CHAPTER II
BACKGROUND THEORY AND LITERATURE REVIEW

This chapter will be present the background theory and literature review for support this research.

2.1 Material handling system

Material handling is defined by American Society of Mechanical Engineer as the art and science involving the moving, packaging and storing of substances in a form. Although the best solution to the materials handling problem, is no handling, or the simplest solution to the materials handling, no movement no cost. Both solutions are hardly possible for a complete manufacturing process. Therefore, the main objective of material handling is to decrease the number of handling equipments (Srisom, 2003).

A material handling system (MHS) is system for improve performance of a manufacturing system such as reducing work-in-process (WIP) delivering the right amount of materials, to right place, at the right time and at the lowest cost (Kulak, 2005).

2.1.1 Material handling equipment

In manufacturing system, Material handling equipment (MHE) is the most important part and it is playing an important role in the productivity of the manufacturing as increasingly rate. The selection of MHE system is complex and there are considerable of capital investment required. As the handling activities account for 30-40% of the production costs (Tompkins and White, 1984), so the appropriate MHE should be selected by aiming to reduce production cost and increase profit. For these reasons, researchers have to find out the solutions by using various methods such as expert systems, mathematical models, MCDM method, etc. For this study, researcher has emphasized on Multi criteria decision making (MCDM) methods.

Material handling equipments are divided into seven main group of conveyor, overhead conveyors, cranes, industrial trucks, automated guided vehicles (AGVs) robots and storage/retrieval systems (Table 2.1).

Table 2.1 Typical material handling equipment types used in the research

1. Conveyors	Chute conveyor, Powered-roller conveyor, Wheel conveyor, Flat-belt conveyor, Gravity-roller conveyor, Slat conveyor, Apron conveyor, Toughed-belt conveyor, Vibrating conveyor, Pneumatic conveyor, Gravity-bucket conveyor, Screw conveyor, Vertical reciprocating conveyor, Continuous vertical conveyor
2. Overhead conveyors	Chain operated overhead conveyor, Self-powered monorail conveyor, Continuous vertical conveyor
3. Cranes	Jib crane, Bridge/gantry crane, Stacker crane, Mobile crane, Overhead traveling crane
4.Industrial trucks	Hand truck/cart, Hand pallet truck, Powered pallet truck, Narrow-aisle side-loading lift truck, Narrow-aisle reach truck, Pallet base stacker, Straddle base stacker, Pedestrain pallet truck, Low-lift order picker, High-lift order picker, Drive elevating order picker, Fixed-platform truck, Counter-balanced lift truck, Side-loader fork truck, Straddle carrier, Tractor-trailer
5. Automated guided vehicles (AGVs)	Low-lift AGV, High-lift AGV, Tugged AGV, Roller deck AGV, Stationary deck AGV, Lift deck AGV, Manual load/unload AGV, Roller carrier
6. Robots	Pneumatic robot, Electric robot, Hydraulic robot, Mechanized manipulator
7. Storage/retrieval system	Block stacking on floor, Block stacking in rack, Bulk storage system, Shelf storage system, Shelf storage system, Bin rack system, Pallet rack system, Flow-through rack system, Cantilever rack system, Unit load AS/RS, Mini-load AS/RS, Man-on-board AS/RS

Source: Chan et al., 2001

There are many studies that utilized Multi criteria decision making (MCDM) methods focusing on material handling equipment (MHE) problem (Önüt et al., 2008). This method can give an advantage that they can account for both financial and non-financial impacts (Kulak 2005). Park (1996) developed an intelligent consultant system with AHP method for material handling equipment selection. Chan et al. (2001) presented an intelligent MHE selection system that integrated with analytic hierarchy process (AHP). A multi criteria decision model for MHE selection problem in cellular manufacturing systems was utilized the AHP and integer linear programming techniques in this model by Braglia et al. (2001). In the recent year, Chakraborty and Banik (2006) proposed the selecting of the optimal MHE by using AHP technique and in 2006, Chakraborty et al. (2007) used AHP technique and capital investment in developing a hybrid model to find out the best alternative MHE for a warehouse.

2.1.2 Conveyor system

A complexity of conveyor equipment selection is a problem for many manufacturers (Fonseca et al., 2004). There are several factors and limitation involving with conveyor equipment selection. A conveyor system is a part of mechanical handling equipment that used to move materials from one location to another (Tompkins et al., 2002). Wherever several of the materials to be handled and the move to be performed, so a various types of conveyor can be used. The types of conveyors can be categorized in several ways. For example, a belt conveyor can be used for bulk and unit loads, so it can be located overhead or on the floor. Bulk materials that are grain, dry chemicals and saw dust, these can be conveyed using a chute, belt, bucket or vibrating conveyors. Unit materials that are castings, machined parts, and materials placed on pallets and cartons or tote boxes, these can be conveyed using chute, belt, roller, wheel, or tow conveyors. Material can be conveyed on belt, roller, wheel, vibrating, pneumatic or tow conveyors.

The number of study that involved with conveyor equipment selection is less. There is not the study that proposed the suitable model of conveyor equipment selection as lacked of system thinking. For example, Fonseca et al. (2004) have been developed a prototype computer-based system for selecting the suitable conveyor equipment, but there are some limitations that this model cannot be analyzed to quantifiable factors such as cost and equipment utilization.

2.1.2.1 Type of conveyors

Fonseca et al. (2004) have been developed a prototype computer-based system for selecting the suitable conveyor equipment from a list of 76 conveyor types. These conveyor types have categorized into 2 main types of unit and bulk handling conveyor according to the material types that they are handled.

