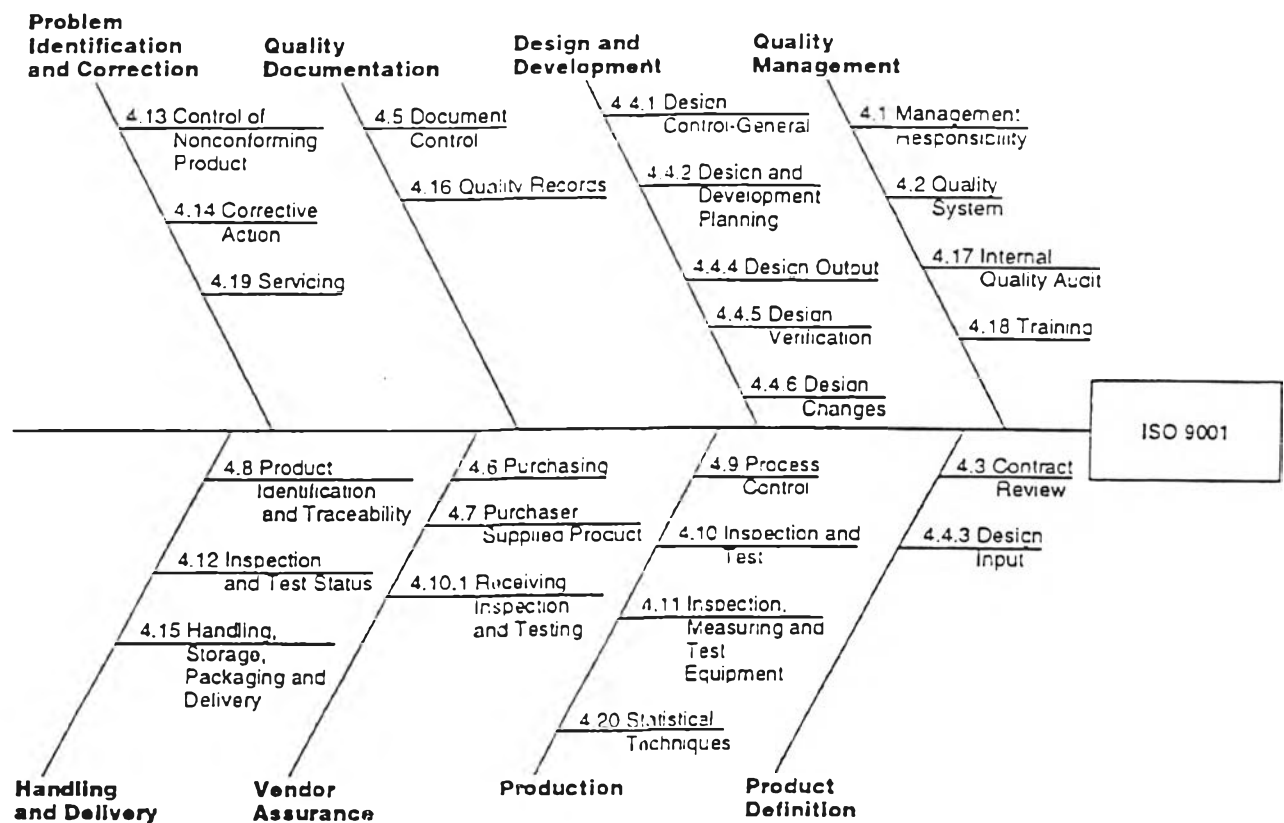# CHAPTER III

METHODOLOGY

The objective of this chapter is to develop a conceptual framework for assessing the quality management systems and practices in Thai telecommunication company. Such framework is developed based on two international quality standards: ISO 9000 and the Baldrige Award. ISO 9000 has become one of the most popular standards in recent years. Conversely, the Baldrige Award is one of the world-class quality awards focusing on an achievement of the quality improvement target.

This chapter starts with a design of an assessment model of ISO 9000. This model comprises a number of criteria and subcriteria with references to ISO 9000 (1987). A design of an assessment model of the Baldrige Award comprising a number of criteria and subcriteria with references to the Malcolm Baldrige National Quality Award 1992 is also presented. Next, this chapter identifies the theoretical implications of methods for collecting the data, calculating weights of criteria and subcriteria, and synthesising scores of a company. The application of such method is also presented. Finally, this chapter explains a certain number of the outranking methods.

3.1 Design of an assessment model of ISO 9000

As said by Liebesman, the ISO 9000 series standard can be divided into 8 main requirements and 26 subrequirements as seen in Figure 3.1 [Liebesman, 1993]. In this study, this framework is adapted to become the assessment model of ISO 9000 which include 8 quality criteria and 26 quality subcriteria as below: [Johnson, 1993]

Figure 3.1 ISO 9000 [Liebesman, 1993]

Problem Identification and Correction
- 4.13 Control of Nonconforming Product
- 4.14 Corrective Action
- 4.19 Servicing

Quality Documentation
- 4.5 Document Control
- 4.16 Quality Records

Design and Development
- 4.4.1 Design Control-General
- 4.4.2 Design and Development Planning
- 4.4.4 Design Output
- 4.4.5 Design Verification
- 4.4.6 Design Changes

Quality Management
- 4.1 Management responsibility
- 4.2 Quality System
- 4.17 Internal Quality Audit
- 4.18 Training

ISO 9001

Handling and Delivery
- 4.8 Product Identification and Traceability
- 4.12 Inspection and Test Status
- 4.15 Handling, Storage, Packaging and Delivery

Vendor Assurance
- 4.6 Purchasing
- 4.7 Purchaser Supplied Product
- 4.10.1 Receiving Inspection and Testing

Production
- 4.9 Process Control
- 4.10 Inspection and Test
- 4.11 Inspection, Measuring and Test Equipment
- 4.20 Statistical Techniques

Product Definition
- 4.3 Contract Review
- 4.4.3 Design Input

3.1.1 Criterion 1: Quality management (A1)

Quality management (A1) here deals with planning and management of a quality system with high effectiveness and efficiency, and ultimately leads to an achievement of the required product quality. Also, all major considerations in quality management may be about management responsibility, quality system, internal quality audit and training.

3.1.2 Criterion 2: Product definition (A2)

This criterion is concerned with defining the specific products which are or even are expected to be available in an organisation with reference to contract review and design input.

3.1.3 Criterion 3: Design and development (A3)

This criterion reflects one of product realisation processes; its primary goal is to design and innovate new products. The "design and development" requirements include design control, design and development planning, design output, design verification and design changes.

3.1.4 Criterion 4: Quality documentation (A4)

Quality documentation is one of the main support processes. It deals with documentation and record keeping of quality procedures and quality records within a reasonable and prudent level; in other words, by being limited to the extent being pertinent to the application.

3.1.5 Criterion 5: Vendor assurance (A5)

Vendor assurance means all activities and function concerned with the attainment of quality of the vendors' processes and supplied products. This requirement can be involved with purchasing, purchaser supplied product, receiving inspection and testing.

3.1.6 Criterion 6: Handling and delivery (A6)

Handling and delivery should be a supporting process which ensures that only verified conforming output reaches customers. ISO9000 quality system requirements for

handling and delivery are product identification and traceability, inspection and test status, and handling, storage, packaging and delivery.

3.1.7 Criterion 7: Production (A7)

This criterion is one of product realisation processes which focus mainly on producing output (product or service) being consistent with customer expectations under planned, controlled and documented conditions. Its requirements can be involved with process control, inspection and test, inspection, measuring and test equipment, and statistical techniques.

3.1.8 Criterion 8: Problem identification and correction (A8)

The extent to which problem should be identified and corrected for controlling and improving output can be based on control of a nonconforming product, corrective action and servicing.

3.1.9 Subcriterion under quality management

1. Management responsibility (A11)

Since the success of the quality system is directly relevant to the consistency and intensity of management's commitment, Management Responsibility requirement becomes one of the most important component of the standard. In general, management have to define its quality policy and execute it through an organisation of people and resources. As well, top management is obliged to participate an activity in the quality system by conducting verification and reviewing activities. For example, the standard requires management to designate a management representative (MR) to be responsible for conducting regular, documented management reviews of the quality system.

Checklist of requirements

a)   Management has defined quality policy.

b)   Management has defined responsibilities of people whose work affects quality (such as through an organisation chart or job responsibility).

c)   Management conducts activities to verify effectiveness of design, production, installation and service activities.

d)   A management representative has been designated to be responsible for quality.

e)   Management conducts regular review meetings to discuss the quality system. Records of these meetings are kept.

2. Quality system (A12)

The primary goals of an establishment of the quality system are to develop and implement quality plans for new products, services or processes, and to provide sufficient and continuous control over all activities affecting quality. According to the quality system, clearly defined responsibility, authority and relationship among such activities must also be considered.

Checklist of requirements

a)   An organisation has prepared procedures to ensure that product conforms to the requirements.

b)   The organisation has effectively implemented those procedures.

c)   The organisation documents those procedures.

d)   The organisation has provided adequate resources needed to meet required quality objectives.

e)   The organisation's monitoring activities ensure the compatibility of design, production process, inspection and testing, installation, and relevant documentation.

f)   The organisation identifies acceptance criteria of all specified requirements.

g)   The organisation develops the measurement requirements.

3. Internal quality audit (A13)

Regular internal audit has to be conducted to measure the effectiveness of a quality system designed to achieve stated objectives. The standard suggests a number of crucial areas for internal audit attention which include procedures, resources, facilities, measurement systems and results, and so on.

Checklist of requirements

a)   Internal quality audits are planned, conducted and documented.

b)   The audits are prioritised based on importance of auditing area to the quality system.

c)   Corrective actions arise from the audits.

d)   Management reviews the effectiveness of corrective actions.

4. Training (A14)

It is clear that an organisation should recognise how important personnel are to the success of its quality system. Therefore, training should be provided to employees with respect to the organisation's documented training plan. In addition, the organisation should provide whatever training is required to enable employees to meet the documented qualifications of their posts. However, this may lead to staff retention problems later on. To overcome them, various motivational techniques such as giving rewards and focusing on worker involvement can also be involved.

