index' (an empirical Indian automobile industry specific risk model), 'Force Field Analysis of Strategic Sourcing Risk Barriers and Enablers' and 'Risk-Adjusted Total Cost of Ownership Model for Strategic Sourcing Decisions'. The architecture of research design and research methodology of this study bringing out the research objectives, data collection (source, type, and methodology), data analysis/ statistical tools/ techniques employed and analysis/ outcome is given at Fig. 3.1. Brief description of the data collection and data analysis techniques is provided hereafter in this chapter.

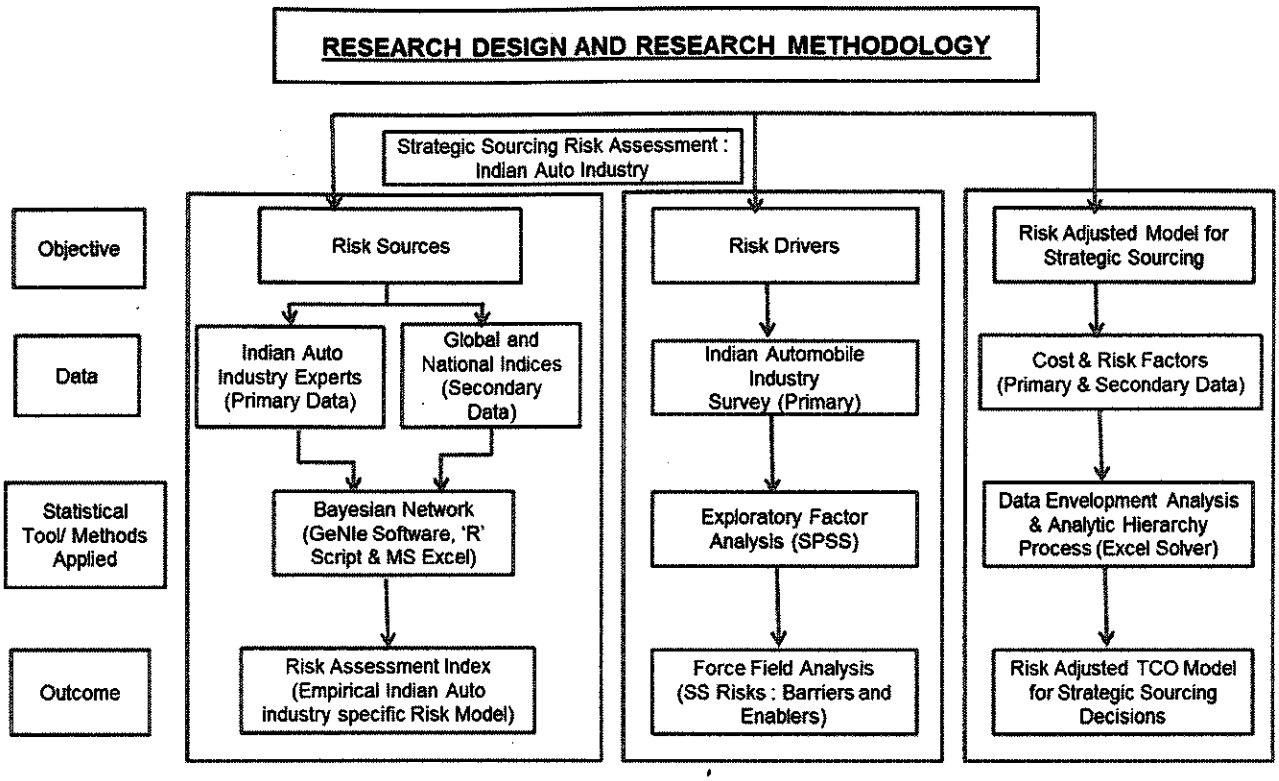

Fig. 3.1: Research Design and Research Methodology Architecture

3.3 Survey, Instrument and Data Collection

Survey research is used to quantitatively examine relationships between various constructs using a sample of the population and is subjective in nature (Jamil and Yang, 2013). There are many variables involved in this study and therefore to study many variables at a time and finding a pattern in these variables, survey research methodology seems most appropriate. Survey method is widely used especially when the aim is to collect as large number of responses as possible and is comparatively simple to administer and obtain responses (Hair et al., 2013; Arena et al., 2017). The survey research method is employed when the study pertains to assess/ identify practices, situations or views at one point in time. Data collection methods include questionnaires, interviews, etc. Various analytical techniques including quantitative are applied to draw inferences regarding existing relationships. A mixed mode survey approach is adopted in which the bulk of the responses are elicited through both mail survey and personal interviews. In addition to the primary data, the secondary data sets have also been utilized in respect of risk factor parameters for which global and national indices/ data are available, namely exchange rates, raw material price, GDP, GNI per capita etc.