1) Unit handling conveyors: Unit handling can benefit in many working areas such as automotive assembly lines, order picking in warehouses, can conveying in food plants, and stacking materials in storage racks with lift trucks (Kuwiec, 1985). Table 2.2 shows type of conveyor in the category of unit handling conveyors.

2) Bulk handling conveyors: The characteristics of bulk material handling can be presented by continuous-flow, involving materials in an aggregate form, often in unpackaged form. The materials that it handled can be solids, fluids and gas. For example, grains, grits, dry powder, dry powders, granules, flakes, resins, coal, fertilizer, sulfur, and salt (Kuwiec, 1985). Table 2.3 shows type of conveyor in the category of bulk handling conveyors (Fonseca et al., 2004).

Table 2.2 Unit handling conveyors

Chain conveyors	
Flat top chain	Chain-on-edge
Slat Chain	Drag Chain
Roller conveyor	
Chain driven	Line shaft
Belt driven	
Belt conveyors	
Roller bed belt	Slider bed belt
Trash belt	
Gravity conveyors	
Skatewheel	Chute
Gravity roller	
Monorail System	
Overhead power and free	Overhead monorail
Inverted power and free	Automated electrified monorail system
Vertical conveyors	
Reciprocating	Opposed shelf
Continuous	Arm
Sortation conveyors	
Right angle pusher	Line shaft diverter
Panograph sorter	Roller diverter
Motor driven sorter	Sliding shoe sorter
Pneumatic puller	Tilt tray sorter
Powered wheel diverter	Belt carriage sorter

Source: Fonseca et al., 2004

Table 2.3 Bulk handling conveyors

Belt conveyors	
Rubber belt grade 1	Mobile stripper
Rubber belt grade 2	Stationary stripper
Rubber belt grade 3	
Pneumatic conveyors	
Pressure dense phase system	Portable vacuum pressure system
Fan type system	Dilute phase system
Hooper loader system	Vacuum dense phase system
Screw conveyors	
Troughed and shafted	Tubular and shafted
Troughed and shaftless	Tubular and shaftless
Bucket conveyors	
Gravity discharge	Pivoted bucket
Chain conveyors	
Deep pan apron	Flight
Hinged pan apron	Sliding chain
Shallow pan apron	Slat
Enmasse	
Bucker elevators	
Belt type centrifugal discharge	Super capacity bucket style F
Chain type centrifugal discharge	Super capacity bucket style G
Chain type continuous discharge	Super capacity bucket style H/HL
Belt type continuous discharge	Positive discharge
Internal discharge	
Vibrating conveyors	

Source: Fonseca et al., 2004

Roller conveyor

The roller conveyor is an extremely popular type of material handling conveyor, it may be powered (or live) or nonpowered (or gravity). Material handling must have a stiff riding surface and three rollers is a minimum for support smallest loads at all times. For Powered roller conveyors are mainly either belt or chain driven (Tompkins et al., 2002).

Belt conveyor

A variety of belt conveyor is employed in modern MHS. The most popular types are flat belt conveyor (normally used for transporting medium to light weight and load between department, level, building, and operation), telescoping belt conveyor (most popular at shipping and receiving dock where must used conveyor for unloading/loading material from inbound/outbound trailers),trough belt conveyor, and magnetic belt conveyor (a steel belt and either a magnetic pulley or a magnetic slider bed is used for containing iron material vertically, upside down, and around corners) (Tompkins et al., 2002).

Chain conveyor

One or more endless chains that loads can be carried directly, called the "Chain convey". For the transportation of bulk materials, the materials will be pulled through the located chain at the bottom of a trough. Frequently conveyors are used in transportation of tubs, tote boxes, pallets, and heavy loads such as large casting, stacks of steel sheet, steel coils. Although, there are often using that only two or three chains typically is required for providing the sufficient supports of materials movement. The cost of chain conveyors investment is cheaper than other types for loading over long distance. (Tompkins and Smith, 1988; Tompkins et al., 2002).

The source of criteria and sub-criteria for material handling equipment selection that has been structured were: Chan, Ip and Lau (Chan et al., 2001; Tuzkaya et al., 2010; BraGlia, 2001) in Table 2.4.

Table 2.4 The criteria and sub-criteria for material handling equipment selection

	Author										
	Chan				Tuzkaya				Braglia		
Sub-criteria \ Criteria	Performance	Technical	Economic	Strategic	Operational	Economical	Environmental	Strategical	Cost	Benefits	Compatibility
Speed	✓									✓	
Load	✓									✓	
Accuracy	✓									✓	
Efficiency	✓										
Repeatability	✓										
Maintenance		✓							✓		
Convenience		✓									
Compatibility		✓									✓
Risk		✓						✓			
Safety		✓						✓		✓	
Initial cost			✓			✓			✓		
Operation cost			✓			✓			✓		
Flexibility				✓						✓	
Manufacturer				✓							
Future Plan				✓				✓			
Power and space requirements					✓						
Reliability					✓						
Maintability					✓						
Adaptability					✓						
Supervision easiness					✓						
Operational flexibility					✓						
Load-unload and usage easiness and speed					✓						
Suitability to the purchasing aim					✓						
Purchasing cost						✓					
End-of-use value						✓					
Reusability as raw-material							✓				
Re-manufacturability							✓				
Power usage							✓				
End-of-use hazardous waste							✓				
Supplier's environmental behaviors and image							✓				
Productivity								✓			
Supplier relations								✓			
Quality								✓			
Energy cost									✓		
User training cost									✓		
Guaranty										✓	
Payment										✓	
Operative flexibility										✓	
Reliability (Operation)										✓	
User friendliness (Operation)										✓	
Space (Operation)										✓	

In the past, there are many authors who are studied about material handling equipment selection. These studies have classified in various ways according to Table 2.4. Table 2.4 presents that there is obtained a consensus aligned among the authors especially the sub-criteria of safety, initial cost and operation cost.