Checklist of requirements

a)   Qualifications, in terms of education, training and experience, exist for each employee whose work affects quality.

b)   Training needs are identified.

c)   An organisation provides such training where needs exist.

d)   The organisation maintains training records.

e)   The organisation motivates all employees toward quality performance.

3.1.10 Subcriteria under product definition

1. Contract review (A21)

The Contract Review criteria obliges an organisation to maintain procedures for evaluating customer requirements and comparing them with the organisation's capabilities.

Checklist of requirements

a)   A contract is reviewed with the customer.

b)   Customer requirements are fully defined.

c)   The customer requirements are within organisation capabilities.

d)   The differences between the customer and organisation are resolved.

e)   The contract and customer requirements records are maintained.

2. Design input (A22)

According to the standard, the chief goal of the design process is to translate customer requirements into technical specifications for output. These requirements and

other elements such as design personnel, testing equipment and so on represent sources of design input.

Checklist of requirements

a)   Sources of design input (such as design personnel, test equipment and so on) are identified.

b)   They are documented.

3.1.11 Subcriteria under design and development

1. Design control (A31)

In an ISO9000 quality system, design process is expected to be planned, controlled and documented with clear and definitive responsibility and authority.

Checklist of requirements

a)   An organisation has procedures for controlling and verifying a product design.

b)   Such design satisfies customer requirements.

c)   The relationships among functions involved in the design process as well as interfaces between the design process and other process elements are identified.

2. Design and development planning (A32)

Design and development planning which are generally time-phased should be planned and disciplined considering the application, sophistication and innovation of the output.

Checklist of requirements

a)   An organisation has procedures for design planning and development process.

3. Design output (A33)

In general, an organisation should clearly define its types of design output such as blueprints, design checklists and so on.

Checklist of requirements

a)   An organisation has defined its types of design output (e.g. blueprints, design checklists, etc.).

4. Design verification (A34)

An organisation's system for verification whether designs meet input requirements should be defined. Moreover, the system should cover at least two of the following methods: design reviews, qualification tests, alternative calculations or comparison with proven designs.

Unlike the inspection, the design verification is directly related to not only finished output specifications but also some internal process requirements.

Checklist of requirements

a)   An organisation has procedures to verify the achievement of input requirements. At least two of the following methods (design reviews, qualification tests, alternative calculations or comparison with proven designs) should be incorporated.

5. Design changes (A35)

Design changes can lead to many problems such as higher development costs, some losses of competitive advantages and more time-consuming tasks and so on. Consequently, configuration management procedures are expected to be adequate enough to handle such changes to ensure that output conforms to customer expectations. Example of such procedures is the extent to which activities should be scheduled for planning and implementing changes.

Checklist of requirements

a) Design changes are verified depending on their own causes.

b) They are approved.

3.1.12 Subcriteria under quality documentation

1. Document control (A41)

Under ISO9000, an organisation primarily have to define responsibility and authority for creation, distribution, collection, revision and control of quality-related documents. According to a recent survey of AT&T units, document control is the most difficult element to satisfy.

Checklist of requirements

a) An organisation has procedures to create quality-related documents.

b) Types of such documents have been identified.

c) All documents are available where needed.

d) The organisation has procedures to discard outdated documents.

2. Quality records (A42)

Quality records being pertinent to quality system requirements must be created depending on documented procedures. In addition, they comprise drawings, specifications, blueprints, procedures and many other types of records.

Checklist of requirements

a)   An organisation has procedures to create the quality records.

b)   Quality records present effective operation of the quality system.

c)   The quality records report status of the required quality levels and actions taken corresponding to the nonconformances.

d)   All records are readily retrievable by all concerned to use them.

e)   The organisation has procedures for discarding obsolete records.

3.1.13 Subcriteria under vendor assurance

1. Purchasing (A51)

Purchasing activities have to be planned and controlled with clearly defined responsibility and authority in order to acquire quality of purchased products and services. Also, purchasing data is very important since it must be communicated to vendors in a way of ambiguity or confusion reduction.

Checklist of requirements

a)   There are procedures for planning, controlling and documenting the procurement of materials.

b)   There are procedures for communicating to suppliers in an unambiguous way.

c)   There are procedures for verifying the conformity of purchased materials.

d)   Appropriate supplier records are monitored.

2. Purchaser-supplied product (A52)

The Purchaser-Supplied Product requirement applies solely to a special classification of organisation. Such organisation will, as part of its process, receive materials, products or services owned by customers, and included in the output which is then supplied back to them.

For instance, a book manufacturer usually prints and binds books for sale to a book publisher. As part of the process, the book manufacturer receives a computer disk being supplied by the publisher containing the text which is to be included in the final output. That disk is purchaser-supplied product.

Such purchaser-supplied product being distributed to an organisation must be monitored and secured at each point under the organisation's control.

Checklist of requirements

a)   An organisation has procedures for verifying incoming customer-supplied materials or products to determine conformance with respect to features, quantity and condition.

b)   The organisation keeps customer-supplied products or materials safe.

c)   The organisation reports to the customer any occurrences of nonconformance, shrinkage, damage, etc., affecting the customer-supplied products or materials.

3. Receiving inspection and testing (A53)

The standard requires an organisation to verify conformity to requirements at critical stages of the process: input, process points being crucial to quality and output. However, the receiving inspection and testing requirement focuses only on received products.

Checklist of requirements

a)   An organisation has procedures for verification of receiving materials.

b)   Verification methods are documented. Results are recorded.

c)   The output exempted from this receiving verification should be traceable in case of recall.

3.1.14 Subcriteria under handling and delivery

1. Product identification and traceability (A61)

Often, the extent to which an organisation implements identification and traceability procedures depends on the organisation's quality needs. For example, a printing company may want to be capable of tracing output back to an employee relevant to a specific press. In some cases, those procedures may be wholly unnecessary. In other cases, they may be in accordance with legal requirements.

Checklist of requirements

a)   If appropriate and/or if required by customer contract, legal requirement or regulatory requirement, organisation has a documented system for identified products.

b)   If appropriate and/or if required by customer contract, legal requirement or regulatory requirement, the organisation has a documented system for tracing the origin, application and/or location of products.

2. Inspection and test status (A62)

The standard obliges an organisation to identify a clear and definitive outcome of inspection and testing: conforming and nonconforming status. These identification procedures can be effected by a number of methods such as physical marking, records (hard copy or software) and so on.

This conformance status is so important to delivery system. This is because the extent to which the organisation have to be able to distinguish between conforming and nonconforming product is based on the final verification point. Nevertheless, these activities can also be conducted at every critical checkpoint in the process.

Checklist of requirements

a)   An organisation has procedures to identify inspection and test status of products.

b)   Such procedures provide traceability to verification activity.

3. Handling, storage, packaging and delivery (A63)

Handling and storage should be appropriate to the protection of the output and its shelf life, and consistent with the contract. Also, stored items should be periodically inspected. Packaging should be appropriate to use and environment, consistent with the contract, and governed by written procedures. Delivery should conform to procedures aiming at protecting the quality of product.

Checklist of requirements

a)   An organisation has means for handling of products to prevent damage or deterioration.

b)   The organisation has means for storage of the products to prevent damage or deterioration.

c)   Packaging does protects the products.

d)   Final products are controlled from final inspection to acceptance by customers.

3.1.15 Subcriteria under production

1. Process control (A71)

Process control is very crucial because its scope covers all aspects of production affecting quality: materials, equipment, procedures, personnel, supplies, environment and more. It should also be planned, controlled and documented in the most appropriate possible manner. For example, one of the main considerations in production planning is a sequence of production processes.

Checklist of requirements

a)   Process areas affecting quality have been clearly stated.

b)   Quality-related processes are in control and capable.

c)   Special processes which are of high importance to quality are implemented.

d)   Documentation exists for normal and special processes.

2. Inspection and test (A72)

Whatever procedures an organisation utilises to verify conformance to requirements-whether inspection and testing or other means-have to be documented. These documented procedures must be conducted consistently and the results should be recorded in accordance with the procedures.

Checklist of requirements

a)   Organisation has procedures for verifying conformance to requirements at each critical process points including input, in-process and output.

b)   Verification methods are documented. Results are recorded.

c)   Products exempted from such verification should be traceable in case of recall.

3. Inspection, measuring and test equipment (A73)

One of the main Inspection, Measuring and Testing Equipment requirements is that all devices employed to assess conformance to requirements should be selected and then controlled sufficiently to ensure confidence in decisions made on the basis of measurements. Such devices may include gauges, instruments and sensors, special test equipment, and jigs, fixtures and process instruments.

According to the AT&T study, this requirement is one of the most difficult elements to be conformed to, especially calibration of devices.

Checklist of requirements

a)   Organisation has procedures for selecting equipment capable of required accuracy and precision.

b)   Equipment is calibrated against national standards or equivalent at prescribed intervals.

c)   Organisation fully reports calibration procedures and results.

d)   Organisation has procedures for verifying such results when pieces of equipment are non-conforming.

e)   Organisation has procedures for preserving accuracy and fitness for use of equipment.

4. Statistical techniques (A74)

The standard requires an organisation to have procedures for identifying the statistical techniques employed to assess process capability and output characteristics. In addition, the statistical techniques are often used for two main stages in the quality system: production and inspection phase. However, they can also be determined for nonproduction areas including market analysis, design and performance assessment.

Examples of the existing statistical techniques are design of experiment analysis, variance analysis and statistical sampling inspection.

Checklist of requirements

a)   Organisation has procedures for identifying statistical techniques used in assessing process capability and product characteristics.

3.1.16 Subcriteria under problem identification and correction

1. Control of nonconforming product (A81)

An organisation's quality system should have procedures for segregating and disposing a nonconforming product so as to prevent it from inattentional use; in other

words, from reaching customers. These procedures should kick in once the nonconformity is detected.