The extent of measurement error in this study has been sought to be reduced by using a standard questionnaire applied through mail survey, the respondents being well versed with the domain of study and personal interviews where necessary. The questions in the survey instrument have been kept simple and short as possible (Kim and Chai, 2017). The instrument has been developed by careful consideration in avoiding leading questions and any bias in them in order to reduce measurement error (Salant and Dillman, 1994; Joshi et al., 2017).

3.3.1 Survey Instruments

The survey instruments have been in the form of structured questionnaire with respective constructs and indicators designed to elicit responses from higher management and purchasing/ procurement professionals. The survey instrument is formulated based on an extensive literature survey as well as consultants in the automotive industry. The scale items are then amalgamated suitably in the form of questionnaires. The questionnaire is divided into two parts. Part A is preceded by a brief explanation and objectives of the study, contained unstructured questions and is open-ended in nature designed to ascertain information about the respondents company such as name, major products/ vehicle variants, number of employees. The covering note to the questionnaires, besides elucidating the background, purpose and significance of the study, also stresses the fact that the response shall be confidential and that if the respondent so desired, the summary of results and recommendations will be sent to them.

3.3.2 Biases

Biases have been identified a major source of systematic measurement error (Podsakoff et al., 2003) adversely affecting validity of results including aspects of causal relationships. However, studies have noted that the 'variance due to method biases varied considerably by discipline and by the type of construct being investigated' (Podsakoff et al., 2003). Adequate care has been taken to reduce the possibility of method bias and common method variance, such as avoidance of negatively worded items. Some of the measures taken to reduce the biases incorporated during the study are as follows:

- Avoidance of negatively worded items.
- Wording the questions in a manner so as to avoid indicating a pattern to the respondent.

- Optimal scale length to balance between respondent convenience and method bias.
- No intermixing of items on the questionnaire.
- Using multiple research formats - administering, questionnaire, secondary sources and also face-to-face interviews.
- Permitting anonymous response by making it optional to fill in personal and company name.

Ideally, to address the issue of bias (Podsakoff et al., 2003) the measurement of constructs in a longitudinal manner is suggested. This is not as per the research setting of the study which is cross-sectional in nature. Common method bias can also be reduced by using mixed measurement scales but this has not been followed in this study which measured indicators on 7-point Likert scale for ease of response and uniformity. However, scales are differently worded for the constructs to the extent possible in order to reduce monotony in responding and generate interest in the aspects covered.

3.3.3 Pre-Testing of Questionnaire

The survey instruments have been pre-tested in the following stage-wise manner:

- The instrument has been examined for relevance and applicability by senior managers responsible for sourcing/ procurement and supply network function in their respective companies.
- The instrument is then pre-tested for content validity, clarity and relevance by obtaining responses from 25 practitioners including management consultants from the automobile industry and managers from associated trade bodies.
- Based on the above, suitable modifications have been made to the questionnaire and a partial pre-test was done involving a different set of respondents.
- The final stage of the pre-testing of questionnaire involved discussing it with a few members of automotive trade associations (ACMA, SIAM and CII) as well as academics and consultants associated with this sector. Their suggestions, as relevant, have been incorporated in finalizing the questionnaires.
- The finalized questionnaires, after the above-mentioned stage wise pre-testing process, have been then transcribed into form suitable for electronic means of transmission.

3.3.4 Survey Administration and Response

The survey has been carried out to seek responses from the sample population. Survey method is widely used especially when the aim is to collect as large number of responses as possible and is comparatively simple to administer and obtain responses (Hair et al., 2013). ACMA and SIAM, the industry bodies comprising auto component manufacturers (suppliers) and OEMs and CII provided assistance and advice in providing the e-mail addresses of their member companies as well as of the senior managers and CEOs. The relevant details about the number of professionals and companies have been approached and their relevant details are covered in the subsequent chapters, i.e. Chapter No. 4 to Chapter No. 7.

The administration of the survey instrument was done in two stages. The first stage involved transmission through e-mail and simultaneously posting it by normal mail post. Concurrently with the electronic means, the questionnaires have been mailed by post to the surveyed population along with a postage paid envelope for returning the completed questionnaire. The mail survey, both by e-mail and surface mail has been complemented by a number of randomly selected interviews where it has been felt that respondents may require intervention to facilitate the process of completing research instruments. The possibility of self-selection bias and false representation (Zikmund and Babin, 2007) was addressed by ensuring that each respondent fills in their business details. The details of responses received have also been covered at appropriate places in the subsequent chapters.