Criteria of conveyor selection system both unit conveyor and bulk conveyor are presented in Table 2.5.

Table 2.5 The criteria for conveyor selection system

Plane of movement:	it means to the movements of the conveyors to the horizontal, inclined or vertical plane
Power source:	it means to the gravity or electric power that makes the convey or move the materials
Speed:	it means to the required speed of the movements of the materials
Temperature:	it means to the hotness of the transported materials
Loading capacity:	it means to the weight carrying capacity for a conveyor type
Horizontal carry:	it means to the maximum horizontal distance that needs to be
Product shape:	it means to the shape of the transported material that can be of regular or irregular type
Accumulate:	it means the ability of the conveyor type to pile up transported materials along the path
Flexibility:	it means the ability of the conveyor to adapt to changes. High flexibility conveyors can be moved from one place to the other, while low flexibility conveyors can be moved only after incurring very high disbursement
Loading:	it means to the feeding of the materials on to the conveyor that loading must be either controlled or uncontrolled

Table 2.5 The criteria for conveyor selection system (cont.)

Discharge:	it means to the material transfer that can take place at the head end, head or foot end, at one place in between (single intermediate), at many places with equal intervals in between (multiple intermediate), and at various places with unequal intervals between the head and foot end (variable intermediate)
Angle of inclination:	it means the slope at which the material needs to be transported
Complexity:	it means to the conveyor profile that can be straight-line or compound. Straight-line conveyors have a constant angle of incline, and no discontinuity in between, while a compound conveyor is made of two or more separate conveyors joined at their ends
Vertical lift:	it means to the maximum vertical distance that can be traversed by the conveyor device
Material size:	it means to the size of the transported bulk materials
Angle of repose:	it means the angle made by the uppermost layer of the bulk material with the horizontal
Corrosiveness:	it means to the eroding ability of the transported material
Friability:	it means to the brittleness of the materials

Source: Fonseca et al., 2004

2.2 BOCR

Saaty has proposed one of the general theories of the ANP (Saaty, 2004), that is BOCR or benefits, opportunities, costs, and risks in a decision making (Chen et al., 2010). Actually BOCR analysis is similar to a SWOT analysis, where not only the internal aspect of Strong (S), but also the external aspect of opportunities (O) of a firm are taken into account such as the good entering chanced to a new market and other favorable situations (Wijnmalen, 2007).

Opportunities, in the BOCR analysis, mean the expectations about positive spin-off, future profits and gains of future positive developments, while benefits mean current income or those profits gained from the positive developments. These are similarly to organization's weak (W) points, but may not tell the whole story of negative aspects in SWOT analysis; external threats (T) involving competition or unfavourable developments in society must be faced with as well (Wijnmalen, 2007).

For Risks in BOCR analysis, these mean the expected consequences of future negative development, while costs mean the current losses and efforts and consequences of negative developments. The using of BOCR analysis enables to achieve more efficient analysis than a mere BC analysis. However, the identifying of aspects and their relationships are usually difficult (Wijnmalen, 2007).

The categories which consist of lead time, cost, quality, and service level are similar to benefits, costs, risks, and opportunities (BCRO), therefore some literatures use these categories instead of BCRO (Agarwal et al., 2006).

In 2005, Erdogmus et al. applied the strategic criteria of benefits (B), opportunities (O), costs (C), and risks (R) with ANP based model in evaluating the high-tech alternatives (Erdoğmuşa et al., 2005). The enterprise information system (MES) project selection based on ANP with BOCR was proposed by Liang in 2008 and it applied in the case study of MES project selection in a Chinese undershirt manufacturer (Liang and Li, 2008). In 2009, there are many researches such as Chen et al. presented the ANP associated with benefits, opportunities, costs, and risks (BOCR) for selecting the suitable feeder management system (FMS) project in 2009 (Chen et al., 2010) while Lee et al. constructed the model that applied ANP with BOCR to consider various aspects of buyer-supplier relationships (Lee et al., 2009), Yazgan et al. proposed the ANP model based on BOCR with choquet integral in selecting the dispatching rules in FMS (Yazgan et al., 2010), and Chang et al. has used the fuzzy Delphi, ANP with BOCR and zero-one goal programming (ZOGP) to select the best of seven revitalization strategies (Chang et al., 2009).

2.3 Delphi method

"Delphi" is name of the ancient Greek temple where people could be found the oracle (Grisham, 2009). The Delphi method as a research tool was developed by Norman Dalkey of the RAND Corporation, the Santa Monica, California in the 1950s. The purpose of this technique is to get reliable consensus in the opinion of a panel of selected expert (Dalkey & Helmer, 1993). It is widely popular in many fields, such as education, business, education, health care, engineering and other fields (Gupta & Clarke, 1996; Loo, 2002) as following Table 2.6. Delphi technique was utilized to technological forecasting, management science, and operations research during the year of 1950 – 1960 (Helmer, 1996) as follow Figure 2.1. The method was applied to planning, project evaluation, and cost-benefit analysis field in the 1970s (Shefer, 1982) as following Table 2.6.