Checklist of requirements

a)   An organisation has procedures for segregating and disposing nonconforming products to prevent from reaching its customers.

b)   The organisation has procedures for reworking, acceptance, rejection and regrade of products.

c)   The organisation documents all of the above.

2. Corrective action (A82)

After nonconforming output is prevented from reaching customers, causes of nonconformance should be identified and consequently appropriate correction actions should be designed and implemented. Where appropriate, some process changes may be conducted to protect the recurrence of systematic nonconformances.

Checklist of requirements

a)   Corrective action procedures are established and consistently followed.

b)   Postaudits are conducted to determine the effectiveness of corrective action.

3. Servicing (A83)

The standard suggests that an organisation should establish procedures for performing all contractual service and verifying whether the service meets specified requirements. Servicing requirements may cover customer use documentation, installation

instructions and postsale support facilities. However, in general, it is necessary only for organisations of which customer contracts require them to provide postsale servicing.

Checklist of requirements

a)   An organisation has procedures for performing contractual required services.

b)   The organisation has procedures for verifying that such services meet the established customer requirements.

The assessment model of ISO 9000 can be summarised as shown in Figure 3.2

3.2 Design of an assessment model of the Baldrige Award

The assessment model of the Baldrige Award is designed and developed based on the Malcolm Baldrige National Quality Award 1992. It is composed of 7 quality criteria and 27 quality subcriteria which can be described as follows: [Case and Blgelow, 1992; Desatnick, 1992; Heaphy, 1992; Lelfeld, 1992; Marquardt, 1992; Nam, 1995]

3.2.1 Criterion 1: Senior executive leadership (B1)

A company's senior leaders must create a customer focus, clear and visible quality values, and high expectations. Reinforcement of the values and expectations, and even encouraging leadership in all levels of management require great personal commitment and involvement. Also, the leaders have to take part in the creation of strategies, systems and methods for achieving excellence.

Figure 3.2 Assessment model of ISO 9000
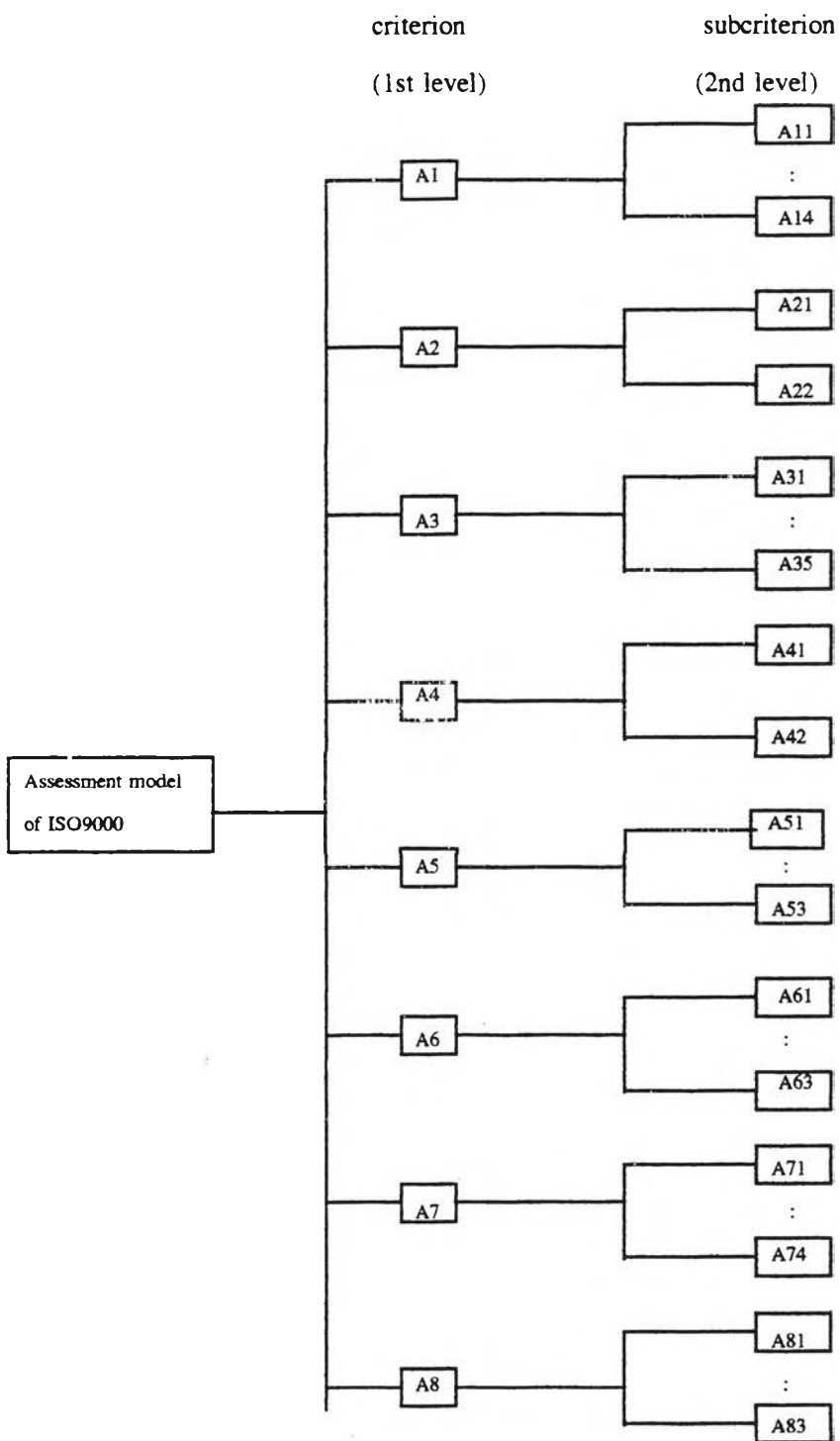
3.2.2 Criterion 2: Information and analysis (B2)

This category deals mainly with the scope, validity, analysis, management and use of data and information to drive quality excellence and improve competitive performance. Another thing to be included is the adequacy of a company's data, information and analysis system to support improvement of the company's customer orientation, products, services and internal operations.

Recently the quality information has played a more and more important role. This is because it has been easier to aggregate and analyse data, and produce information for management decision making as the degree of sophistication of information system has increased continuously.

3.2.3 Criterion 3: Strategic quality planning (B3)

This category places a substantial emphasis on a company's planning process and now to link between all key quality requirements and overall business planning. Moreover, the company's quality and performance plans for the short term (1-2 years) and the longer term (3 year or more), and the ways the company's strategies and planning can be deployed to all work units have to be conducted.

3.2.4 Criterion 4: Human resource development and management (B4)

This criteria focuses on the key elements of how a company realises the full potential of its employees in the pursuit of the company's quality and performance objectives. It also examines the company's efforts to create and maintain an environment for quality excellence being conductive to full a participation and personal and organisational growth.

It is clear that the skills and motivation of the company's workforce are very important to succeed in its competitive environment. Major challenges in the area of workforce development are to integrate human resource management selection, performance, recognition, training and career advancement, and to align human resource management with business plans and strategic change processes.

3.2.5 Criterion 5: Management of process quality (B5)

Management of process quality is one of the most vital categories that affect quality of a company. The company which succeeds in this management will prevent; reduce defects and losses, and gain continuous improvement in quality and performance.

This category focuses on the systematic processes the company utilises to achieve ever higher quality and performance. The key elements or indicators related to process management, which include design, management of process quality for all work units and suppliers, systematic quality improvement, and quality assessment, need to be evaluated.

3.2.6 Criterion 6: Quality and operational results (B6)

Quality and operational results category examines the quality levels and improvement trends in quality, operations and suppliers. It also deals with a company's quality and performance levels compared to those of its competitors. Moreover, this category provides key measures to evaluate and improve quality system processes and practices. Well-presented results help transform data into information and knowledge necessary for improving quality. For instance, such results can state performance levels and improvement trends of product and service measures.

3.2.7 Criterion 7: Customer focus and satisfaction (B7)

This category focuses on a company's relationship with customers, and its knowledge of customer requirements and of the key quality factors that consider marketplace competitiveness. Also concerned is the extent of the company's procedures for determining current levels of customer satisfaction and its trends, and these results relative to competitors.

Currently, it is clear that quality is judged by customers. This concept of quality deals with not only the product and service characteristics that meet basic customer expectations, but also these characteristics which enhance them and differentiate them from competitors. For this reason, new offerings, combinations of product and service offerings, rapid response, or special customer-supplier relationship is depended upon.

3.2.8 Subcriteria under senior executive leadership

1. Senior executive leadership (B11)

This criterion is concerned with the senior executive leadership, personal involvement and visibility in developing and maintaining an environment for quality and operational performance excellence. The more regularly senior executives communicate and reinforce the company's customer orientation and quality values with managers, supervisors and all employees, the more closely the company quality and performance objectives can be met, for instance.

Checklist of requirements

a)   Level of senior executives' leadership, personal involvement and visibility in quality related activities.

b)   Senior executives communicate and reinforce customer focus and quality values with manager, supervisors and all employees.

c)   Senior executives evaluate and improve the effectiveness of their personal leadership and improvement.

2. Management for quality (B12)

Management for Quality category deals with the extent to which a company's customer focus and quality values are integrated into day-to-day leadership, management, and supervision of all work units. In other words, it focuses on how the company's customers focus and quality values are translated into requirements for all managers and supervisors with respect to their key roles and responsibilities within an intra unit and between different units. Also determined is how the company evaluates and improves managers, and supervisors' effectiveness in reinforcing the company's customer focus and quality values.

Checklist of requirements

a)   An organisation's customer focus and quality values are translated into requirements for all managers and supervisors, including their principal roles and responsibilities within their units and those with other units.

b)   Overall organisation and work units quality and operational performance are reviewed. The organisation assists the units that are not performing according to plans.

c)   The organisation evaluates and improves managers' and supervisors' effectiveness in fostering the customer focus and quality values.

3. Public responsibility (B13)

This category requires a company to add its responsibilities to the public in its quality policies and practices. Moreover, the company has to assess potential impacts on society of its products and services, and look for determining future public concerns.

