CHAPTER 3

TOOLS, TECHNIQUES, AND METHODOLOGY

Four research objectives were covered in section 1.8 of the first chapter. Various approaches are accessible for each research goal. The approaches employed to accomplish the objectives were briefly outlined in this chapter. Additionally, the justifications for using specific approaches for particular aims are examined.

To identify the factors that can help a firm to achieve a competitive position and to establish the contextual relationships among these factors, TISM and MICMAC are used. MICMAC uses binary numbers for a relationship that fails to explain the strength of relationships. Even though these approaches are outdated, researchers continue to pay attention to them because of their validated consistency, low expert involvement in decision-making, ease of application, suitability for use in complicated situations, and other factors.

DEMATEL is utilized to determine the cause-and-effect relationship between the various elements. Although DEMATEL is mainly used for objective data, it has recently gained popularity for subjective data. The documented uses of DEMATEL in numerous decision-making domains, including smart energy city obstacles (Addae and al., 2017), website parameters (Cebi, 2013), technology adoption (Lu et al., 2013), and hospital service quality criteria, indicate DEMATEL's broad appeal (Shieh et al., 2010). To manage and organize the complex causal relationship model, DEMATEL was used. DEMATEL was developed by the Science and Human Affairs Program of the Battelle Memorial Institute in Geneva to address complicated issues (Hsu et al., 2013).

The QFD method involves service planning to satisfy customers more effectively. The client's requirement is this tool's initial phase or the driving force. The customer requirements in the manufacturing industry are set and recorded. Since it is challenging to fix required conditions, retail in-sector customer value perception determined from the research's initial objective is employed in place of requirements. The second research aim is also used to inform the design specifications. In the 1960s, QFD began building super tanker cargo ships from Japan before transitioning to the automobile business. Further, this tool is adopted by aerospace, defense, education, lifecycle analysis, logistics, software, process engineering, telecommunications, health care, etc. (Bolar et al., 2014). In the retail sector, QFD has been adopted by some authors like Simons and Bouwman (2006), Hsu and Lin (2006), and Seker (2019).

3.1 Total Interpretive Structural Modelling:

John Nelson Warfield proposed the ISM in 1974. ISM enables a group of experts (Warfield, 1974) and individuals (Ravi and Shankar 2005, Faisal et al. 2007, Alawamleh and Popplewell, 2011) to solve the complex problem using some basic concepts of graph theory. ISM is a methodology that identifies items and summarizes their relationship (Mandal and Deshmukh 1994) for an issue. It is a structural model to identify the objects, define relationships among them for unclear or poorly limpid mental models, and visualize it in a hierarchical model. The relationship between the chosen pieces is discovered using interpretive structural modeling (ISM), which helps people better understand how a system is structured. In ISM, node interpretation has typically carried the elements that indicate it. However, the performance of connections is constrained to the direction and context of relationships between items in pair-wise comparisons. As ISM does not explain how the directed links would achieve the desired contextual relationship, the interpretation of links is some. Depicting the relationship between the indicated pieces in the produced digraph requires practical interpretation to understand that repetitive structural modeling is utilized to overcome this problem. TISM is interpretive as it depends on experts' judgment to establish the relationship between variables (Patel et al.,2014). These relationships create structures that are extracted from a complex set of variables. TISM provides an interpretative matrix that gives absolute interpretation township depicted in the (*Interpreting the Interpretive Structural Model*, 2015) (Jena, 2016). The flow of digraph is shown in Figure 3.1