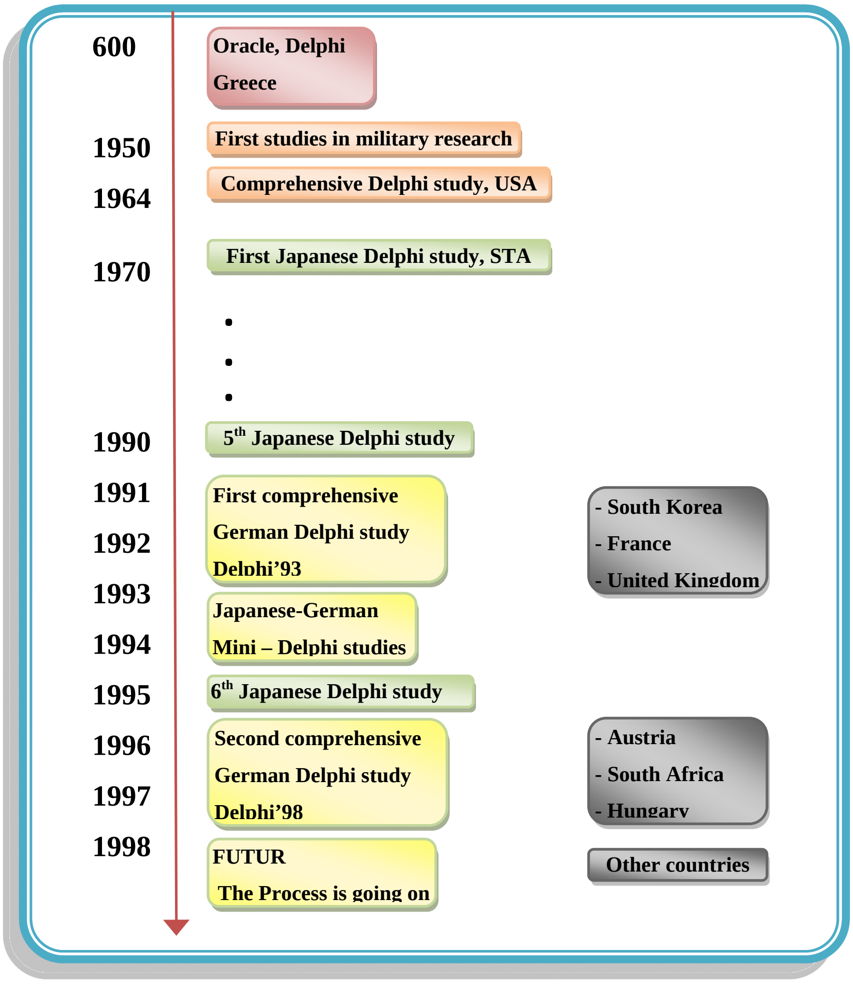

Figure 2.1 Genealogical tree of Delphi

Source: Cuhls, 2004

Table 2.6 Classification of primary application papers used Delphi method

Classification	Count
Education	54
Business	12
Management	12
Marketing	12
Manufacturing	7
Finance	6
Economics	3
Human resources	3
Health Care	27
Information and management	9
Real estate	7
International	5
Social science	5
Engineering	4
Leisure and tourism	4
Environment	3
Transportation	3
Miscellaneous	12

Source: Gupta & Clarke, 1996

2.3.1 Characteristics of the Delphi

The Delphi method is a repetitive process to collect knowledge and consensus from multiple experts by using series of questionnaires. This technique is a way reduce the negative face-to-face interactive and panelist have equal opportunity for sharing idea or feel, such as "the tendency of low-status members in spite of contrary feeling" (Torrance, 1957; Geist, 2010) subordinate in panelist have different feeling or idea. Major characteristics of Delphi method are list of members or respondents were not disclosed, respondents must be familiar or expert in the topic of research not general person, questionnaires have repeating process three or four rounds, have feedback reports (qualitative feedback) between researcher with the panel and have quantitative feedback such as medians, inter-quartile ranges, and standard deviation to group member or panelists (Loo, 2002). Three important features of the technique are: (Hakim & Weinblatt, 1993).

- Anonymity: Panelist have freedom to express an opinion and change them because each member are don’t know identity and answer of other member or panelist throughout the process.
- The relevant information will be asked to the panel directly through the feedback procedure. Thus, it can be avoid the biased result.
- Statistical group consensus: Feedback of Delphi technique to each member will report only their own answer and range of panel’s answers by used statistical

There are strengths and weaknesses among the comparison between the Delphi method and the traditional survey as Table 2.7.

