economically a firm's resources are utilized while providing a pre-specified level of customer satisfaction. Discussions of sustainability are driven by the basic notion that a supply chain's performance should be measured not just by profits, but also by the impact of the chain on ecological, social systems, economics and resources (Gladwin, Kennelly and Krause 1995; Starik and Rands 1995; Jennings and Zandbergen 2005; Keeble, 2003). What is essential to supply chain performance is improving the effectiveness of materials management – the set of business processes that support the complete cycle of material flows from purchasing and internal control of production materials, through the planning and control of work-in-process, to the warehousing, shipping, and distribution of finished products (Markley and Davis, 2007).

Evaluating the performance of the firms in a supply chain is a very difficult and sophisticated task. Although there are many different models and indicators used for supply chain performance measurement in literature (Kaplan and Norton, 1992, Tangen, 2004, Pariada and Cattopadhyay, 2007), in view of the sustainable development this number decreases drastically (Singh et al., 2007, Labuschagne et al., 2005). However, in case of using too many indicators, it is quite difficult to assess sustainability. Further, since managing decisions, such as sustainable supply chain, properly imply involving various participants and perspectives, it is argued that it is impossible to reduce all dimensions to a single unity of measure. Then the issue is that all valuations should somehow be reducible to a single one-dimension standard. Multi-criteria evaluation introduces a framework to remedy this issue (Erol et al, 2011).

In this study, a multi-criteria decision making method to select the best performance in a sustainable supply chain within the alternatives is given. For this reason, DEMATEL method is used to highlight the relations between the performance criteria with graph theory and matrix approach which are used to visualize the relations and calculate the index value for the numerical function.

2. Sustainable performance indicators

In this study, sustainability criteria which are usually seen as economic, social and environmental aspects are evaluated under the performance measurement view with the addition of the business dimension. Resource usage criterion which is evaluated under the environment dimension is taken as a discrete sustainability criterion for the performance evaluation of the firms.

Criteria used for the evaluation of sustainability of the firms in a supply chain are given:

Sustainable economic performance criteria: Innovations created through supplier partnerships, Total sales, The number of shareholders, Promoting new investments, Establishing new employment opportunities, Total tax paid, Competitiveness of the forward and reverse supply chain sub-criteria are used to evaluate the sustainable economic performance.

Sustainable social performance criteria: training time, applied innovative ideas generated by employees /employee, personnel turnover, recordable incidents with respect to harassment and violence/employee, recordable accidents/employee, recordable employee complaints/employee, customer complaints, Fraction of total sales invested for social projects / year, Effectiveness of discipline management, Effectiveness of compensation management, Effectiveness of Personnel Recruitment and Selection, Organization's openness to stakeholder involvement in decision making, Institutional efficiency, Effectiveness of performance management system sub-criteria are used to evaluate the sustainable social performance.

Sustainable environmental performance criteria: Waste minimization, Number of ISO standards developed, Fraction of facilities using renewable energy, Effectiveness of reverse logistics system, Effectiveness of supplier training in environmental issues, Fraction of suppliers certified in ISO 14001, Fraction of facilities using HFC powered units, Use of recycled materials, Effectiveness of the 3PL company, with which the company works, sub-criteria are used to evaluate the sustainable environmental performance.

Sustainable resource performance criteria: Total size of the stores, The number of stores, The number of people employed, Energy consumption, Water consumption, sub-criteria are used to evaluate the sustainable resource performance.

3. Methods

The following procedural diagram depicts the overview of the DEMATEL combined with Graph theory and matrix approach adopted in the present research. As shown in Figure 1, the various inputs have been collected from various sources for instance feedback from supply chain experts, supply chain mangers.