3.4 Analysis of Data

Figure 3.1 enumerates the multi-variate techniques employed for undertaking analysis and interpretation of the results with respect to objectives of the study. A healthy mix of both qualitative as well as quantitative statistical tools/ techniques have been employed in the research. The data analysis reports the descriptive statistics of the sample as well as development of the measurement model and subsequently relevant descriptive statistics of the sample are covered along with the application of EFA and Bayesian network techniques and estimation of the model by DEA. The score reliability is estimated as reliability coefficients and a commonly used type is 'coefficient alpha' or 'Cronbach's alpha' (Hair et al., 2013). In this study, construct reliability was ascertained at the EFA stage and the results along with fit indices are reported. A brief overview of the Bayesian network (BN) employed for development of risk sources index to meet the first research objective, exploratory factor analysis (EFA) for inter-relations between the risk drivers and force field analysis (FFA)

(of barriers and enablers) pertaining to second research objective and data envelopment analysis (DEA) and analytical hierarchical process (AHP) for developing the risk-adjusted total cost of ownership supplier selection model for the third research objective employed in this study are covered hereafter.

3.4.1 Bayesian Network (BN)

A Bayesian network, Bayes network, belief network, Bayesian model is a probabilistic graphical model that represents a set of variables and their conditional dependencies via a directed acyclic graph (DAG). Bayesian networks are DAGs whose nodes represent variables in the Bayesian sense. Edges represent conditional dependencies; nodes that are not connected (there is no path from one of the variables to the other in the Bayesian network) represent variables that are conditionally independent of each other. A particular set of values for the node's parent variables, gives the probability of the variable represented by the node. Net child node in our study is 'Effect on Gross Turnover of Industry'.

Quantitative tools in risk assessment (RA) commenced with decision tree analysis to select amongst the risk options vis-à-vis risk factor itself. One dimensional scenario analysis is also predictive in nature, though it is purely a qualitative approach. The Bayesian network technique is a comprehensive one in that it estimates multiple and inter-related dependence relationships and corrects for measurement errors during estimation. It is often used to analyse causal relationship between entities. For example, a Bayesian network could represent the probabilistic relationships between risks and outcome/ impact on industry. Given outcome, the network can be used to compute the probabilities of the presence of various risk factors. The following aspects have been considered in ensuring an adequate specification of the model:

- Appropriate inclusion of variable has been based on extensive literature survey in the domain of strategic sourcing and risk management in the automotive sector as well as on in-depth interviews and interactions with industry practitioners and experts.
- The constructs have been measured using multiple indicators with a minimum of three per construct.

An empirical Bayesian network model to assess and evaluate industry specific risk (including financial risks, economic risks, sourcing/ supply network risks and natural calamities risks) has been developed using GeNiE software. The RA model has been developed in this research for quantifying sourcing/ supply risks in Indian automobile industry employing nine

identified risk factors (RFs), grouped into three intermediate level RFs, i.e. Business, Economic and Environmental. Risk factors have been identified (data based structural development & evaluation through expert's elicitation of parameters) and then relationships between them have been established through Delphi method. Delphi method entails conversion of opinions of panel of experts into an informed consensus through a highly structured feedback mechanism (Goodman, 1987). It is generally applied to long term forecasting of demand, particularly for new products or situations not suited for quantitative analysis and it provides good ballpark estimates when little or no data is available (Hutt and Thomas, 2012; Garvey et al., 2015). Data has been collected from various sources and two domestic and two MNCs representatives of Indian auto industry. Subsequently one of the three discrete states (high, medium and low) have been assigned to variables using 'R' Script and conditional probability tables have been arrived at, followed by the last step of sensitivity analysis. As the Bayesian network modelling incorporates probabilistic risk assessment (PRA) concepts, available historic data and experts' judgments/ opinions and thus suited the study's risk assessment in Indian automotive sector context. The conceptual constructs and modelling steps have been covered in detail in the fourth chapter.

3.4.2 Exploratory Factor Analysis (EFA) and Force Field Analysis (FFA)

Exploratory factor analysis (EFA), a multivariate statistical method, has been used to uncover the underlying structure of the risk drivers of strategic sourcing risk management (SSRM) in view of the relatively large set of variables. Overarching goal of the factor analysis in EFA has been to identify the underlying relationships between measured variables. Usually, researchers would have large number of measured variables, which are assumed to be related to a smaller number of 'unobserved' factors. EFA has been adopted in view of its results being more accurate when each factor is represented by multiple measured variables in the analysis. EFA is based on the common factor model. In this model, manifest variables are expressed as a function of common factors, unique factors, and errors of measurement. Each unique factor influences only one manifest variable, and does not explain correlations between manifest variables. Common factors influence more than one manifest variable and 'Factor loadings' are measures of the influence of a common factor on a manifest variable. EFA assumes that any indicator/ measured variable may be associated with any factor. EFA has been employed to determine underlying risk drivers for SSRM in Indian automobile industry.