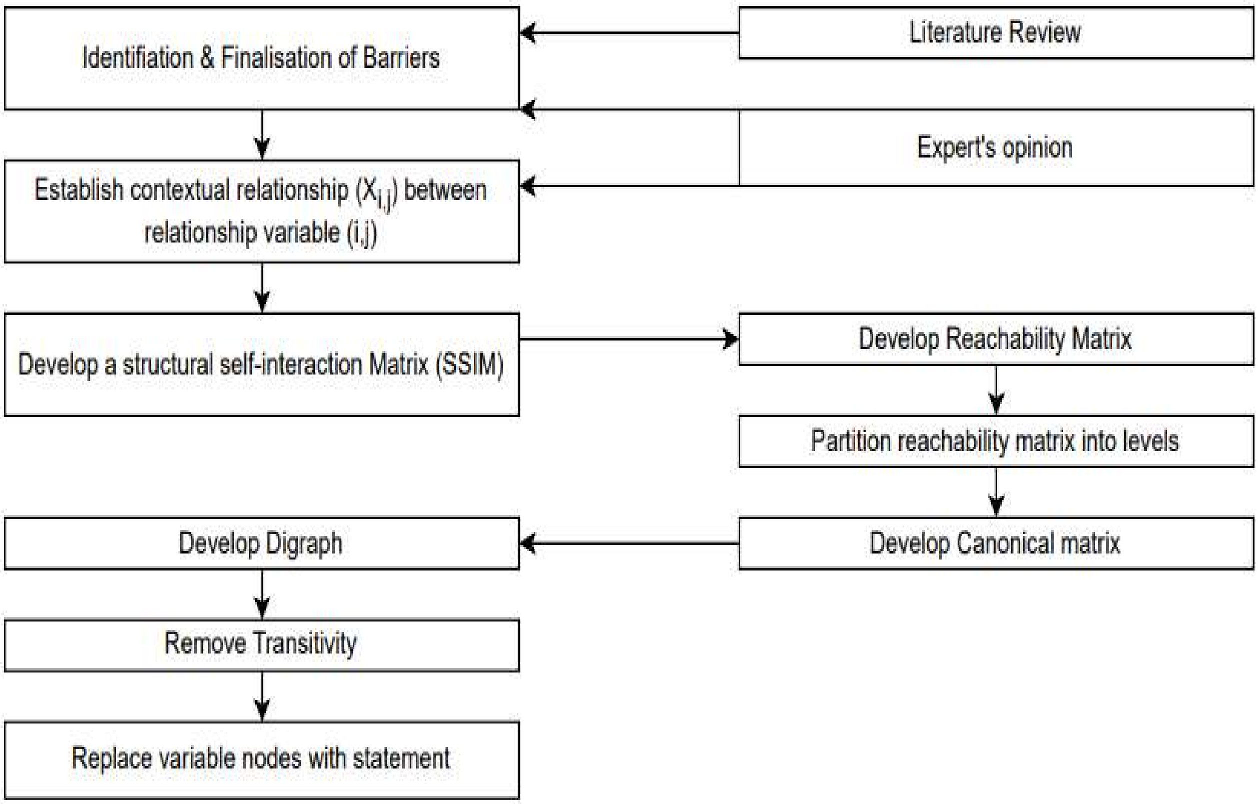

Figure 3.1 Flow of Work

3.1.1 Identification and Finalization of Items:

The first phase in the TISM approach for a problem is identifying and finalizing possible factors. Big data can identify factors—a review of the relevant literature. After compiling a list of contributing factors, it is crucial to determine the critical elements of a particular problem. Here, a team of professionals participating in the factors' finalization uses various collaborative problem-solving strategies, including the Delphi technique.

3.1.2 Establish the contextual Relationship and develop SSIM:

A semi-structured questionnaire has been created using the elements from the previous part that were finalized. The total of associations that can exist if N elements are chosen randomly from expert suggestions is N*(N-1)/2. For instance, if the overall factor is 5, there are ten potential associations. SSIM is shown in Table 3.1

Table 3.1 Structural Self-Interaction Matrix

Factors	Factor1	Factor2	Factor3	Factor4	Factor5
Factor1	Y	N	N	N	
Factor2	Y	N	Y		
Factor3	N	Y			
Factor4	N				
Factor5					

TISM assists people or groups in organizing their knowledge and modeling interrelationships in a way that improves their capacity to comprehend complexity.

SSIM has been developed, and a questionnaire has been provided to the experts. Each row and each column were compared by experts, who chose one value from (Y and N). The two symbols in this session represent the relationship between the two components (i j).

3.1.3 Develop Reachability Matrix:

The initial reachability matrix can be obtained by changing binary digits 0 and 1 to Y and N symbols. A few principles must be followed to convert a sign to a binary digit reachability matrix's (i j) value becomes one of the (i j) symbols in the SSIM are Y.

- The reachability matrix's (i j) value becomes 0 if the (i j) symbol in the SSIM is N.

The initial reachability matrix has been created using the rule mentioned above. In the relationship matrix, it is feasible for one factor (A) to lead to another (B), for element (B) to lead to factor (C), and finally, for factor (A) to lead to factor (C). It is referred to as transitivity. The initial reachability matrix must be used to determine all transitivity that may be present. A technique first suggested by Malone (1975) and again described by Ojha et al. is employed to accomplish the transitivity from the initial matrix (2014). This procedure involves the following steps:

Step 1: Multiplying the initial reachability matrix by itself.

Step 2: Substitute values bigger than one for ones from the generated matrix.

Step 3: Compare the obtained matrix from Step 2 with the prior matrix. Transitivity matrix if the obtained matrix is the same as the preceding matrix. There is the final reachability matrix, which has been achieved. If the obtained matrix differs from the prior matrix, continue the methods described above until transitivity is established.

3.1.4 Partition of Reachability Matrix:

This section serves as the foundation for the hierarchical structure. The factors are categorized using the final reachability matrix from the previous section levels. To do this, the last data set should be mined for the reachability and antecedent set accessibility chart. Each factor's reachability set includes both the factor itself and other factors. Put all row items for the reachability set as a factor in the final reachability matrix. Each antecedent set is the two components of a factor: the actual factor and other factors that affect it. The antecedent set comprises all column elements for specific criteria in the final reachability matrix.

The reachability and antecedent sets are also used to create the interaction set for each factor. When a factor's reachability set and intersection set match, the level number is assigned to that factor, and the factor and number are then removed from further processing. Up till every level is formed, this process is repeated. The top factor in the hierarchical model, unhelpful for achieving other factors, is the first level factor. The hierarchical model is constructed using these indicated levels.

3.1.5 Developing Canonical Matrix:

The factors in this matrix are arranged as follows: The factors with the most rows of zero are placed at the top of the matrix, whereas the factors with the most unitary rows are placed at the base of the matrix.

3.1.6 Formation of Model:

Building a TISM model begins with the canonical matrix, which aids in creating a digraph. The digraph indicates the relationship by an arrow pointing from i to j or j to i (Hasan et al., 2009). According to the debate, the first paragraph has direct and indirect relationships between the components. For instance, if factor "A" is connected to factor "B" and factor "B" is connected to related "C," factor "A" is related to factor "C." A to C is an indirect relationship referred to as transitivity, whereas A to B and B to C are direct relationships. Set the digraph elements according to their levels (as found in section 3.2.4), then use a conical matrix to construct the relationship. The final TISM model was created once the transitivity was removed and the nodes were replaced with statements. Verifying the produced model for conceptual inconsistencies and making necessary adjustments is essential.