Table 2.7 Comparison of traditional survey with Delphi method

Evaluation criteria	Traditional survey	Delphi method
Summary of procedure	The researcher selected a random sample size in the population and designed questionnaire. Questionnaires have been sent to respondents and returned after respondents fill out already, then the researcher analyzed and summarized the results.	First step, it is a step for selecting panel member who are experts and qualify the answers of the questions. Next step, questionnaire designed is sent panelists, after that panelist returned the questionnaire back to the researcher. The results from the previous round, it will be used in constructing the second round of questionnaire and sent to the panelists again. The researchers will be ingeminates the processes until reaching to the consensus degree.
Representativeness	Only a representative sample is needed for randomly checking through statistical sampling techniques.	A virtual panel of experts gathered are required to arrive at an answer to a difficult question in the Delphi study.
Sample size for statistical power and significant findings	A sample size is large enough for statistically significant effect in the population.	The Delphi group size recommends 10-18 experts on panelists
Individual vs. group response	The sample will be averaged out individuals' responses to determine the average response that they can generalize to the relevant population.	the Delphi study have a consistency because the expert judgement will be produced based on group decision processes.
Reliability and response revision	In evaluating surveys, the reliability of the measures is importance. Researcher should make assurely by pretesting and retesting.	Pretesting is so important for the reliability of the measures while test-retest is not necessary because researchers have expected that respondents are who revise their responses.
Construct validity	Construct validity is assured by careful survey design and by pretesting.	For Delphi study, the validity of survey can be found. Further construct validation occurred by asking experts to validate the researchers interpretation and the facts will be explored.
Anonymity	Panelists are often anonymous to the researcher, while almost always anonymous to each other	Panelists are never anonymous to the researcher, but always anonymous to each other.
Non-response issues	The investigation of non-response is needed to assure that the study achieve the representative of the population.	The assurances of respondents' participation are obtained, so the investigation of non-response is not required.
Attrition effects	In the single survey, the reducing of respondents is a non-issue, but researchers should ascertain attrition that it is random and non-systematic for the multi-step survey.	Similar to non-response, the reducing of respondents have tended to be low in Delphi study and researcher can investigate the cause easily by talking with the dropouts.
Richness of data	The richness of data rely on the depth and form of the questions.	Delphi method have multiple repetition and response revision by feedback, therefore this method provide valuable data.

Source: Okoli and Pawlowski, 2004

2.3.2 Method of Delphi technique

The objective of this section is explained steps for Delphi

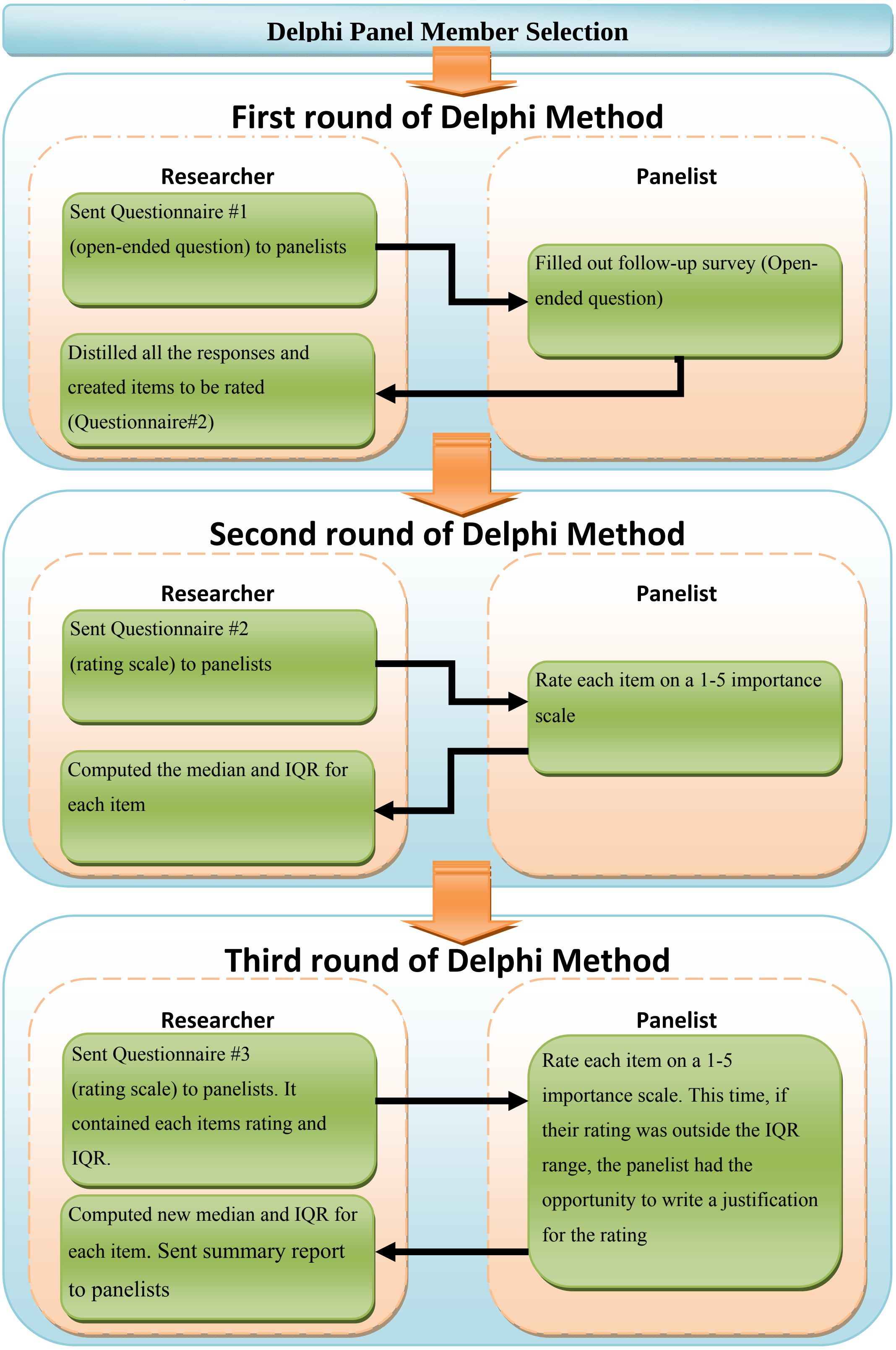

Figure 2.2 Steps for Delphi method

In Figure 2.2 shows steps of Delphi method that the explanation are follow:

2.3.2.1 Problem description

Problem description, it is so important step. Researcher should be addressed problem definition clearly and ensured that the scope of the problem is investigated and reached to the expected outcomes of the study (Loo, 2002).