Checklist of requirements

a)   An organisation adds its public responsibilities into its quality values and practices.

b)   The organisation anticipates public concerns, and assess potential impacts on society of its products, services and operations.

3.2.9 Subcriteria under information and analysis

1. Scope and management of quality and performance and information (B21)

A company is required to have procedures for determining data andinformation used for planning day-to-day management and evaluation of quality. Also required is how data and information reliability, timeliness and success are assured.

Checklist of requirements

a)   An organisation has criteria for selecting types of data and information used for planning, day-to-day management and evaluation of quality.

b)   The types of data and information include: (1) customer-related, (2) internal operations, (3) company performance and (4) cost and financial.

c)   Each of such types supports quality improvement.

d)   The organisation has an approach for ensuring that data and information get more reliable, quicker and accessible.

e) The organisation evaluates and improves the scope and quality of its data and information.

2. Competitive comparisons and benchmarks (B22)

This criterion deals with whether a company has its own approach to selecting data and information for competitive comparisons and key world - class benchmarks to support quality and performance planning evaluation and improvement.

Checklist of requirements

a) The organisation has criteria for selecting data and information for competitive comparisons and benchmarks.

b) Types of such data and information include: (1) product and service quality, (2) customer satisfaction, (3) internal operations and (4) supplier performance.

c) Competitive and benchmark data are used to encourage new ideas and improve understanding of processes.

d) The organisation evaluates and improves the scope, sources and uses of the competitive and benchmark data.

3. Analysis and uses of company-level data (B23)

The focus is on how to collect, analyse and translate quality-and performance-related data into actionable information to support a wide range of activities based on a company's overall operational and planning objectives. Examples of such activities are creating the company-level strategies and making key decisions to direct the company.

Checklist of requirements

a)   Customer-related data are aggregated, analysed and translated into actionable information for quality improvement.

b)   Internal operation performance data are aggregated, analysed and translated into actionable information for quality improvement.

c)   Key cost, financial and market data are aggregated, analysed and translated into actionable information for quality improvement.

d)   The effectiveness of analysis is evaluated and improved.

3.2.10 Subcriteria under strategic quality planning

1. Strategic Quality and company performance planning process (B31)

This category places an emphasis on how a company develops short term (about 1-2 year) and longer term (3 years or more) plans and strategies. These quality strategies need to be interrelated to the overall business planning; otherwise, many problems may happen. For example, the company's senior executives might want to implement a TQM (Total Quality Management) process; however, they assign the development and goal setting to the quality staffs. Without the involvement of the top executives, the staffs may try to do the best but the acquired improvements could have nothing to do with the company's optical success factors.

Furthermore, the company is obliged to determine how planning process evaluations and improvements are conducted.

Checklist of requirements

a)   An organisation develops the short-term (1-2 years) and long-term (3 years or more) strategies and business plans for achievement of quality and performance requirements.

b)   This planning process consider: (1) customer requirements, (2) financial, marketing, technical and societal risks, (3) company capabilities, (4) competitor capabilities, and (5) supplier capabilities.

c)   The organisation evaluates and improves its planning process.

2. Quality and performance plans (B32)

This category focuses on how a company summarise its quality and company performance plans and goals for the short and longer term to achieve quality and customer satisfaction leadership.

Checklist of requirements

a)   An organisation summarises its key short-term quality and performance plans and goals.

b)   The organisation summarises its key long-term quality and performance plans and goals.

3.2.11 Subcriteria under human resource development and management

1. Human resource management (B41)

This category deals with the extent to which a company's overall human resource development and management plans and practices support its quality and performance plans. Such human resource plans and practices can affect a number of

employee related activities such as education and training, recruitment, hiring, recognition, and so on.

Checklist of requirements

a)   Human resource plans supports an organisation's quality and performance plans.

b)   Such plans include: (1) education, training and related skill development, (2) recruitment , (3) involvement, (4) empowerment and (5) recognition.

c)   Different training and development needs are clearly defined for different types of employees.

d)   The organisation evaluates and improves effectiveness of the entire work force by using all employee-related data.

2. Employee involvement (B42)

A company is required to have management practices and specific mechanisms for promoting employee contributions individually and in group, to achieve the company 's quality and performance objectives. This depends on different categories of employees and company needs.

Checklist of requirements

a)   An organisation has mechanisms to promote employee contributions, empowerment, responsibility and innovation.

b)   The organisation evaluates and improves effectiveness of involvement of all types of employees.

3. Employee education and training (B43)

A company has to describe how to determine what quality and related education and training is needed by employees. Different types of quality and related education and training are generated to various categories of employees. Examples of such education and training are quality awareness, leadership, process analysis, process simplification and so on. In addition, how the company uses the knowledge and skills acquired is examined.

Checklist of requirements

a)   Different needs for the types and amounts of quality and related education and training are contributed to different types of employees.

b)   Summary and trends in quality and related education and training received by employees are conducted.

c)   The summary and trends address: (1) quality focus of new employees, (2) percent of employees receiving such education and training per employee annually.

d)   The effectiveness of such education and training are evaluated and improved.

4. Employee performance and recognition (B44)

This criterion is concerned with how a company recognises, promotes, compensates, rewards and provides feedback to employees based mainly on each employee's achievement of quality and performance goals.

Checklist of requirements

a)   An organisation recognises, promotes, compensates, rewards and provides feedbacks to employees.

b)   The employees contribute to the approaches above.

c)   The actual performance and recognition trend data are considered.

d)   The organisation evaluates and improves its performance and recognition processes.

5. Employee well-being and morale (B45)

This category deals with well-being and morale factors such as health, safety, satisfaction and ergonomics being included in quality improvement activities. A company have to summarise key improvement goals, methods and indications for each factor pertinent to its work environment. For example, to overcome accidents and work-related health problems, the company initially needs to identify how root causes are determined and how adverse conditions are prevented.

Also considered is about some special services, facilities and opportunities the company provides for its employees. This might cover one or more of the following: counseling, assistance, recreation, non-work-related education and out placement.

Checklist of requirements

a)   Employee well-being and morale factors such as health, safety, satisfaction and ergonomics are considered in quality improvement activities.

b)   An organisation has procedures for mobility, flexibility, and retraining in job assignments to support employee development.

c)   The organisation offers special services, facilities and opportunities to employees. These might include counseling, assistance, recreational education and more.

d)   Trends in key indicators of well-being and morale are considered. This should address, as appropriate; satisfaction, safety, absenteeism, turnover, strikes and worker compensation.

3.2.12 Subcriteria under management of process quality

1. Design and introduction of quality products and services (B51)

This category deals with how new and/or improved products and services are designed and introduced. As well, it is concerned with how processes are designed to meet key product and service quality, and company performance requirements.

Checklist of requirements

a)   An organisation develops the designs of products, services and processes.

b)   Customer requirements are translated into design requirements.

c)   All quality requirements are addressed early in the overall design process as appropriate.

e)   The design requirements are expected to be translated into production and delivery requirements.

f)   A plan for selecting, setting and monitoring key process characteristics is developed.

g)   The organisation evaluates and improves the effectiveness of its designs and design processes.

2. Process management or process quality control (B52)

This category focuses on how a company manages and maintains the quality of production and delivery processes in accordance with product and service design requirements. The company is obliged to have means for handling out-of-control occurrences considering root cause determination, correction and verification of correction, for example.

Checklist of requirements

a)   An organisation maintains the quality of processes in accordance with design requirements. This should address types and frequencies of measurements, and how to handle out-of-control occurrences.

b)   The organisation evaluates and improves the effectiveness of processes. This should address, as appropriate: process simplification, waste reduction, process research and testing and use of alternative technologies.

3. Business process and support services (B53)

A company is required to identify how its business processes and support services (such as finance and accounting, and software services) are managed so that the current quality requirements are obtained, and quality and performance are continuously improved. To help create these tasks, there are many considerations: process performance data, process simplification, use of alternative technologies, benchmark information and more.

Checklist of requirements

a)   An organisation manages its business processes and support services.

b)   The following are considered: process performance data, process and organisational simplification, use of alternative technologies, benchmark information, information from customers of business processes and support services and challenging goals.

4. Supplier quality (B54)

A company is obliged to describe how the assurance and continuous improvement of the quality of materials, components and services provided by the

company's suppliers are conducted. A variety of methods utilised to ensure supplier's achievement of the company's quality requirements may include audits, process reviews, receiving inspection, vendor rating systems and so on. Current strategies and actions to improve the quality and timeliness of suppliers may cover partnerships, incentives, recognition, supplier selection and more.

Checklist of requirements

a)   An organisation has procedures to define and communicate its quality requirements to suppliers.

b)   The organisation has methods to ensure the suppliers' achievement of quality requirements. Such methods may include audits, process reviews, receiving inspection, certification, testing and rating systems.

c)   The organisation has current strategies and actions to improve the quality and timeliness of suppliers. These may include partnerships, training, incentives and recognition, and supplier selection.

5. Quality assessment (B55)

Quality Assessment criterion places an emphasis on how a company assesses the quality and performance of its systems, processes and practices, and the quality of its products and services. Also to be dealed with is how assessment findings and results are subsequently used for continuous improvement.

Checklist of requirements

a)   An organisation has procedures for assessing and improving its systems, processes, practices, and products and services.

3.2.13 Subcriteria under quality and operational results

1. Product and service quality results (B61)

This category deals with the extent to which current levels and trends for all key measures of product and service quality are summarised. A well-conceived set of key measures and results should reflect the most important factors that anticipate customer satisfaction and quality in customer use. Examples include measures of accuracy, precision, timeliness, performance, after-sales services, documentation, appearance and so on.

It is also concerned with current quality level comparisons with major competitors, industry averages, industry leaders and key world-class benchmarks, regardless of the some industry.

The assessment is based:

a) An organisation has trends and current levels for all key measures of product and service quality. Such measures may include accuracy, reliability, timeliness, performance, behaviour, after-sales services, documentation and appearance.

b) The organisation has current quality level comparisons with its key competitors. Basis for such comparisons includes independent surveys or studies, benchmarks, and factory evaluation and testing.

