

CHAPTER 4

THE DESIGN OF EVALUATION MODEL FOR SAIDI TARGETS OF REGIONAL DISTRIBUTION SYSTEMS

4.1 Introduction

Regarding the SAIDI metric value of Taipower' s system, the service interruptions of distribution system account for 95% of the total distribution and transmission service interruptions. Among them, the forced service interruptions account for 17%, and the scheduled service interruptions accounts for 83%. This Chapter shall enumerate all the major disparity factors among the regional distribution systems that have impacted the regional SAIDI metric values of Taipower. On basis of three disparity factors, the AHP hierarchy model and the evaluation indices selected as the model parameters as well as the questionnaire design for acquisition of relative weights among disparity factors are presented in the following of this section.

4.2 Disparity Factors of SAIDI for Distribution Forced Service Interruption

Among the variety of factors which affect the SAIDI metric value of distribution forced service interruption, the most important have been selected to formulate the AHP sub-model to be presented in the following paragraphs.

Forced service interruption occurred at the distribution system are largely stem from foreign object contact, natural and insulation deteriorations, overload, saline hazard, chemical hazard, lightning stroke, substandard quality or construction, and so forth. Besides management related measures taken to reduce the probability that the foresaid factors may occur, and taken into account the characteristics at various

regional distribution districts, a further analysis has yielded other major factors that may affect the SAIDI metric values of forced interruption at various distribution service regions, which are:

- Weather environments (lightning and saline hazards),
- Total circuit length of distribution feeders,
- Feeders' mean load factor at peak hours,
- Overhead/underground feeders count,
- Geographical environment (referring to urban area, suburbs, mountainous areas and so forth),
- Ratio of automated feeders,
- Feeders' load transfer capability,
- Customer density and so forth.

The 3-layer AHP sub-model for evaluating the average times (denoted by $V_{j, \text{frq}}$ in Eq. 2-22), The 3-layer AHP sub-model for evaluating the average duration (denoted by $V_{j, \text{drt}}$ in Eq. 2-22) and the 3-layer AHP sub-model for evaluating the average number of customers affected (denoted by $V_{j, \text{ctm}}$ in Eq. 2-22) of distribution forced service interruption are shown in Fig. 4.1~4.3, respectively. These factors shall be detailed in the following paragraphs.

(1) Total Circuit Length

A longer total circuit length of a distribution system provides higher probability of forced system interruption.

(2) Feeders' Peak Load Rate

Excessive feeder load factor invariably leads to a higher probability of forced service interruption and provides limited load transfer ability, notwithstanding a larger number of customers will be affected following a fault occurred.

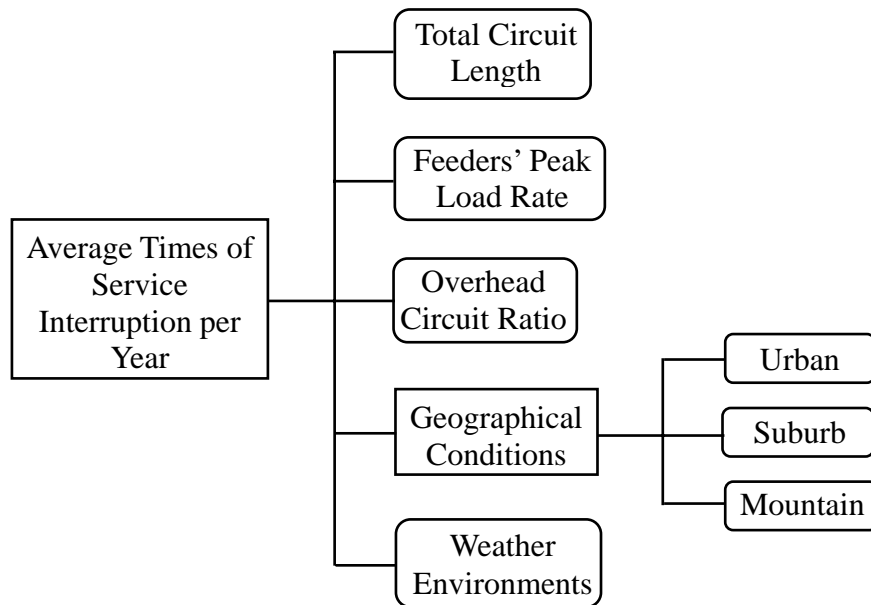


Fig. 4.1 The 3-layer model for evaluating $V_{j, \text{frq}}$ of distribution forced service interruption.