3.1.7 MICMAC Analysis:

Matrice d'Impacts Croises Multiplication Applique and Classment is what the acronym MICMAC stands for (Yadav and Barve, 2015). The final reachability matrix is employed in the MICMAC study, and driving and reliance power are analyzed. The driving force of a particular factor is defined as the sum of the row of elements. At the same time, the total of a column's constituents is referred to as the factor's dependence power. The factors are split into four groupings based on driving and dependence power: autonomous, dependent, linkage, and driver (or independent). According to Figure 3.2, separate clusters have strong driving power but weak dependent power, linking clusters have strong driving power but weak, dependent power, and autonomous clusters have weak driving and dependent solid power.

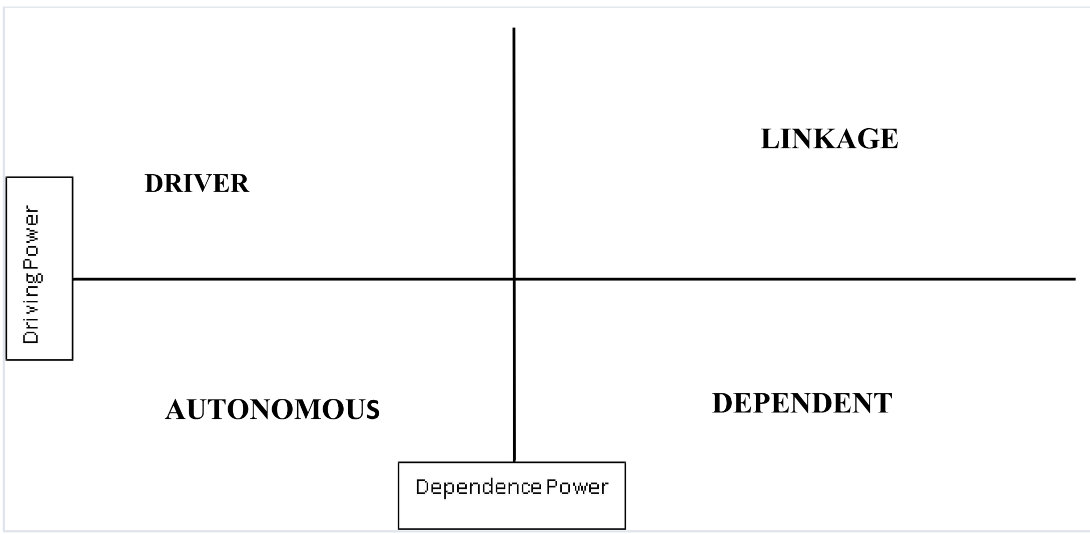

Figure 3.2 MICMAC Results

3.2 DEMATEL:

The documented uses of DEMATEL in numerous decision-making domains, including smart energy city obstacles (Addae and al., 2017), website parameters (Cebi, 2013), technology adoption (Lu et al., 2013), and hospital service quality criteria, indicate DEMATEL's broad appeal (Shieh et al., 2010). To manage and organize the complex causal relationship model, DEMATEL was used. The Battelle Memorial Institute of Geneva's Science and Human Affairs Program developed DEMATEL to address complicated issues (Hsu et al., 2013). The structural modeling technique DEMATEL uses a causal diagram to determine how interdependently related system components are (Wu et al., 2010; Tseng, 2009; Kim, 2006).

The DEMATEL approach involves three steps: computing the total relation matrix, computing the normalized direct relation matrix, and obtaining the cause-and-effect parameter. The criteria will be determined in this case with expert opinion and literature. The systematic procedure of DEMATEL is as follows.

3.2.1 Direct Relationship Matrix:

A total of L respondents (Experts) have chosen N barriers of HCWM. Each respondent participated in evaluating the direct influence of barriers i over barriers j with the help of the Likert scale varies from 0 to 4.

$$K = \begin{pmatrix} a_{11} a_{12} \ldots\ldots a_{1n} \\ a_{21} a_{22} \ldots\ldots a_{2n} \\ \vdots \qquad\qquad \vdots \\ a_{n1}\ a_{n2} \ldots\ldots a_{nn} \end{pmatrix}$$

$$K = [a_{ij}]_{n*n}$$

0 is for No influence, 1 is for Low influence, 2 is for medium influence, three is for High influence, 4 is for Very High influence

3.2.2 Development of Normalized Relationship Matrix:

The direct relationship matrix contains the integer values that will convert into a Normalized relationship matrix using the following formula.

Y (Normalized Relationship Matrix) = K/S

$$S = \max\left\{ \max_{1 \le i \le n} \left\{ \sum_{j=1}^{n} |x_{ij}| \right\}, \max_{1 \le j \le n} \left\{ \sum_{i=1}^{n} |x_{ij}| \right\} \right\}$$

Where i, j∈ {1,2…n}

3.2.3 Development of Total Relationship Matrix:

The total relationship matrix, T, is calculated with the help of the equation given below.

$T= Y*(I-Y)^{-1}$ subscript here i, j ∈{1,2…n}

Where I is the identity matrix.