2.3.2.2 Panel size and panel selection

Delphi technique recommends 10 -18 respondents on a panel (Paliwoda, 1993) by Figure 2.3 shows the relationship between group size and mean accuracy.

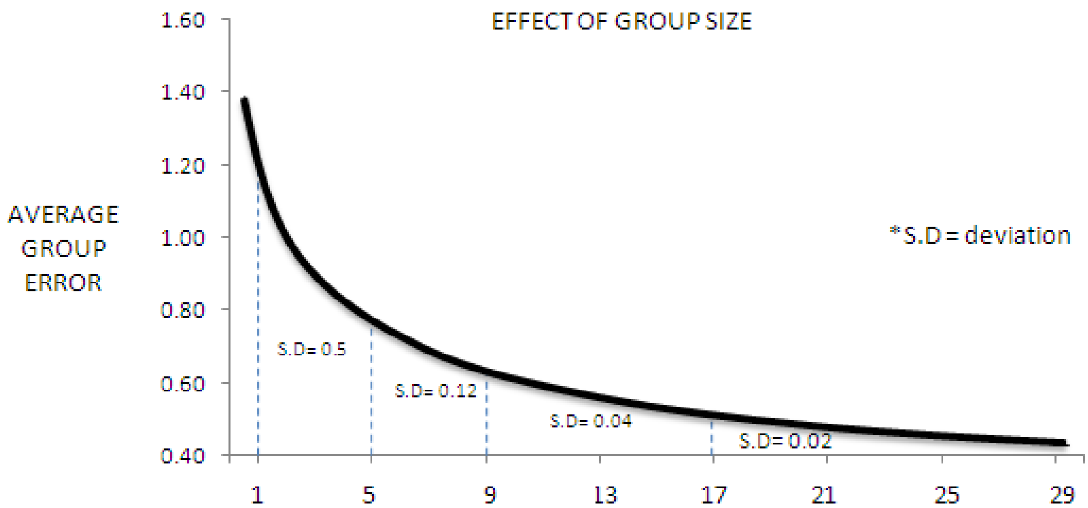

Figure 2.3 The dependence on group size of the mean accuracy of a group response

Source: Macmillan, 1971

For selected panel members is important step, There are four necessity for select respondents: i) knowledge in the field, have deep understanding in that topic; ii) voluntariness to cooperate throughout the study; iii) Have enough time to provide support throughout the process; and, iv) have the skills to communicate better (Adler & Ziglio, 1996).

2.3.2.3 Series of questionnaires

Method of Delphi technique is a series of questionnaires. The first questionnaire is two ways for design it, the first is open-ended questions and the second by extract ideas from literature review (De Villiers, 2005). The results and feedback from the first questionnaire will be using for design a second questionnaire (De Villiers, 2005). The second questionnaire is not open-ended question, but it is Likert or rank-order scales (Loo, 2002). For the third questionnaire and next questionnaires are the same as the previous round just added to statistics, such as median, inter-quartile ranges, and include previous answers of respondents for each item (Geist, 2010). For stopping questionnaires, researcher should stop when general agreement was reached to the criteria, or when the results are repeated.

2.4 Analytic network process (ANP)

The analytic network process was introduced by T.L.Saaty, a generalization of the analytic hierarchy process (Saaty, 2004). The analytic network process (ANP) is an improved model of the analytic hierarchy process (AHP). AHP was proposed in 1980 by Thomas L. Saaty as decision-making method. ANP permits mutual dependence and feedback among criteria therefore ANP different from AHP (Liang and Li, 2008). ANP is adopted for solving many problems due to

- Criteria weight or priorities can be established by ANP, base on pair-comparison ratio scale by decision-makers judgment instead of arbitrary scales (Kim et al., 1997; Saaty, 2004; Erdoğmuşa et al., 2005).

- ANP can consider both tangible and intangible criteria (Lee and Kim, 1997; Momoh and Zhu, 1998; Saaty, 2000).

- For comparative analysis, ANP have useful in transforming the qualitative values into the numerical values (Momoh and Zhu, 1998;Lee and Kim, 2000;Saaty, 2004).

- ANP is not complex and instinctive approach that can be trust by decision-makers (Predley and Meade, 1999; Sarkis and Sundarraj, 2003; Erdoğmuşa et al., 2005).

- The systematic of ANP approach aimed to set priorities and tradeoff among objectives and criteria (Mishra et al., 2002).

- ANP is a facilitate to solve multicriteria decision problems with multiactors (Erdoğmuş et al., 2005).

2.4.1 ANP method

AHP is designed for solving the independence problem among alternatives or criteria problem while ANP is designed for solving the dependence problem among alternatives or criteria problem (Lee and Kim, 2000). Therefore, AHP would not be appropriate for a complex relationship because the structure is a linear from top-to-bottom, the ANP allows for complex interrelationship among clusters or elements by replacing hierarchies with network as show in Figure 2.4.