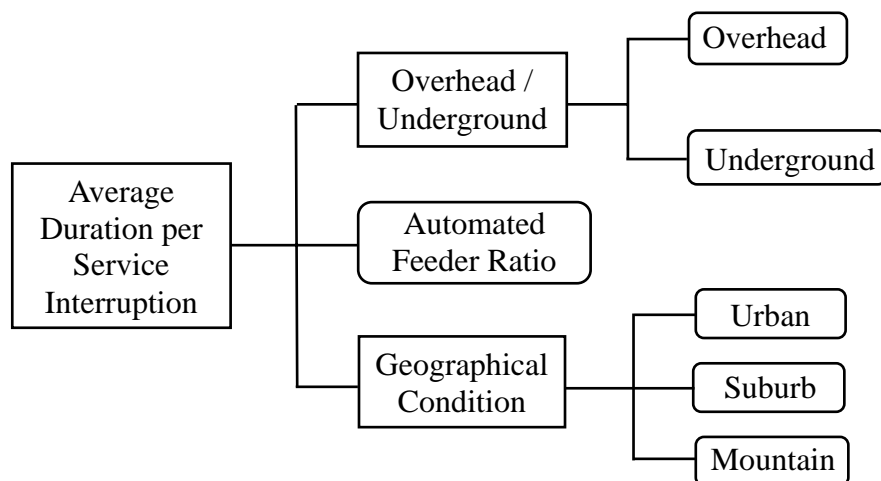


Fig. 4.2 The 3-layer model for evaluating $V_{j, \text{drt}}$ of distribution forced service interruption.

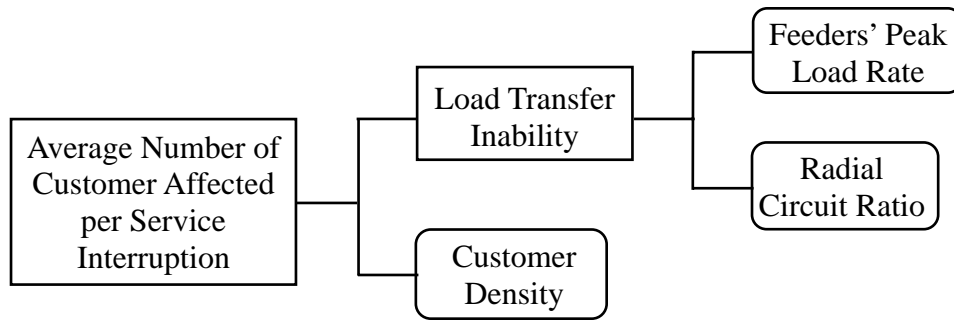


Fig. 4.3 The 3-layer model for evaluating $V_{j, ctm}$ of distribution forced service interruption.

(3) Overhead /Underground Circuit Ratio

Overhead feeders are more prone to incidents but require a relatively shorter time to repair, whereas underground feeders are less prone to incidents but require a relatively longer time to repair.

(4) Geographical Condition

Varied geographical environments, such as urban areas, suburbs, and mountainous regions, tend to have a varied probability of incidents. And the time needed for incident repair also varies according to region; for instance, remote mountainous regions would tend to require a longer emergency repair time.

(5) Weather Environments

Areas that are prone to severe lightning/saline/fog hazards tend to have a higher probability of forced or incident, power interruption.

(6) Automated Feeder Ratio

Distribution automation helps to greatly cut down the forced power interruption duration and minimize the area of power interruption and customers subjected to power interruption to a least possible level for it automatically detects and isolates the feeder fault and proceeds to execute load transfer to the neighboring feeders. Hence, the number of automated feeders would come to

affect forced power interruption duration.