3.2.4 Degree of Influence:

The Sum of Rows and Columns, known as the Degree of Influence, is obtained using the following formula, denoted by Di and Rj respectively.

$$Di = [\sum_{j=1}^{n} t_{ij}] \quad \forall\ j = \{1,2 \dots n\}$$

$$Rj = [\sum_{i=1}^{n} t_{ij}] \quad \forall\ i = \{1,2 \dots n\}$$

3.2.5 Set up threshold and plot digraph:

Matrix T shows the information on how one barrier affects another. A threshold value is required to avoid negligible effects. The threshold value is usually set by the mean (μ) and standard deviation (σ) of all elements of matrix T (= μ + σ). In the causal digraph, the horizontal axis (prominence) is determined by (Di + Rj), and the vertical axis (relation) is determined by (Di – Rj). When the (Di – Rj) value is positive, it is in the cause category; if negative, it is in the effect category.

Flow chart for the DEMATEL analysis is shown in Figure 3.3

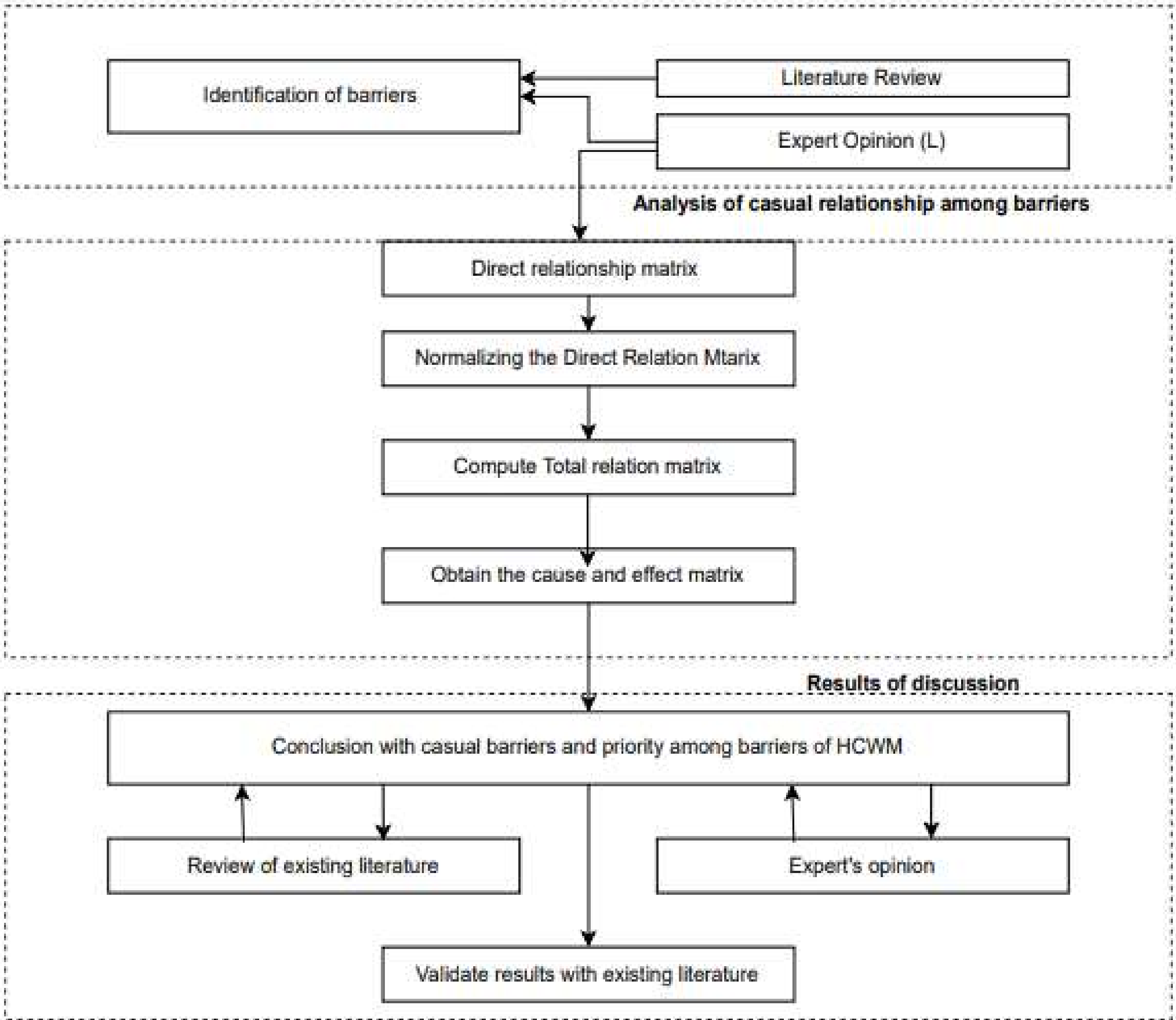

Figure 3.3 Flow Chart for DEMATEL

3.3 Quality Function Deployment:

The QFD was developed in the 1960s by Shigeru Mizuno and Yoji Akao. It was used for the first time at Mitsubishi Heavy Industries Limited in the Kobe Shipyard, Japan, in 1972. QFD is an effective method for providing customers with additional value (Cherif et al., 2010). QFD was created as a TQM practice tool to develop a product but also received much support for services (Debata, 2012).

QFD applies to all planning procedures (Cohen, 1995). In a 2001 survey of 400 American and Japanese businesses, Cristiano et al. found that QFD could reduce the initial internal issues. DiMingo (1988) Two different types of positioning have been proposed: market and psychological. To achieve a position in the market or to claim that this positioning is connected to the firm's desired outcome, the firm controls the processes and actions. A business aims to distinguish itself from competitors in customers' minds through psychological positioning. There aren't many studies accessible for companies that focus on services—Day (2006) claimed that rather than the "4Ps," service-centric businesses may compete based on relationship, performance, and price.