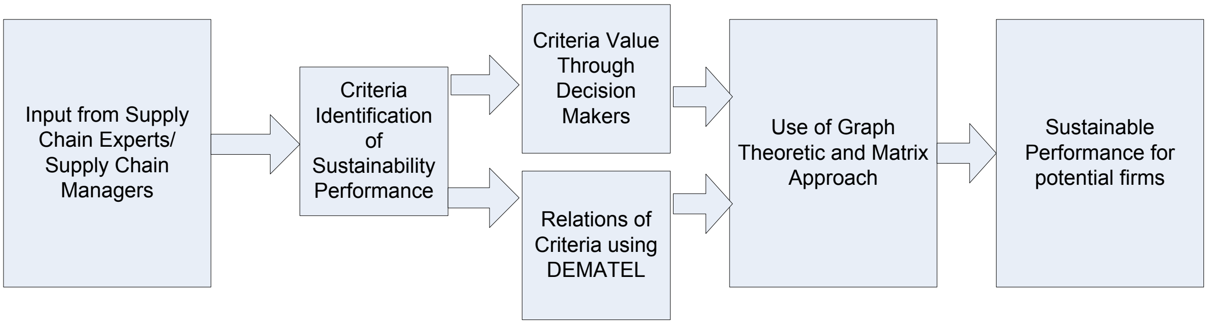

Figure 1 Procedural steps adopted for firm's selection

3.1. Dematel

The Decision-Making Trial and Evaluation Laboratory (DEMATEL) technique is a comprehensive method for building and analyzing a structural model involving causal relationships between complex factors (Wu and Lee, 2007). DEMATEL has been built on the basis of graph theory, enabling analyzes and solves problems by visualization method. This structural modeling approach adopts the form of a directed graph, a causal effect diagram, to present the interdependence relationships and the values of influential effect between factors. Through analysis of visual relationship of levels among system factors, all elements are divided into a causal group and an effected group. And this can provide researchers with a better understanding of the structural relationship between system elements, and help find ways to solve complicated system problems (Herrera et al., 2000; Wang and Chuu, 2004). The relationships between cause and effect factors are converted into the DEMATEL. Suppose that a system composes a set of elements $C = (C_1, C_{2,} C_3, \dots C_n)$ and particular pair-wise relations are decided for modeling with respect to a mathematical relation. The major following steps are:

1. Generating the direct relation matrix. Measuring the relationship between criteria requires that the comparison scale be designed into four levels: 0 (no influence), 1 (very low influence), 2 (low influence), 3 (high influence), and 4 (very high influence). An initial direct relation matrix A is a nxn matrix obtained by pair-wise comparisons, in which T_{ij} is denoted as the degree to which the criterion i affects the criterion j, i.e.,

$$T = [t_{ij}]_{nxn} \quad T = \begin{bmatrix} 0 & 3 & 1{,}7 & 1 \\ 3{,}2 & 0 & 2{,}5 & 2 \\ 1{,}7 & 2{,}2 & 0 & 1{,}8 \\ 1 & 1{,}5 & 1{,}8 & 0 \end{bmatrix}$$

2. Normalizing the direct relation matrix. On the base of the direct relation matrix A, the normalized direct relation matrix I can be obtained through the equation.

$$S = kxA$$

$$k = \frac{1}{max1 \leq i \leq n \sum_{j=1}^{n} a_{ij}} \quad S = \begin{bmatrix} 0{,}00 & 0{,}39 & 0{,}22 & 0{,}13 \\ 0{,}42 & 0{,}00 & 0{,}32 & 0{,}74 \\ 0{,}22 & 0{,}29 & 0{,}00 & 0{,}23 \\ 0{,}13 & 0{,}19 & 0{,}23 & 0{,}00 \end{bmatrix}$$

3. Attaining the total relation matrix. Once the normalized direct relation matrix S is obtained, the total relation matrix I is denoted as the identity matrix.

$$T = S(I - S) - 1$$

4. Producing a causal diagram. The sum of rows and the sum of columns are separately denoted as vectors D and R within the total relation matrix M. A cause and effect graph can be acquired by mapping the dataset of (D+R, D-R). The horizontal axis vector (D+R) named "Prominence" is made by adding D to R, which reveals how much importance the criterion has. Similarly, the vertical axis (D-R) named "Relation" is made by subtracting D from R, which may group criteria into a cause group. Or, if the (D-R) is negative, the criterion is grouped in the effect group.

$$T = [t_{ij}]_{nxn} \qquad i, j = 1,2, \dots, n$$

$$D = \left[\sum_{i=1}^{n} t_{ij}\right]_{ixn} = [t_j]_{nx1}$$

$$R = \left[\sum_{j=1}^{n} t_{ij}\right]_{ixn} = [t_j]_{nx1}$$

D+R	D-R
12,10056	0,513467
15,82013	3,013241
11,90484	-0,11232
12,59498	-3,41438

5. Obtaining the inner dependence matrix. In this step, the sum of each column in total relation matrix is equal to 1 by the normalization method, and then the inner dependence matrix can be acquired.

3.2. Graph Theory and Matrix Approach

Graph theory is a logical and systematical approach. The advanced theory of graphs and its applications are very well documented. Graph/digraph model representations have proved to be useful for modeling and analyzing various kinds of systems and problems in numerous fields of science and technology (Chen, 1997, Jense and Gutin, 2000, Rao, 2006). The matrix approach is useful in analyzing the graph/graph models expeditiously to derive the system function and index to meet the objectives.

The main steps of the methodology are as follows:

• Step-I

Identify the firm selection attributes for the given product or part and short-list the firms on the basis of the identified attributes satisfying the requirements. A quantitative or qualitative value or its range may be assigned to each identified attribute as a limiting value or threshold value for its acceptance for the considered application. A firm with each of its attribute, meeting the criterion, may be short-listed.

• Step-II

1. After short-listing the firms, find out the relative importance (*rij*) relations between the attributes and normalize the values of attributes (*Ai*) for different alternatives.

2. Develop the firm selection attributes digraph considering the identified selection attributes and their relative importance. The number of nodes must be equal to the number of considered attributes in Step 1 above. The magnitude of the edges and their directions will be determined from the relative importance between the attributes.