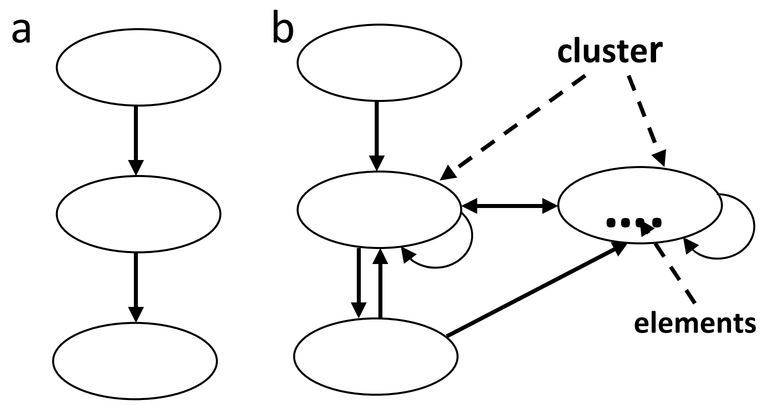

Figure 2.4 Structural difference between a hierarchy and a network

Source: Chung et al., 2005

The ANP is comprised of four standard procedures shows in Figure 2.5.

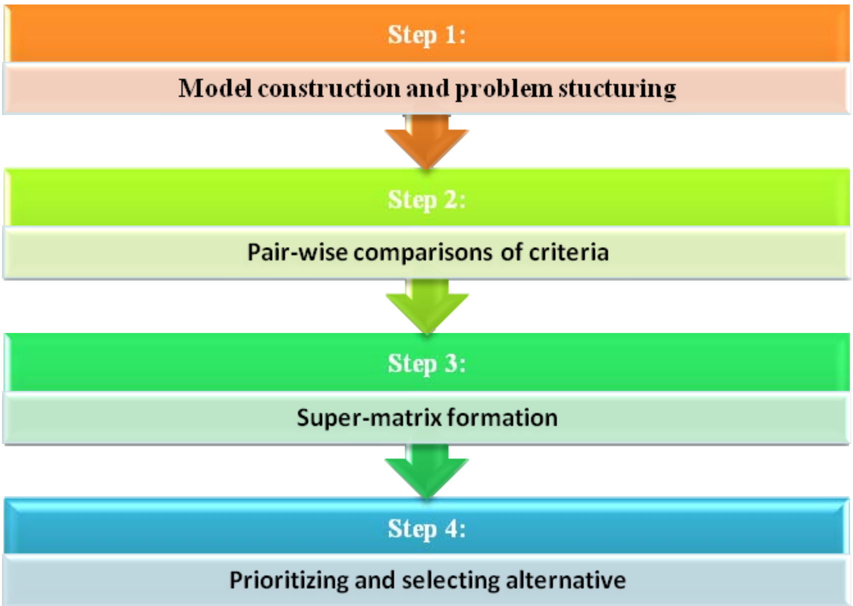

Figure 2.5 Steps of ANP study

Source: Chung et al., 2005

- Step 1: Model construction and problem structuring: The problem should be began distinctly and decomposed into a rational system as a network. This network structure can be obtained by the opinion of decision makers through brainstorming or other appropriate methods (Chung et al., 2005).

- Step 2: Pairwise comparison matrices and priority: At each cluster, all pairs of the decision elements are compared with respect to the important of elements towards their control criteria. The clusters are also compared their pairwises themselves with respect to their contribution to the purpose. Experts who a decision maker is asked to determined the relative important of each criterion with a scale of 1 to 9 (Wijnmalen, 2007). A score of 1 represents equal importance while a score of 9 represents the extreme importance of one element (row component in the matrix) compared to the other one (column component in the matrix) as follows Table 2.8.

Table 2.8 Scale of relative importance

Intensity of importance	Definition	Explanation
1	Equal importance	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 or demonstrated importance	An activity is favoured very strongly over another; its dominance demonstrated in practice
9	Extreme importance	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it
2, 4, 6, 8	For compromise between the above values	When compromise is needed

Source: Saaty, 1980

Reversing the comparison between already compared elements, a reciprocal value is assigned to the reverse comparison; that is $a_{ij} = 1/a_{ij}$ (Lee et al., 2009) and then, the paire-wise comparison matrix was developed and solved by the following equation:

$$A \times w = \lambda_{max} \times w,$$

Where A is the matrix of pair-wise comparison, w is the eigenvector, and λ_{max} is the largest eigen-value of according to the approximating w of several algorithms by Saaty (Lee et al., 2009).

- Step 3: Supermatrix formation: For the supermatrix concept, it s similar to the Markov chain process (Yazgan et al., 2010). The local priority vectors are entered in the appropriate column of a matrix, known as a super-matrix by aiming to obtain global priorities in a system with interdependent influences. As a result, a super-matrix is actually a partitioned matrix, where each matrix segment represents a relationship between two nodes (components or clusters) in a system (Wijnmalen, 2007). Let the clusters of a decision system be C_k, k = 1, 2, …, n, and each cluster k has m_k elements, denoted by e_{k1}, e_{k2}, …, e_{kn}. The local priority vectors obtained in Step 2 are clustered and placed in the suited positions in a supper-matrix based on the influence flow from one cluster to another, or from a cluster to itself, as in the loop. A standard form for a super-matrix is as known in Figure 2.6.