Based on the theories of DiMingo (1988), Day (2006), and Amonini et al. (2010), an attempt was made in this case to integrate the viewpoint of the consumer and the design specifications of the firm to satisfy the customer and position the stores in the customer's mind. Here, the House of Quality (HOQ) framework is the most well-known type of QFD.

The six primary components of a typical HOQ are depicted in Figure 3.4. A structured and systematic method of converting client requirements into priority functional design requirements makes HOQ shown in Figure 3.4, a crucial component of QFD. The HOQ technique can vary in different presentations (Griffin & Hauser, 1993; Cohen, 1995; Cherif et al., 2010).

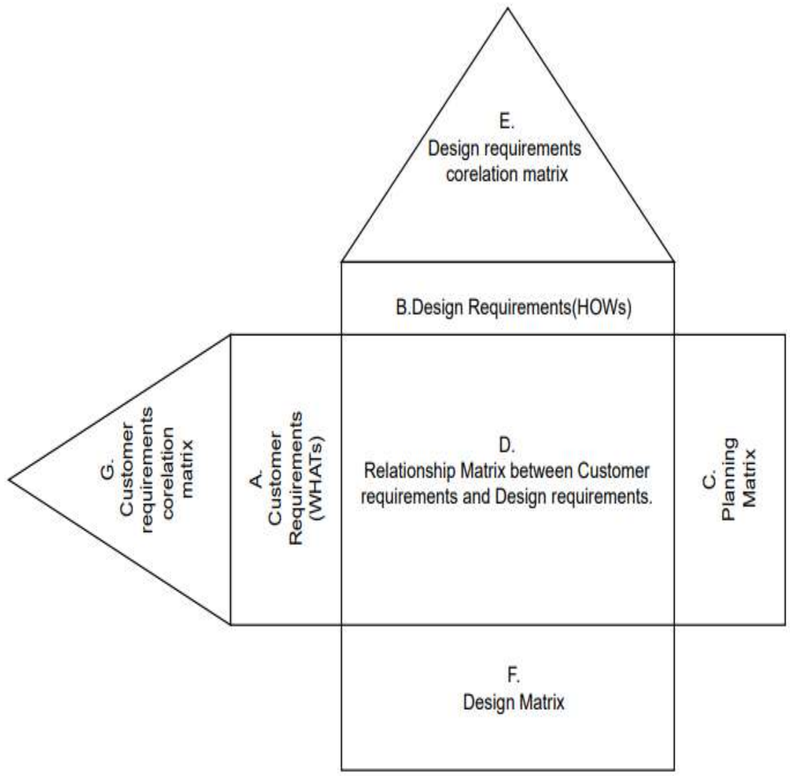

Figure 3.4 House of Quality

Customer requirements, design requirements, how customer needs and design requirements relate to one another, the planning matrix, the design matrix, and the design requirement correlation matrix are the six key components. Specific authors refer to the customer needs correlation matrix (Debata et al., 2012) as the seventh part of QFD. The following details all seven components:

- **Customer Requirements (What's):** QFD is a customer-centric tool that begins with the customer? Typically, the final client can be the survey's primary objective. Finding their list comes next after customer identification. An immediate need with the aid of diverse techniques. Here, the survey approach is employed. to compile the list of demands. Additionally, this section must discuss the relative importance of the client's needs (CRs).

- **The relative importance of the customer requirements:** Data from customer surveys are frequently simultaneous; the relative importance of requirements must be included.
- **Design Requirements (How's):** This section deals with the expert-compiled list of design specifications. A systematic set was created with pertinent and quantifiable design requirements to satisfy the customer's needs.
- **Relationship between What's and How's:** Finding the degree of correspondence between client and design requirements is the goal of QFD. Due to the numerous dependencies on design requirements for each customer request, it isn't easy to trace the relationship. This part has been filled using the symbolic scale.
- **Inner dependence on the Customer requirements:** The customer's needs are interdependent and mutually supportive. The triangular matrix of inner support can be used to pinpoint these relationships.
- **Interrelationship among design requirements**: The triangle matrix at the top of the HOQ shows the relationship between the design requirements. Here, symbols are used to represent the strength of connections; for instance:
  - ++ denotes a solid connection.
  - The moderate relationship is symbolized by +.
  - **-** denotes a shaky connection.
  - -- symbolizes an extremely flimsy connection.
- **Overall priorities of design requirements and additional goals (Design Matrix):** Here, the ultimate rank of HOWs can be derived using the results from the earlier steps. Ratings for design requirements are another name for this.

3.4 Analytic Hierarchy Process: According to the literature, the challenge of making decisions with many competing criteria can be solved in various ways. However, out of all of them, Analytic Hierarchy Process (AHP) is the most well-liked and universally acknowledged. Thomas L. Saaty created AHP in 1980. Since then, it has undergone extensive testing by thousands of organizations worldwide (Opydo, 2013). Despite being a 35-year-old decision-making approach, AHP is still a strong option for MCDM tools. It is because of its clear logic and simple applicability, strong consistency, wide range of applications, and other factors. AHP has been utilized in virtually all decision-related applications (Vaidya and Kumar, 2006).

3.4.1 Steps Involved in AHP:

The following are the steps involved in making decisions using the AHP method:

Step 1: Finding the problem's aim, the selection criteria and the alternatives is the first stage in the AHP technique.