2. Company operational results (B62)

This category is concerned with the extent to which current levels and trends for all key measures of overall company operational performance are summarised. They could address productivity index, waste reduction, cycle time reduction environmental improvement and other measures of improved overall company performance. In addition,

it deals with comparisons of performance with principal competitors and appropriate benchmarks.

Checklist of requirements

a)   An organisation has trends and current levels for key measures of operational performance.

b)   The organisation conducts comparisons with competitors and key benchmarks with the world-class ones.

3. Business process and support service results (B63)

This criterion deals with the extent to which current levels and trends for key measures of quality and performance of business processes and support services. Key measures of performance here should represent the principal quality, productivity, cycle time, cost and other effectiveness requirements for business processes and support services. And, this criteria again is concerned with comparisons of performance appropriately chosen companies and benchmarks.

Checklist of requirements

a)   An organisation conducts trends and current levels for key measures of business process and support service performance.

b)   The organisation conducts comparisons of performance with competitors and key benchmarks.

4. Supplier quality results (B64)

This criterion focuses on the extent to which current levels and trends for the most crucial indicators of supplier quality. Also emphasised is how to compare a company's supplier quality with that of competitors and with key benchmarks.

Checklist of requirements

a)   An organisation has trends in quality levels of suppliers.

3.2.14 Subcriteria under customer focus and satisfaction

1. Customer relationship management (B71)

A company is required to have procedures for determining effective management of relationships with its customers. For example, the company should have means for providing information and easy access to allow its customers to seek assistance to comment or complain. The company also has to utilise information obtained from them to improve the future customer relationship management plans and strategies.

Checklist of requirements

a)   An organisation develops the strategies and plans to maintain and build relationships with customers.

b)   The most important factors to be taken into account for achieving this are fulfillment of basic customer needs, provision of information to customers and roles of all customer-contact employees.

c)   The organisation ensures that complaints and feedback received by all organisation units are resolved promptly and effectively.

d) The organisation evaluates and improves its customer relationship management.

2. Customer satisfaction determination (B72)

This standard obliges a company to state comparison with competitors. Understanding of market segment and customer groups, and key customer satisfaction requirements for each segment or group is the prerequisite.

Checklist of requirements

a) An organisation has methods for determining customer requirements, satisfaction and dissatisfaction.

Note Customer dissatisfaction indicators include complaints, claims, refunds, repairs, warranty work, warranty costs, incomplete orders.

b) The organisation determines customer satisfaction relative to its competitors.

c) The organisation evaluates and improves such methods above.

3. Customer satisfaction results (B73)

This category deals with the extent to which current levels and trends for a company's customer satisfaction.

Checklist of requirements

a) An organisation has trends and levels of its customer satisfaction.

b) The organisation has trends and levels of its customer dissatisfaction.

4. Customer satisfaction comparison (B74)

The standard requires a company to describe comparisons of its customer satisfaction with key competitors. The measurement may be based on gaining or losing customers to the competitors.

Checklist of requirements

a) An organisation has trends and levels of its customer satisfaction relative to competitors.

b) The organisation has trends and levels of its customer dissatisfaction relative to competitors.

5. Future requirements and expectations of customers (B75)

This category deals with how a company determines future customer requirements and expectations.

Checklist of requirements

a) An organisation has procedures for determining future requirements and expectations of customers.

Note Examples of the determination of them are the approaches for getting customer-related information and improvement of survey design.

b) The organisation projects key product and service features and relative importance of these features to customers and potential customers.

The assessment model of the Baldrige Award can be summarised as shown in Figure 3.3.

Figure 3.3 Assessment model of the Baldrige Award
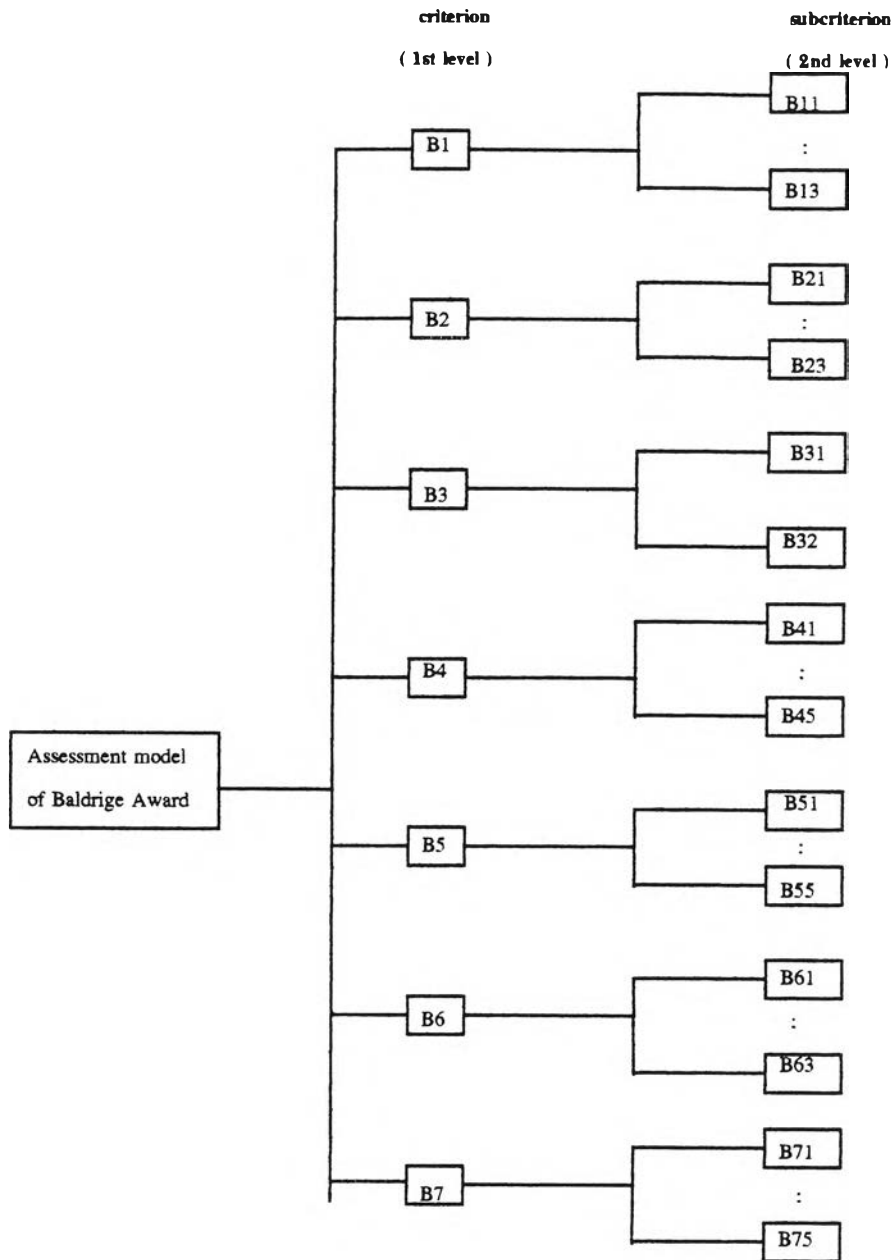
3.3 Method for data collection

3.3.1 The Delphi method

The Delphi approach is undoubtedly the most widely used of technological or qualitative forecasting methods. This approach originally developed at Rand Corporation, is principally a method for obtaining a consensus from a group.

Like other consensus methods, the Delphi approach is aimed to obtain a reliable consensus of opinion from a group of experts that can be used as a future forecast. However, one major difference between the Delphi approach and the others is that the experts are kept apart from one another. This helps reduce the undesirable aspects of group interaction such as specious persuasion, the unwillingness to abandon publicly expressed opinions and the bandwagon effect of majority opinion.

An example of how this approach has been used will demonstrate its procedural characteristics: [Helmer and Resher, 1959]

Phase 1. The experts on the panel were asked in a letter to name inventions and scientific breakthroughs that they thought were both urgently needed and could be achieved within the next 20 years. Each expert was then asked to send his or her list back to the coordinator of the panel. From these lists, a general list of 50 items was compiled.

Phase 2. The experts were then sent a list of the 50 items and asked to place each of those items in one of the 5-year time periods into which the next 20 years had been divided. The basis for this categorisation was that there would be a 50-50 probability that it would take a longer or shorter period of time for each breakthrough to occur. Again, the experts were asked to send their responses to the panel coordinator.

(Throughout this procedure the experts were kept apart and asked not to contact any of the other members of the panel.)

Phase 3. Letters were again sent to the experts telling them on which items there was a general consensus and giving them the responses falling in the middle 50 percent, as well as in each of the higher and lower quartiles on those items where there was not a general consensus.

The experts were also asked to state their reason for any widely divergent estimates they had made. Several of the experts, as a result of this, reassessed their estimates in a narrower range.

Phase 4. To narrow the range of estimates further, the phase 3 procedure was repeated. At the end of this phase, a number of the original items on the list were grouped together as breakthroughs for which a relatively narrow time estimate of their occurrence had been obtained. Thus, the final result of such a procedure was not only information based on expert opinion as to what breakthroughs were likely to occur, but also information as to when those breakthroughs would most likely to be achieved.

In some cases, the Delphi approach comprises a few rounds. In other cases, it might be composed of hundreds of rounds. This varies depending upon the applications and group characteristics. However, one similar thing is that if in any round a controlled feedback provided by the coordinator or interviewer reflects deviant opinion, the deviants will be asked to justify their position. In a number of studies, it is evident that after each round is finished, the quartile range of the estimates or opinion becomes narrower.

There are various situations within business and government in which the Delphi technique can be used with only minor modifications [Makridakis, Wheelwright and McGEE, 1983]. In the corporate setting, the experts in the group usually come from both

inside and outside the company. One important issue is that an expert which is qualified in such group is not necessary to be in the same portion of the area of interest. Rather, the expert's background can come from solely subparts of the area, with at least one expert in every subpart. In this way, the entire problem area is represented.