$$
W = \begin{array}{cc} & \begin{array}{ccccccccccccccc} e_{11} & e_{12} & \cdots & e_{1m1} & \cdots & e_{k1} & e_{k2} & \cdots & e_{kmk} & \cdots & e_{n1} & e_{n2} & \cdots & e_{nmn} \end{array} \\
\begin{array}{cc} C_1 & \begin{array}{c} e_{11} \\ e_{12} \\ \vdots \\ e_{1m1} \end{array} \\ \vdots & \vdots \\ C_k & \begin{array}{c} e_{k1} \\ e_{k2} \\ \vdots \\ e_{kmk} \end{array} \\ \vdots & \vdots \\ C_n & \begin{array}{c} e_{n1} \\ e_{n2} \\ \vdots \\ e_{nmn} \end{array} \end{array} & \begin{bmatrix} W_{11} & \cdots & W_{1k} & \cdots & W_{1n} \\ \vdots & & \vdots & \vdots & \vdots \\ W_{k1} & \cdots & W_{kk} & \cdots & W_{kn} \\ \vdots & & & \vdots & \\ W_{n1} & \cdots & W_{nk} & \cdots & W_{nn} \end{bmatrix} \end{array}
$$

Figure 2.6 A standard from for a super-matrix

Source: Yazgan et al., 2010

As an example, the representations of the super-matrix for a hierarchy with three levels as shown in Figure 2.4a, is as follows (Yazgan et al., 2010):

$$W = \begin{bmatrix} 0 & 0 & 0 \\ W_{21} & 0 & 0 \\ 0 & W_{32} & I \end{bmatrix}.$$

Where W_{21} is a vector that represents the effect of the objective on the criteria, W_{32} is a matrix that represents the effect of criteria on each alternative, I is the identity matrix, and all of zeros corresponding to those elements that have no influence. For the previous example, if the criteria are interrelated among themselves, the hierarchy is replaced by a network shown in Fig 2b. The presence of the matrix element W_{22} of the super-matrix W_n can be represented the interdependency that the super-matrix would be (Yazgan et al., 2010):

$$W_n = \begin{bmatrix} 0 & 0 & 0 \\ W_{21} & W_{22} & 0 \\ 0 & W_{32} & I \end{bmatrix}.$$

Note that if there is an interrelationship of the elements within a cluster or between two clusters, then any zero value in the super-matrix can be replaced by a matrix. As there usually is interdependence among clusters in a network, the columns of a super-matrix may sum to more than one. However, the super-matrix must be modified so that each column of the matrix sums to unity. Saaty (Yazgan et al., 2010) has a recommended approach that is to determine the relative importance of the cluster as the controlling component (Wijnmalen, 2007). Raising a matrix to powers gives the influences of long term relative to the elements on each other. To obtain a convergence on the importance weights that the weighted super-matrix is raised to the power of 2k+1, where k is an arbitrarily large number, and it is a new matrix that called the limit super-matrix (Yazgan et al., 2010). The limit super-matrix form has similar to the weighted super-matrix, except that all the columns of the limit super-matrix are the same. The normalizing each cluster of this super-matrix can be reached the final priorities of all elements in the matrix. Especially where there is a relative few of the number of elements in the model, the final priorities can be calculated by using matrix operations. In order to easily convey the steps of the methodology, it can be used matrix operations and represented how the dependencies are work out.

- Step 4: Selection of the best alternatives: When the super-matrix formed in Step 3 covers the whole network, the priority weights of the alternatives can be found in the column of the alternatives in the normalized super-matrix. On the other hand, if a super-matrix only composes clusters that are interrelated, necessary of additional calculations must be made to achieve the overall priorities of the alternatives. The best alternative is come from the judgment of the calculations made using matrix operations, so the alternative with the largest overall priority should be selected.

ANP is a technique which similar to the Analytic Hierarchy Process (AHP). The characteristic between criteria and sub-criteria of ANP is a network while AHP is a hierarchy. In addition, ANP is also similar to others technique as well. For example, Multi-Attribute Utility Technique (MUAT), Cross-Impact analysis and Cost-Consequences Analysis (CCA), these are categorized under the alternative selection analysis as well as AHP or ANP.

Multi-Attribute Utility Technique (MUAT) results are based on the majority, this method can eliminate the argument occurred among group. When MUAT compare with AHP or ANP, it has a similar concept that focused on the choice of the most important ideas of the experts. Thus, it can reach to the desired goal or purpose.

Cross-Impact Analysis is a technique that can assist the process of scanning the field of possible futures to reduce uncertainties and it is combined with the Delphi method. This technique is mainly used in prospective and technological forecasting rather than in foresight exercises itself (Enzer, 1972), but this technique has many interactions that should be considered as the number of interactions equal to n^2-n where n is the number of events. Therefore, the number of events from this technique will be between 10 to 40 events (Gordon and Stover, 1978), such as if n=10, the number of interactions that should be considered is equal to 90 while AHP and ANP, the number of interactions that should be considered is equal to 45 where $(n^2-n)/2$. For Cost-Consequences Analysis (CCA), it has similar to MUAT, Cross-Impact Analysis, AHP and ANP, but there is some difference occurred that this method has used the capital budget for each alternative as a factor in decision (Wongwanij, 2005). For, ANP with BOCR can combine the score of each alternative by five method.

1. Additive: $P_i = bB_i + oO_i + c[(1/C_i)_{Normalized}] + r[(1/R_i)_{Normalized}]$
2. Probabilistic additive: $P_i = bB_i + oO_i + c(1- C_i) + r(1- R_i)$
3. Subtractive: $P_i = bB_i + oO_i – cC_i – rR_i$
4. Multiplicative priority powers: $P_i = B_i^b O_i^o [(1/ C_i)\text{Normalized}]^c [(1/ R_i)\text{Normalized}]^r$
5. Multiplicative: $P_i = B_iO_i / C_iR_i$