(7) Load Transfer Inability

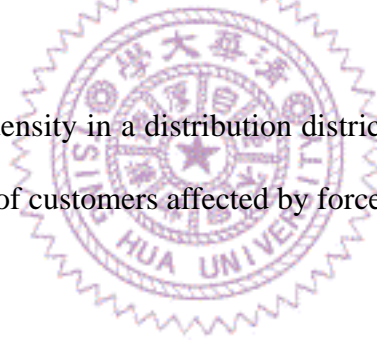
A surplus in feeder loading capabilities guarantees a stronger load transfer capability, which in turn warrants a scaled-down range of incident power interruption or no interruption at all. On the contrary, a limited surplus in feeder loading capabilities, or the inability to provide any load transfer capability would often lead to a forced power interruption. Factors that affect load transfer capabilities include feeders' peak load rate and radial circuit ratio.

(8) Radial Circuit Ratio

The load on radial feeder can't be transferred when a fault is occurred because of no other feeders connected to it.

(9) Customers density

Varied customer density in a distribution district jurisdictional area naturally influences the number of customers affected by forced system interruption.



4.3 Disparity Factors of SAIDI for Distribution Scheduled Service Interruption

The factors which impact the SAIDI metric value of scheduled distribution service interruption are quite different from the factors considered for forced interruption both of transmission and distribution systems. The most important factors which affect the SAIDI metric value of distribution scheduled service interruption are selected to formulate the AHP sub-model to be detailed in the following paragraphs.

The implementation of distribution construction projects that poise to affect the SAIDI metric values can be roughly divided into five types: customer's

request for power hookup; distribution conductor replacement; distribution transformer replacement or maintenance; distribution line relocation and so forth. Except management related measures taken to reduce the SAIDI metric values caused by the foresaid works, and taken into account the characteristics of various distribution regions, other main factors that have been analyzed to affect the SAIDI metric values of scheduled interruption at various business service regions include:

- Type A (major category) construction work,
- Type B (miscellany) construction work,
- Average feeder load factor at peak hours,
- Total circuit length for feeders,
- Load transfer capability for feeders,
- Overhead/underground feeders count,
- Average customers per feeder, and so forth.

The 4-layer AHP sub-model for evaluating the average times (denoted by $V_{j, \text{frq}}$ in Eq. 2-22), The 4-layer AHP sub-model for evaluating the average duration (denoted by $V_{j, \text{drt}}$ in Eq. 2-22) and the 3-layer AHP sub-model for evaluating the average number of customers affected (denoted by $V_{j, \text{ctm}}$ in Eq. 2-22) of distribution scheduled service interruption are shown in Fig. 4.4~4.6, respectively. These factors shall be detailed in the following paragraphs.

(1) Type A (major category), type B (miscellany) work volume and work types

There are 4 kinds of works included in major category works in Taipower:

- Multi-Year Distribution System Expansion Projects
- Customers Power Hookup Request Construction
- Expansion Work