The Delphi method, like any individual forecasting approach, has its disadvantages. The most common complaint against it are often low level of reliability and its oversensitivity of results to ambiguity in the questionnaire. Therefore, before the Delphi approach is chosen, its disadvantages have to be weighed against its advantages through the corresponding application.

3.3.2 Collecting data by Delphi method

See a detailed explanation of this in **section 5.1.2**.

3.4 Method for calculating weights of criteria and subcriteria

3.4.1 Analytical Hierarchy Process

The analytical hierarchy process (AHP) is a decision-making process in which a decision problem is broken down to a hierarchy of interrelated decision criteria. Moreover, to give the order in which factors affect a decision, consistency of the respondent and a prioritised list of the decisions to be made, AHP uses the pairwise comparisons of the user.

To implement the AHP process, there exists four steps which are as follows:

Step 1-Break down the problem into a hierarchy of interrelated decision elements. It is obliged that the overall goal is placed at the top; but, the main attributes on a level below.

Step 2-Use pairwise comparisons of decision elements for input data collection, in respect of their importance to the parent, every attribute on each level is compared to each other.

Step 3-Utilise the "eigenvalue" method to estimate the relative weights of decision elements.

Step 4-Aggregate the relative weights of decision elements til a set of rankings for the decision alternatives is obtained. The scores representing the weight given to each attribute are adjusted and then summed to achieve a final score for each alternative.

Figure 3.4 shows the decision scheme of the analytic hierarchy process. The most general objective is placed on the highest level; on the other hand, each decision alternative is posed on the lowest one.

The local priorities differ from the global priorities in that the former reflects the importance of an element in a certain level with respect to an element immediately above it; whereas, the latter with respect to the problem focus. These local priorities can be derived by the use of a comparison scale and a pairwise comparison matrix. The decision maker is provided with a comparison matrix A, of dimensions N $\times$ N, where N is the number of alternatives in that level, in order to tabulate this priority level. The decision maker is required to fill every element a_{ij} corresponding to the pairwise comparison result reflecting the extent to which element i dominates element j.

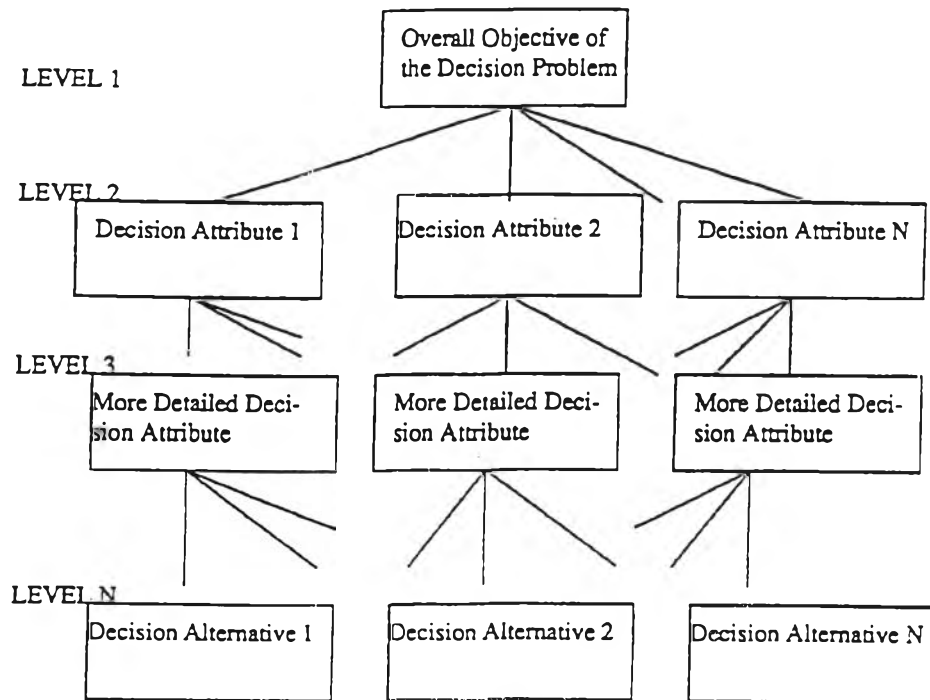Figure 3.4 The AHP decision scheme [Douligeris and Pereira, 1994].

Figure 3.5 is an example showing the consideration of four elements: A. B. C and D to be compared with each other. Its presentation is in the form of 4×4 matrix. Elements in the row on top will be compared to elements in the column on the left.

These pairwise comparisons have to be transformed into a standard scale. The decision maker is required to compare between two elements at each time. And if:

A is equal B. insert 1

A is weakly preferred to B, insert 3

A is strongly preferred to B, insert 5

A is very strongly preferred to B, insert 7

A is absolutely preferred to B, insert 9 in the position (A, B), where the row of A meets the column B.

Figure 3.5 A sample pairwise comparison [Douligeris and Pereira, 1994].

	A	B	C	D
A	1			
B		1		
C			1	
D				1

Clearly, every element is equally important while compared to itself. Considering Figure 3.5 again the meeting of the row and column of A, representing position (A, A) is therefore inserted with 1. Consequently, the main diagonal of a matrix must comprise 1's.

For the reverse comparison of B with A, the decision maker have to insert the suitable reciprocal at which the column of A meets the row of B; in other words, position (B, A). The number 2, 4, 6, 8 and their reciprocals may also be used to reflect a compromise between the slightly distinct judgments.

To calculate the priority vector, sum the elements in each row and normalise this sum by dividing each sum by the total of all sums. The results of all sums should add up to unity. The first entry of the resultant vector reflects the priority of the first element, the second entry the priority of the second element and so on. [Douligeris and Pereira, 1992]

Let the priority vector be represented by w. Then, the principal eigenvector needs to be derived from this vector of priorities. We have $w = \lambda_{max}\, w$, where λ_{max} is the principal or largest eigenvalue of the comparison matrix, that can be shown to satisfy $\lambda_{max} \geq n$ (n is the order of the matrix) with equality holding true only in the perfectly consistent case.

The following steps identify how to compute an approximate λ_{max} manually, suggested by Dyer and Forman: [Dyer and Forman, 1991]

1.   Multiply the first column of the comparison matrix by the priority of the first element, the second column by the second element and so on. Next, calculate the weighted sum for each row.

2.   Divide the weighted sum for the first row by the priority of the first element, the second row by the second element and so on.

3.   Compute the average of the values specified in step 2; this average represents λ_{max}.

The consistency index (CI) is an indicator of the method's accuracy and is defined as:

$$CI = (\, \lambda_{max} - n \,) / (\, n - 1 \,) \qquad\qquad (3.1)$$

The bigger the value of CI is, the less consistent the case is. Consequently, in a perfectly consistent case CI becomes the value zero.

The consistency index of a randomly generated reciprocal matrix from the scale 1 to 9, with reciprocals forced, is named the random index (RI). Table 3.1 shows the order of the matrix across the first row versus the values of RI across the second row.

Table 3.1 The RI table

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.0	0.0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

The ratio of CI to RI for the same order matrix is called the consistency ratio (CR). A consistency ratio of 0.10 or less is considered acceptable. The CR will be zero when the decision maker is perfectly consistent. For instance, if the decision maker comments A is preferred to B by a ratio of 2:1 and B is preferred to C by a ratio of 3:1, then A is preferred C by a ratio of 6:1. Consequently, the CR becomes zero.

3.4.2 Calculating weights of criteria and subcriteria by AHP

AHP is not a complicated process designed to analyse complex problems. It is a simple process for analysing complex problems. For AHP, multiple-criteria variables can be employed to allow the decision maker to incorporate both objective and subjective factors in evaluating alternatives and arriving at a decision. Other multicriteria decision-making methodologies, such as goal programming, cannot handle subjective considerations. [Dyer and Forman, 1991]

AHP has been applied in a wide range of practical implications for the recent years. The application area includes health care, politics, urban planning, space exploration and more. The AHP has been used in ranking, selection, evaluation, optimisation and prediction decision problems. [Golden, Wasil and Levy, 1989]

AHP can also be applied in this study because one major aim of this study is to measure quality management system which is usually subjective. However, the study just utilises AHP for calculating relative weights or importance of subcriteria or criteria for each of two proposed assessment models. This depends on pairwise between subcriteria or criteria in a hierarchical manner. An example of how to calculate them by AHP is presented in Appendix 3.

3.5 Method for synthesising scores of company

3.5.1 The simple weight ranking method

The simple weight ranking method is very easy to calculate the numerical results. The method considers each variable does not need to have the same importance or weight. Its procedure is to simply total the weighted sum of values of individual variables.

3.5.2 Synthesising scores of company by simple weight ranking method

If the weights of each criterion and subcriterion are collected, then they and the scores of individual subcriteria for the selected company (see section 5.3 on how to collect this data) are to be synthesised together.

The values of individual criteria are gained from the weighted sum of scores of corresponding subcriteria for the selected company multiplied by each weight of those criteria; in other words,

$$V_i = (\sum_{j=1}^{n} \alpha_{ij} * S_{ij}) / (\sum_{j=1}^{n} \alpha_{ij}) \qquad (3.2)$$

Where:

i is number of criteria $\qquad i = 1$ to m

j is number of subcriteria of each criteria $\qquad j = 1$ to n

α *ij* is the weight of each subcriteria

S ij   is the score of each such criterion

V *i*   is the value of each category

Then, the value of individual criterion multiplied by its weight represents the achievement value of that criterion's requirements, which can be presented by this following formula:

$$AC_i = \gamma_i * V_i \qquad \text{(3.3)}$$

where :

γi is the weight of each criterion

AC i   is the achievement value of each criterion's requirements

3.6 Method for ranking companies

In cases where the orders or rankings of the companies' achievement of quality management system are needed, a variety of the outranking or decision making methods can be applied. Nevertheless, the study places an emphasis on the simple weight ranking method, the AHP, the PROMETHEE method and the ELECTRE method. Finally, a proposed selection system for the outranking methods will be identified.