Step 2: After identifying the goal, standards, and best option, organize the problem into a structure—the highest-level aim, the criteria, problem hierarchy, lower-level sub-criteria, and the lowest-level alternatives.

Step 3: The following step is creating the questionnaire and gathering information for a pair-wise analysis. Pair-wise comparisons of the criteria according to the aim or objective alternatives that address each condition.

Step 4: Calculate consistency ratios for comparing criteria and assign priority weights to each criterion to ensure that judgments are made consistently.

Step 5: When comparing alternatives pair-wise, calculate the consistency ratio and the priority weights for each alternative about each criterion. The alternatives' local weight refers to each alternative's relative importance to each criterion.

Step 6: After obtaining the local weights for each alternative, the global weight for each alternative is calculated by multiplying the priority weight of the decision alternatives by the priority weight of the selection criterion and adding the results for all criteria.

Step 7: The variables' final prioritization will be determined. The option with the highest priority weights is the most preferable, followed by the option with the next highest priority weight, and so on.

3.4.2 Basic Principles of AHP:

Saaty (1980) stated that there are three basic principles in the AHP method, which are as follows:

i. Establishing hierarchies:

Decomposition, or breaking an issue into smaller components, must be done after defining the problem. A problem will have different levels as a result of the division process. Hierarchical construction is the name given to this analysis procedure for this reason. Figure 3.5 depicts the AHP paradigm, a hierarchy with three fundamental levels. The problem's objective is found at the top level of the order, followed by the selection criteria at the second level and a list of options at the third level.

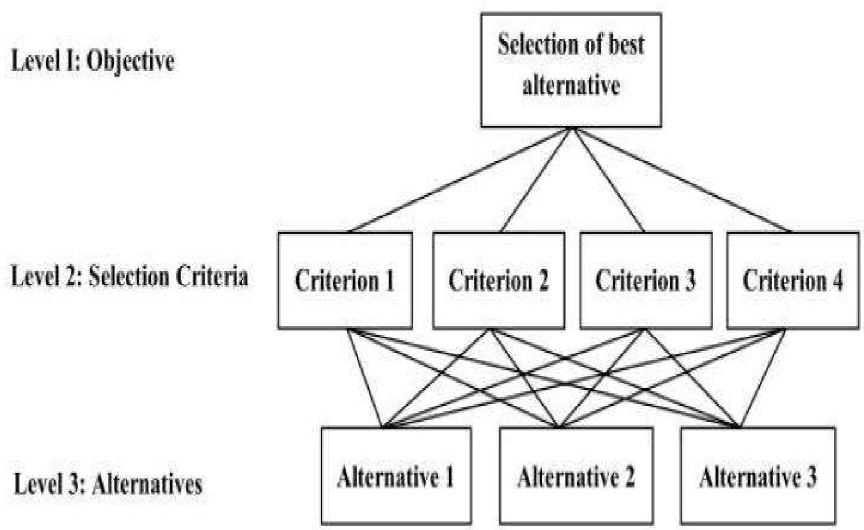

Figure 3.5 Analytic Hierarchy Process

ii. Comparative Evaluation:

The decision-maker assesses the model's components using pair-wise comparisons after constructing it. Comparing the relative relevance of criteria concerning the aim and the relative importance of alternatives concerning each criterion is known as a pair-wise comparison. A nine-point Saaty scale is used to establish the pairwise comparison, and it is displayed in Table 3.2. According to the criterion or property being compared, this scale shows how much more significant or dominant one element is over another.

Table 3.2 Thomas Saaty's nine-point scale for making the judgment

Intensity of Importance	**Definition**	**Explanations**
1	Equal Importance	Two activities contribute equally to the objective Two activities contribute equally to the objective.
3	Moderate Importance	Experience and judgment slightly favor one activity over another
5	Strong Importance	Experience and judgment strongly favor one activity over another
7	Very Strong Importance	An activity is favored strongly over another; its dominance is demonstrated in practice.
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2,4,6,8	Intermediate Values	When compromise is needed between the any two of the value listed above
Reciprocals of above	Assigned to it when	A reasonable assumption

	compared with activity *j*,	

iii. Priority analysis:

After all, comparisons have been made; the decision-maker must determine the priority weights of each pair-wise comparison matrix. The pair-wise comparison matrix is normalized to determine the priority weight by dividing each column's elements by the sum of the associated column. The matching priority vector or priority weight will then be determined by taking the average of each row.

3.4.3 Test of Consistency:

The consistency ratio (CR) is calculated to determine how consistent the judgments have been compared to sizable samples of completely arbitrary decisions; the consistency ratio (CR) is calculated. The consistency ratio is a rough mathematical measure for pair-wise comparison consistency (Canada and Sullivan, 1989). Saaty suggests a practical upper limit of 0.10 for the consistency ratio for the comparison matrix. The pairwise analysis must be redone for consistency if the consistency ratio is higher than 0.10, indicating unreliable judgments. In general, priority weights are more accurate with a smaller consistency ratio. Equation illustrates how the consistency ratio may be stated mathematically as the ratio of the consistency index to the random index.

$$CR = CI/RI$$

Where CR= Consistency Ratio, CI= Consistency Index, RI= Random Index

The following formula gives the Consistency Index for a matrix size 'n.'

$$CI = (\lambda max - n)/(n-1)$$

Random Index (RI) can be obtained from simulation runs and depends upon the order of the matrix. Table 3.3 shows the average values of RI for the matrices of order 1-10 (Saaty,1980).