SPSS software has been utilized to conduct the EFA of the data collected through survey instrument as part of this research. Initially factorability was examined by correlation of factors with each other and Kaiser Meyer Olkin (KMO) measure of sampling adequacy was found to be above the commonly recommended value. In addition, Bartlett's test of sphericity was significant. A total of eight factors correlated atleast 0.3 with other item(s). Descriptive statistics, factor loading and reliability statistics have been reported in detail in Chapter 5. Force field analysis (FFA) was conducted on the identified enablers (Supply flexibility, Partnership with suppliers, Supplier risk assessment and Data sharing in supply network) and barriers (Adhoc or poor planning, Hard visualization of SSRM benefits, Data security/ privy breaches and Cost focus) by employing mean response and factor loadings thereof. Results of FFA and findings have been enumerated in detail in Chapter 5 and it has been observed that the restraining forces contributed by the barriers outweigh the driving forces provided by enablers with respect to the risk drivers of strategic sourcing in the Indian automobile industry.

3.4.3 Data Envelopment Analysis (DEA) and Analytic Hierarchy Process (AHP)

Data envelopment analysis (DEA) is a non-parametric method effective for employment in operations research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision-making units (DMUs). Although DEA has a strong link to production theory in economics, the tool is also used for benchmarking in operations management, where a set of measures is selected to benchmark the performance of manufacturing and service operations (Cook et al., 2014). DEA is referred to as 'balanced benchmarking' by Sherman and Zhu (2014) and Tupa et al. (2017).

The framework has been adapted from multi-input, multi-output production functions and has been applied in many industries. DEA develops a function whose form is determined by the most efficient producers. DEA identifies a 'frontier' which is characterized as an extreme point method that assumes that if a firm can produce a certain level of output utilizing specific input levels, another firm of equal scale should be capable of doing the same. The most efficient producers can form a 'composite producer', allowing the computation of an efficient solution for every level of input or output (Berg, 2010). DEA has been used for both production and cost data. Utilizing the selected variables, such as unit cost and output, DEA software searches for the points with the lowest unit cost for any given output, connecting those points to form the efficiency frontier.

However, these features may not actually represent inputs and outputs at all, in the standard notion of production. In fact, if one examines the benchmarking literature, other terms, such as 'indicators', 'outcomes', and 'metrics', are used. The issue now becomes one of how to classify these performance measures into inputs and outputs, for use in DEA (Cook et al., 2014).

In this study, DEA has been identified to develop a risk-adjusted total cost of ownership (TCO) model for sourcing decisions in the Indian automobile industry, as logical extension of the TCO models and factoring in the identified risks. DEA has been employed in view of the following advantages and applicability in the context of the research by developing an effective model/ quantifiable tool for the Indian automobile industry decision makers in risk-adjusted strategic sourcing:

- No need to explicitly specify a mathematical form for the production function.
- Proven to be useful in uncovering relationships that remain hidden for other methodologies.
- Capable of handling multiple inputs and outputs.
- Capable of being used with any input-output measurement.
- The sources of inefficiency can be analysed and quantified for every evaluated unit.

The methodology has been covered in detail in Chapter 6 and brief outline is covered hereafter. During the first step, 'Define', the TCO cost factors and the risk factors have been defined/ identified. This entailed employing outcome of the study undertaken till this stage, i.e., risk sources, risk drivers and the practices adopted by the automobile industry for sourcing. A total of twelve TCO cost factors, namely, "Manufacturing, Warehouse, Operations, Quality, Logistics, Transportation, Inventory, Administration, Transaction, Training, Communication and Miscellaneous", have been arrived at. Three risk factors have also been established,

namely, transmissions risks, economic risks and external risks. The second step, 'Measurement', involved quantification through assignment of risk priority numbers (RPNs), i.e., probabilty of occurrence of failure, non detection probability and amount of harm/ damage in failure mode and effect analysis (FMEA). The inputs for DEA and RPNs were worked out in close consultation with the subject matter experts (SMEs) of five different Indian automobile OEMs. They have been approached for inputs including with respect to reliability validity of the data sources.

In order to find relative importance of subject risk factors in particular risk category, the analytic hierarchy process (AHP) has been used. AHP is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. It has particular application in group decision making and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, shipbuilding and education. Rather than prescribing a 'correct' decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem.

The AHP helps to convert the SMEs evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This distinguishing capability of the AHP from other decision-making techniques made it amenable to be employed in this research work. A risk-adjusted TCO model for strategic sourcing (SS) decisions/ supplier selection has been evolved employing the DEA and AHP as part of this research work, details of which are covered in Chapter 6.

The architecture and overview of the research design has been covered in this chapter encompassing the data collection and analysis methods adopted as part of this study to formulate a normative SSRM framework for the professionals of the Indian automobile industry. The next three chapters cover the first three research objectives, namely the 'Risk Assessment Index' (risk sources), 'FFA of SS Risk Drivers' (enablers and barriers) and the 'Risk-Adjusted TCO model for Sourcing Decisions' respectively, followed by normative SSRM framework in the seventh chapter.