3.6.1 Simple weight ranking method

As explained in section 3.5.2, the weighted sum of scores of individual subcriteria for the selected company is defined as the values of the corresponding criteria. Similarly, the weighted sum of values of individual criteria represents an achievement value of successful quality management system for each company. Such achievement value (*A V*) is gained from the following formula:

$$AV = \left(\sum_{i=1}^{m} \gamma_i * V_i \right) / \left(\sum_{i=1}^{m} \gamma_i \right) \qquad (3.4)$$

Where:

i is number of criteria $i = 1$ to m

γ_i is the weight of each criterion

V_i is the value of each criterion

In comparison between companies, we may compare the AV for each company together.

The simple weight ranking method has some drawbacks. One is that in the decision problem each criterion has to be either maximum or minimum in the same way. In the simple weight ranking method, the "cost" criterion cannot be aggregated with the "quality" criterion, for instance. The "cost" criterion has to be minimised; whereas, the "quality" criterion should be maximised.

The simple weight ranking method tends to be the most appropriate one when there is not enough time available for decision-making and the decision maker does not understand high-level mathematics.

3.6.2 AHP

As explained in section 3.4.1, it is clear that AHP can be utilised in ranking the companies' achievement of successful quality management system.

AHP allows the decision maker to be inconsistent. As already identified, the consistency ratio which is no more than 0.1 is acceptable.

Moreover, AHP is usually not so good at dealing with the probabilistic problems such as in assessing risky assets and statistical quantities. Rather, it is more appropriate to apply in other contexts such as the estimation of distance between towns and so on. This is because it uses ratio scale estimation. [Harker, 1989]

3.6.3 PROMETHEE method

The PROMETHEE methods, a new class of outranking methods in multicriteria analysis, will be presented as follows: [Brans, Vinke and Mareschal, 1986]

<u>Introduction</u>

Considering the multicriteria decision problem

$$\text{Max} \ \{ \ f_1 (a) , \dots , f_k (a) / a \in k \ \} \ , \qquad 3.1$$

Where K is a finite set of actions, f_i, i = 1, 2, 3, ..., k, are k criteria to be maximised, each of which is an application from K to R or any other ordered set.

B.Roy has introduced a number of the outranking methods in multicriteria analysis. The PROMETHEE methods (Preference Ranking Organisation METHod for Enrichment Evaluations) which represent one family of them include the following two phases:

- Constructing an outranking relation on K and

- Exploiting this relation in order to give an answer to 3.1

For the first phase, the construction of an outranking relation on K is dependent on a generalisation of the notion of criterion. For this reason, a preference index and a

valued outranking graph (, which reflects the preferences of the decision maker,) are thus obtained.

The exploitation of such relation is realised by determining for each action a leaving and an entering flow in the valued outranking graph. The proposed partial preorder (PROMETHEE I) or complete preorder (PROMETHEE II) can help the decision maker achieve the decision problem finally.

The PROMETHEE valued outranking relation

a . Generalised criterion

Let us consider a real-valued criterion:

$f : K \longrightarrow R$ (or any other ordered set)

which is assumed to need the maximisation.

For each action $a \in K$, $f (a)$ is an evaluation of this action.

When two actions $a, b \in K$ are to be compared, the result of this comparison have to expressed in terms of preference. Hence, we consider a preference function P:

$$P : K \times K \longrightarrow (0, 1) \qquad\qquad 3.2$$

which represents the intensity of reference of action a relative to action b and such that

-	$P (a, b) = 0$	is meant a is indifferent from b;
-	$P (a, b) \sim 0$	is meant a is weakly preferred to b;
-	$P (a, b) \sim 1$	is meant a is strongly preferred to b;
-	$P (a, b) = 1$	is meant a is strictly preferred to b.

In practice, this preference function often reflects a function of the difference between the two evaluations; in other words,

$$P(a, b) = \mathcal{P}(f(a) - f(b)) \tag{3.5}$$

Figure 3.6 shows the graph of such a function , which must be a non - decreasing one equal to zero for negative values of $d = f(a) - f(b)$.

In order to achieve a better view of the indifference area, a function H(d) which is directly relevant to the preference function P is considered:

$$H(d) = \begin{cases} P(a, b), & d \geq 0, \\ \\ P(b, a), & d \leq 0. \end{cases} \tag{3.6}$$

Figure 3.7 shows the graph of this function.

Figure 3.6 Preference function $\mathcal{P}(d)$ [Brans, Vincke and Mareschal, 1986]
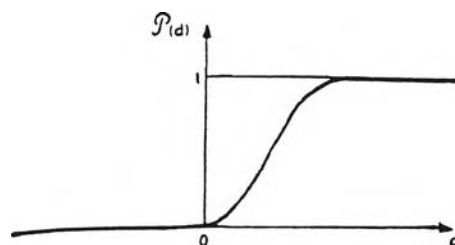
Figure 3.7 Function H(d) [Brans, Vincke and Mareschal, 1986]
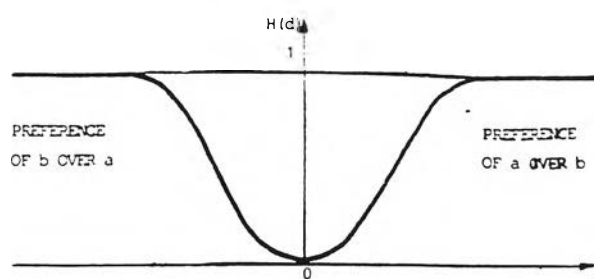
For practicalities, the generalised criteria for applications are recommended. Table 3.2 summarises the six types of generalised criteria among which the decision maker can select, and their corresponding parameters. We think that the presentation of this table could assist the decision maker in easily choosing the function H(d) according to his preferences as appropriate.

b. Multicriteria preference index

Let us assume that the decision maker has already identified a preference function Pi and weight π_i for each criterion fi (i = 1,....., k) of problem 3.1. The relative importance of criterion fi is directly measured by the weight π_i.

Therefore, the multicriteria preference index $\prod$ is considered as the weighted average of the preference functions P_i :

$$\prod(a, b) \quad = \quad \frac{\displaystyle\sum_{i=1}^{k} \pi_i P_i (a, b)}{\displaystyle\sum_{i=1}^{k} \pi_i} \qquad (3.7)$$

Such index indicates the intensity of decision maker's preference of action a over action b when considering all the criteria at the same time. Its typical figures are between 0 and 1, and:

- $\prod (a, b) \sim 0$ means a weak preference of a over b for all the criteria,

- $\prod (a, b) \sim 1$ means a strong preference of a over b for all the criteria.

Moreover, this preference index determines a valued outranking on the set K of actions. This relation can be presented by a valued outranking graph, each node of which is one action of K. Figure 3.8 illustrates an example of this graph which is composed of two arcs having values $\prod$ (a, b) and $\prod$ (b, a) between two nodes, a and b.

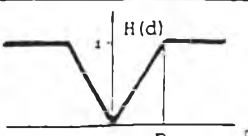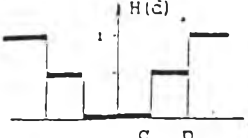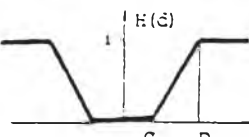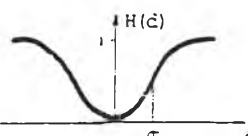Table 3.2 The six types of generalised criteria [Brans, Vincke and Mareschal, 1986]
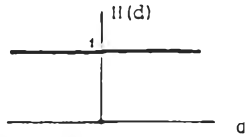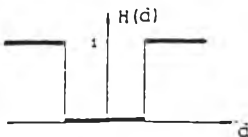
Types of generalized criteria		Param -eters
I. Usual criterion		—
II. Quasi-criterion		q
III. Criterion with linear preference		p
IV. Level criterion		q,p
V. Criterion with linear preference and indifference area		q,p
VI. Gaussian criterion		σ

Figure 3.8 An example of valued outranking graph

[Brans, Vincke and Mareschal,1986]
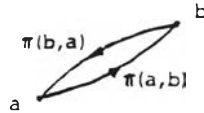
The PROMETHEE rankings

a. Flows in the valued outranking graph

Considering each node a in the valued outranking graph the leaving and entering flow are assumed to be defined as:

$$\varnothing^+ (a) = \sum_{b \in k} \prod (a, b) \qquad (3.8)$$

$$\text{and} \quad \varnothing^- (a) = \sum_{b \in k} \prod (a, b) \qquad (3.9)$$

, respectively.

The leaving flow is the sum of the vales of the are leaving node a and consequently provides a measure of the outranking character of a (see Figure 3.9). On the other hand, the entering flow represents the sum of the values of the arcs entering node a and also measures the outranked character of a (see Figure 3.10).

Figure 3.9 The leaving flow for node a

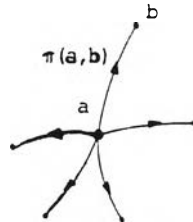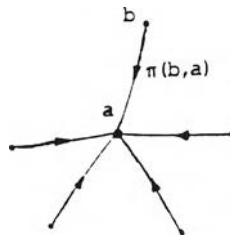[Brans, Vincke and Mareschal, 1986]

Figure 3.10 The entering flow for node a

[Brans, Vincke and Mareschal, 1986]

b. PROMETHEE I

The higher the leaving flow and the lower the entering flow, the better action.