Table 3.3 Random Index

Size of Matrix (n)	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

To get CR, the maximum eigenvalue (λmax) is determined. Before calculating λmax, multiply the priority weight matrix (called matrix B) by the pair-wise comparison matrix (called matrix A), resulting in the new matrix C. (equation 3.6). To create a new vector [D], divide each element of the vector [C] by its corresponding member in vector [B]. Now take the average of the components in vector [D], also known as the maximum eigenvalue and indicated by the symbol max. These equations can compute the consistency ratio for each comparison matrix.

$$[A] * [B] = [C]$$

$$[D] = [C]/[B]$$

3.5 Fuzzy Theory and Decision-Making:

This section explains the fundamentals of fuzzy set theory and decision-making. Lotfi A. Zadeh first developed a fuzzy set theory in 1965, and Bellman and Zadeh then discussed decision-making in such a fuzzy setting in 1970. Since then, this discipline has seen several theoretical advancements. Decisions heavily reliant on expert opinion may need to be more specific. Fuzzy theory can help with vagueness in human thought. A fuzzy and excellent idea is a perfect mathematical method for addressing the uncertainty brought on by ambiguity. The fuzzy theory offers formalized tools to manage uncertainty in decision-making. Many industrial applications, including water treatment, time reduction during transit, subway systems, washing machines, vacuum cleaners, rice cookers, and aircraft flight control, currently use fuzzy logic (Yen and Langari, 1999).

3.5.1 Fuzzy Numbers:

A fuzzy subset A is called a fuzzy number if A is convex and there exists precisely one actual $f_A(a) = 1$. There are many forms of fuzzy numbers (such as triangular, trapezoidal, curved, etc.) to represent imprecise information.

3.5.2 Triangular Fuzzy Number:

Assume that "A" is a positive triangular fuzzy number with the following definition: (a, b, c) depicted in Figure 3.6. The triangular fuzzy number's membership fun, $f_A(x)$, is, corresponding to an actual number in the range [0, 1] and can be described as:

$$f_A(x) = \begin{cases} (x-a)/(b-a), & a \leq x \leq b, \\ (x-c)/(c-b), & b \leq x \leq c, \\ 0, & \text{otherwise,} \end{cases}$$

The triplet A = (a, b, c) parameterizes the triangular fuzzy number (a, b, c). The evaluation data's most likely value is given by the parameter 'b,' which yields the maximum grade of f_A (a), i.e. f_A (b) = 1. The parameters "a" and "c" represent the bottom and upper limits of the region that can be used to store the assessment data.

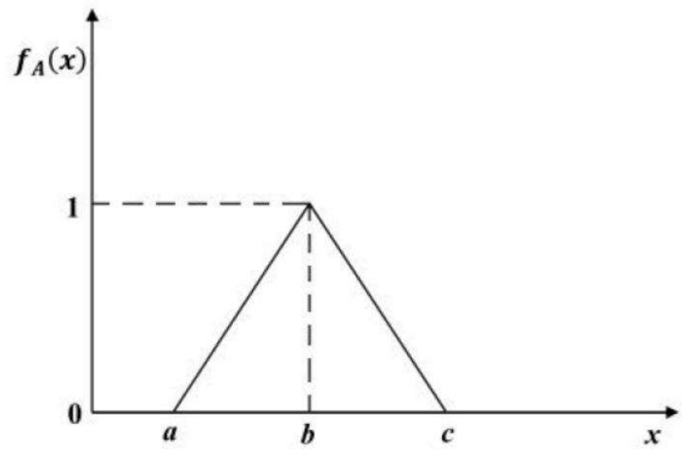

Figure 3.6 Triangular Fuzzy number

3.5.3 Linguistic Variables:

Human thoughts may be vague and imprecise, as was previously discussed. Language can deal with the ambiguity and imprecision of human thought. A linguistic variable is one whose values are phrases or clauses in the natural or invented language (Tseng and Lin, 2011). Excellent and high are two examples of linguistic variables. Because linguistic statements are so ambiguous, it may be challenging to translate them into numbers (Vinodh et al., 2013). Fuzzy logic, a methodology used in artificial intelligence, solves these problems. Furthermore, an undefined number can represent the linguistic value according to the loose sense of fuzzy sets theory.

3.5.4 Ranking of Generalized Triangular Fuzzy Number:

The process of ranking a fuzzy number is known as defuzzification. In many circumstances, having the output expressed as a single scalar quantity makes it simpler to make a clear decision. Ranking the fuzzy numbers is crucial as a result. The literature contains numerous techniques for organizing fuzzy numbers, including the centroid approach, the center of sum method, and the mean of maxima method. In the current dissertation, fuzzy numbers are classified using the centroid approach. This is because the centroid approach is straightforward and straightforward to use (Vinodh et al., 2013).

$$\text{Ranking Score} = (a+4b+c)/6$$

Where:

a = Lower number of triangular fuzzy number

b = Middle number of triangular fuzzy number

c = Upper number of triangular fuzzy number

3.6 Two-Echelon Location Routing Problem: Let's take a look at a two-layer distribution network with three sets of disjoint vertices that represent the Processing Facilities (also known as the depots), Collection Points (often known as the intermediate facilities), and Hospitals (often known as the demand Points), respectively. This allows for the division of the distribution network into two levels.

The first echelon consists of the connections between the collection sites, the Processing facilities, and those that link collection sites. The collection sites are connected via the second echelon to the hospitals and the connections between hospitals. Some collections of weights accessible at one or more Processing facilities must be made to specific hospitals and are forced to transit through the Collection sites—two sets of trucks, one at each echelon, transport waste. Trucks are typically taken for granted within a certain echelon to be homogeneous and capacitated.