The leaving and entering flows induce the following two preorders:

$$
\left\{
\begin{array}{llll}
aP^{+} b & \text{iff} & \varnothing^{+}(a) > \varnothing^{-}(b) & \\
aI^{+} b & \text{iff} & \varnothing^{+}(a) = \varnothing^{-}(b), \text{ and} & 3.3 \\
\end{array}
\right.
$$

$$
\left\{
\begin{array}{llll}
aP^{-} b & \text{iff} & \varnothing^{-}(a) < \varnothing^{-}(b), & \\
aI^{-} b & \text{iff} & \varnothing^{-}(a) = \varnothing^{-}(b), \text{ respectively} & 3.4 \\
\end{array}
\right.
$$

Hence, the PROMETHEE I partial preorder (P_I , I_I , R) is obtained by determining the intersection of those two preorders above.

$$
\begin{array}{ll}
aP_I b \ (a \text{ outranks } b) & \text{if } aP^{+} b \text{ and } aP^{-} b, \\
 & \text{or } aP^{+} b \text{ and } aI^{-} b, \\
 & \text{or } aI^{+} b \text{ and } aP^{-} b; \\
aI_I b \ (a \text{ is indifferent to } b) & \text{iff } aI^{+} b \text{ and } aI^{-} b; \\
aPb \ (a \text{ and } b \text{ are incomparable}) & \text{otherwise.} \\
\end{array}
$$

$$3.5$$

C. PROMETHEE II

For avoiding any in comparabilities, the PROMETHEE II is recommended. The PROMETHEE II complete preorder (P_π , I_π) can be induced by the net flow:

$$aP_\pi b \quad \text{(a outranks b)} \qquad\qquad \text{iff } \varnothing \ (a) \quad > \quad \varnothing \ (b),$$

$$\left\{\vphantom{\begin{matrix}a\\a\end{matrix}}\right.$$

$$aI_\pi b \quad \text{(a is indifferent to b)} \qquad \text{iff } \varnothing \ (a) \quad = \quad \varnothing \ (b).$$

$$3.6$$

Clearly, it is easier for the decision maker to use the complete preorder in order to overcome the assigned decision problem. However, the partial preorder contains more realistic information, especially with respect to in comparabilities.

In comparison with the ELECTRE III method, a sensitivity analysis shows that the changing parameters can lead to more instability for the ELECTRE III method. This analysis further demonstrates that the size of the problem (the number of criteria times the number of alternatives) generally has no impact on the sensitivity of rankings but the disagreement between the criteria is one determinant factor of instability. [Brans, Vincke and Mareschal, 1986] It may be concluded that the larger the size of the problem is and the larger the amount of disagreement between criteria are, the more appropriate the ELECTRE III method is.

3.6.4 ELECTRE method

The ELECTRE I, II and III have represented a family of the outranking methods which are of critical importance. Implemented by Roy and his collaborators, they suggest different ways of envisaging the construction of the outranking relation and the exploitation of the relation. [Roy and Vincke, 1981]

The method ELECTRE I

To facilitate the solution of the multicriteria decision problem a series of the ELECTRE methods which represents one family of the outranking methods developed by ROY and his colleagues can be utilised. But this context will focus solely on the method ELECTRE I.

For the method ELECTRE I a partition of the set A (which is obliged to be finite) including two subsets E and A\E can be provided under these following two conditions:

(1)   at least one action of E outranks every action of A\E

(2)   the actions of A are as incomparable as possible between themselves.

Then, an action a outranks b if

(1)   There exists an sufficient majority among the criteria, ensuring that a is not worse than b;

(2)   No criterion in disagreement with majority leads to too substantial superiority of b relative to a.

A weight π_i (≥ 0) which determines the importance of the criterion is generated to each criterion. The following concordance indicator measures the concordance of the different criteria in favour of the preference or indifference of a with respect to b:

$$c(a, b) = \frac{\sum_{i \in C_{ab}} \pi_i}{\pi}$$

(3.10)

Where C_{ab} is the set of criteria for which a is preferred to or indifferent from b, and where

$$\pi = \sum_{i=1}^{k} \pi_i \qquad\qquad (3.11)$$

In addition, the following three properties belong to this indicator:

(1)   This indicator's typical figures lie between 0 and 1, and increases with the enrichment of C_{ab} ;

(2)   This indicator is equal to 1, iff a dominates b.

Although a point of view i is subdivided and substituted by several other different points of view, this indicator still attains its significance and does not result in any incoherence if the sum of the new weights is equal to $\prod i$.

Nevertheless, for a pair of elements (a, b) of A even when c(a, b) is close to 1 it cannot be exactly concluded that a is better than b.   Some disagreements cannot be extremely ignored, particularly if, for one g_j , the difference $g_j(b) - g_j(a)$ is so large. Consequently, a discordance indicator have to be defined in this manner:

$$d(a, b) = \begin{cases} 0 & \text{if } D_{ab} = \varnothing, \\ \\ \dfrac{1}{\delta} \max_{j \in D_{ab}} \left| g_j(b) - g_j(a) \right| & \text{otherwise,} \end{cases} \qquad (3.12)$$

where D_{ab} is the set of criteria for which a is worse than b, and δ is the maximum difference on particular criterion.

Then, let us consider two numbers between 0 and 1, one of these p is close to 1 and the other q is near to 0. It is stated that a outranks b (aSb) iff

$$c\,(a,\,b) \geq p,$$

$$\left\{ \right. \qquad\qquad 3.7$$

$$d\,(a,\,b) \leq q$$

Remarks (1)   In practice, it is recommended that the parameters of the method $(\prod i, p, q)$ should be varied and the sensitivity analysis corresponding to these variations should be conducted as well.

(2)   For some cases in which certain criteria are absolutely qualitative , the discordance indicator have to redefined accordingly.

In conclusion, the methods ELECTRE I and II are applicable to a case where each point of view is modelled by means of a true-criterion. Conversely, the method ELECTRE III usually deals with a case where a family of pseudo-criteria are to be aggregated.

3.6.5 Selection system for outranking methods

To help you decide which outranking methods to use in what situation, follow this proposed selection system (as seen in Figure 3.11). However, the focus is on just five outranking methods (simple weight ranking method, analytical hierarchy process (AHP), PROMETHEE I, PROMETHEE II and ELECTRE III) which has been the most widely used ones in solving the multicriteria decision problems. This does not include the other outranking or decision making methodologies such as the Delphi technique and the method of listing pros and cons that are less scientific than those identified above.

To identify the most appropriate technique start at the top left-hand side of the chart and answer the questions. Moreover, a dotted line represents the other alternative

route which is probably chosen. For example, let us consider the question "Will the decision maker never be consistent?." If an answer is yes, consider AHP. On the other hand, if an answer is no, we may either go to the next question or, perhaps, choose AHP again (following the dotted line).

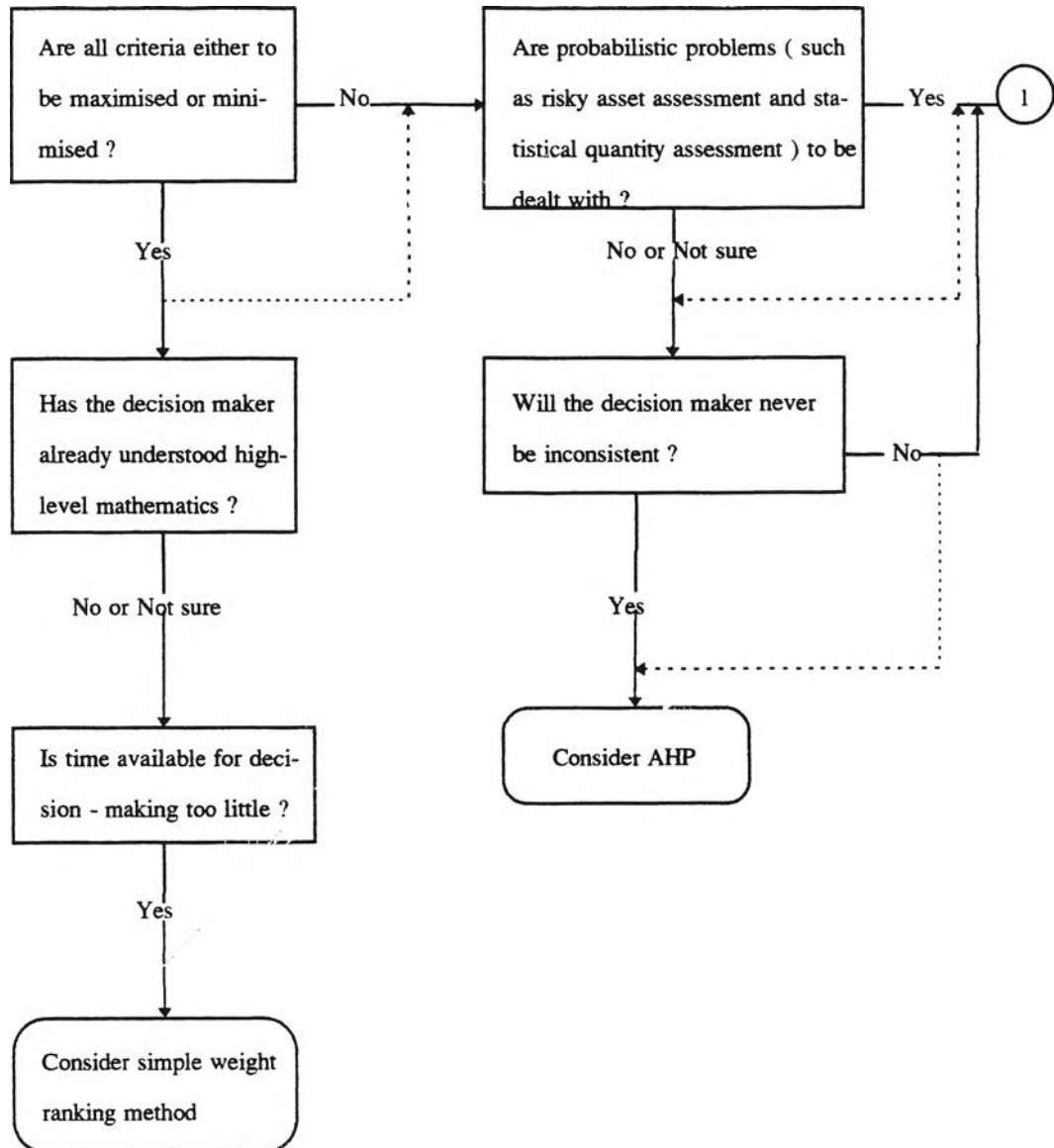Figure 3.11 The proposed selection system for outranking methods

Figure 3.11 The proposed selection system for outranking methods (next)