Primary trucks are those that belong to the first echelon, while secondary vehicles are those that belong to the second echelon. Each Processing facilities and all collection sites have a fixed opening cost. Additionally, each truck typically comes with a fixed price of utilization. The maximum amount of waste that may be handled in the facility is a capacity restriction for each processing facility and collection site. It is believed that each open collection site must be reached by exactly one primary truck that routes from an available Processing site. Additionally, one secondary truck that routes from collection sites must usually serve each hospital.

The Problem seeks to determine the best locations for Processing facilities and collection sites and the best truck routes that meet hospital requests and do not go against capacity constraints, all while reducing system costs overall. The overall cost is determined by adding the fixed opening costs for the open facilities, the usage fees for the routed vehicles, if any, and the routing costs.

The figure depicts an illustration of a workable solution. The Processing facilities are shown as squares, the collection sites as pentagons, and the hospitals as circles. Routes that are part of the first echelon are shown as dashed lines, while those that are part of the second echelon are shown as solid lines.

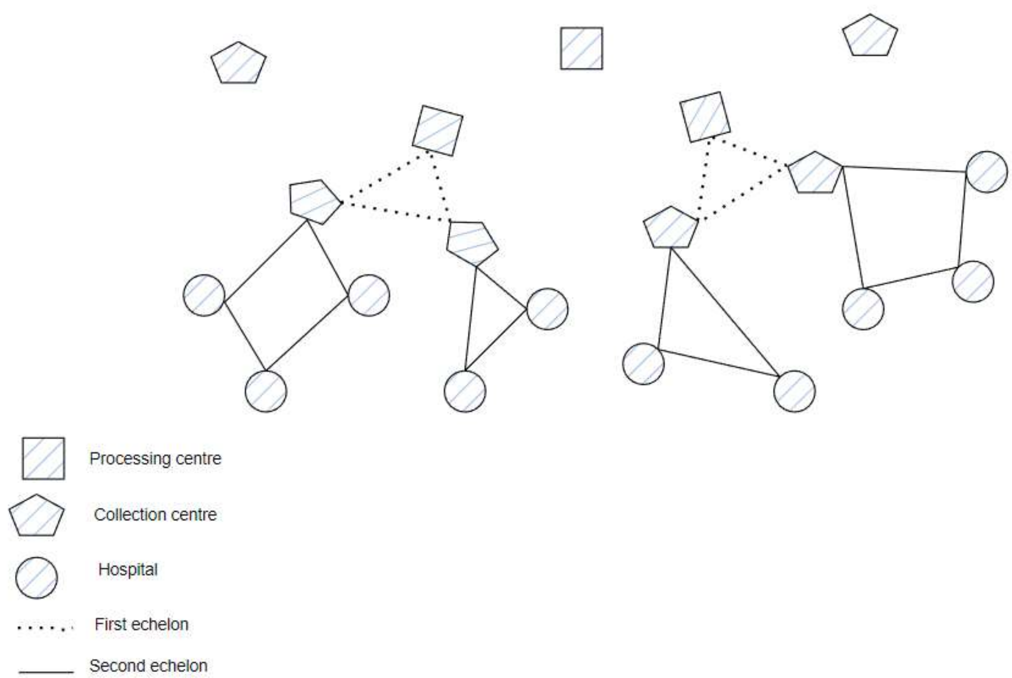

Figure 3.7 Two Echelon

Problem Introduction:

Our issue primarily involves a Processing facility, several collection sites, and several hospitals. They communicate with one another via a disabled truck that makes handling in the first echelon and a group of smaller trucks that make handling in the second echelon.

1. **Processing Facility**: Large Processing facility often placed away from the hospitals. The waste is treated at this facility, which collects it among collection sites before returning it to the Processing facility. Since the vehicle only makes one tour, it returns to the processing facility after ordering from every collection site.

2. **Collection Sites:** Smaller facilities are utilized to transship or consolidate the waste because they are closer to the hospitals than the Processing facility. A tiny truck with some capacity is accessible at each collection site. Each truck collects the waste, tours a subset of the hospitals, and then drives back to the Collection site.

3. **Hospitals:** Endpoints of the distribution are typically situated in areas inaccessible to large vehicles. Only one-second echelon truck per hospital provides service.

Thus, in the problem, one can make the following decisions:

- **Location decisions:** Define the number and location of collection sites.
- **Allocation decision**: Assign each hospital to an open collection site.
- **Routing decisions**: To find the best route with a minimum traveling distance

- RO1: To Identify barriers and find the relationship among them for the healthcare waste management sector.: With the help of the ISM methodology contextual relationship, we will get between the obstacles, and DEMATEL will categorize the barriers as cause-and-effect.
- RO2: Finding customers' Requirements and selecting essential activities for their fulfillment.: To achieve this objective, Quality Function Deployment helps us identify the customers' requirements.
- RO3: Allocation of weight to HCWM barriers and policy recommendations to overcome the obstacles: To allocate weights to the barriers, we have used the Analytic Hierarchy Process(AHP), and to rank the strategies, we have used the Fuzzy TOPSIS method.
- RO4: To deal with Hospital Waste Management Conundrum in an Unplanned City -A Case of Varanasi: The problem was identified as 2 echelon location routing method. We have constructed a mathematical model and solved it by using GUROBI software.