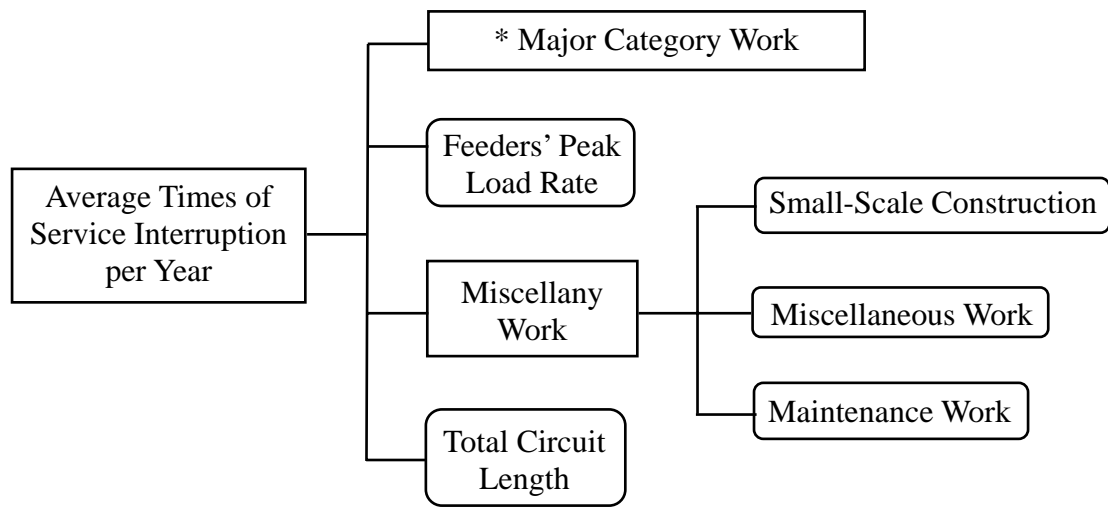


Fig. 4.4 The 4-layer model for evaluating $V_{j, \text{frq}}$ of distribution scheduled service interruption. * indicates that its sub-models are same as depicted in Fig. 4.7.

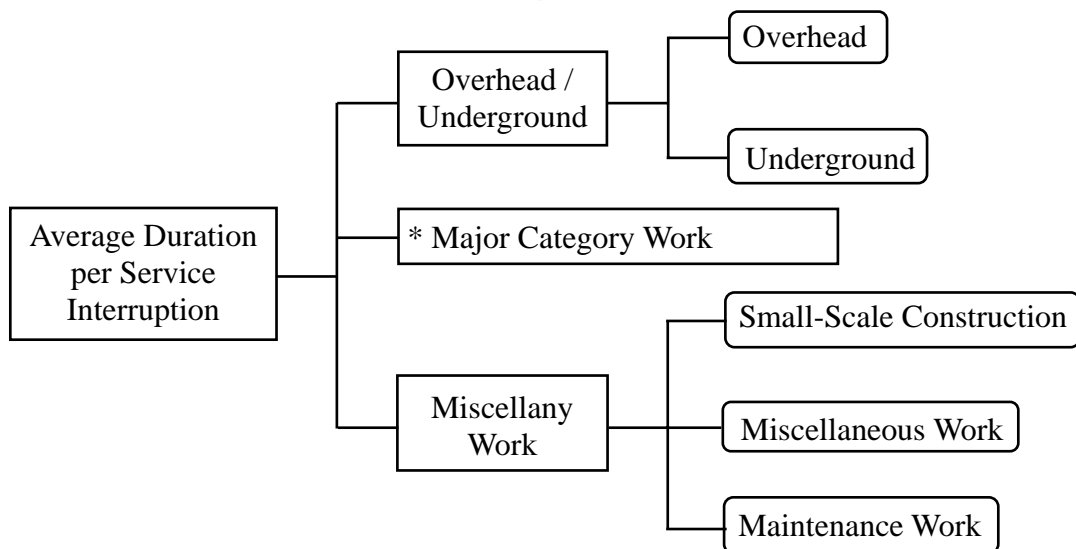


Fig. 4.5 The 4-layer model for evaluating $V_{j, \text{drt}}$ of distribution scheduled service interruption. *ref. the footnote of Fig. 4.4.

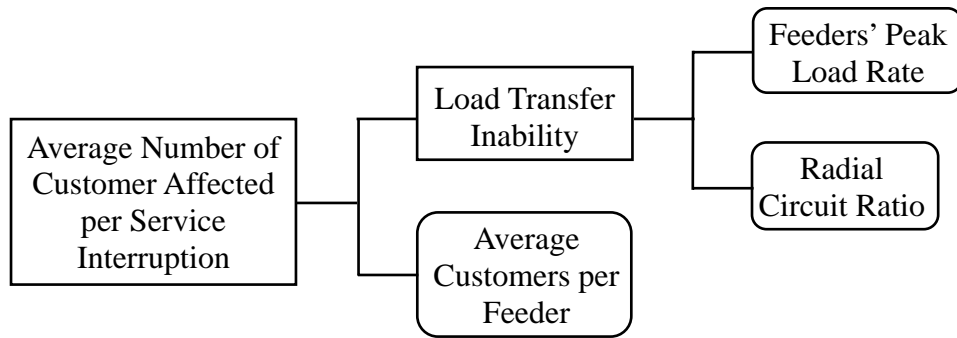


Fig. 4.6 The 3-layer model for evaluating $V_{j, \text{ctm}}$ of distribution scheduled service interruption.

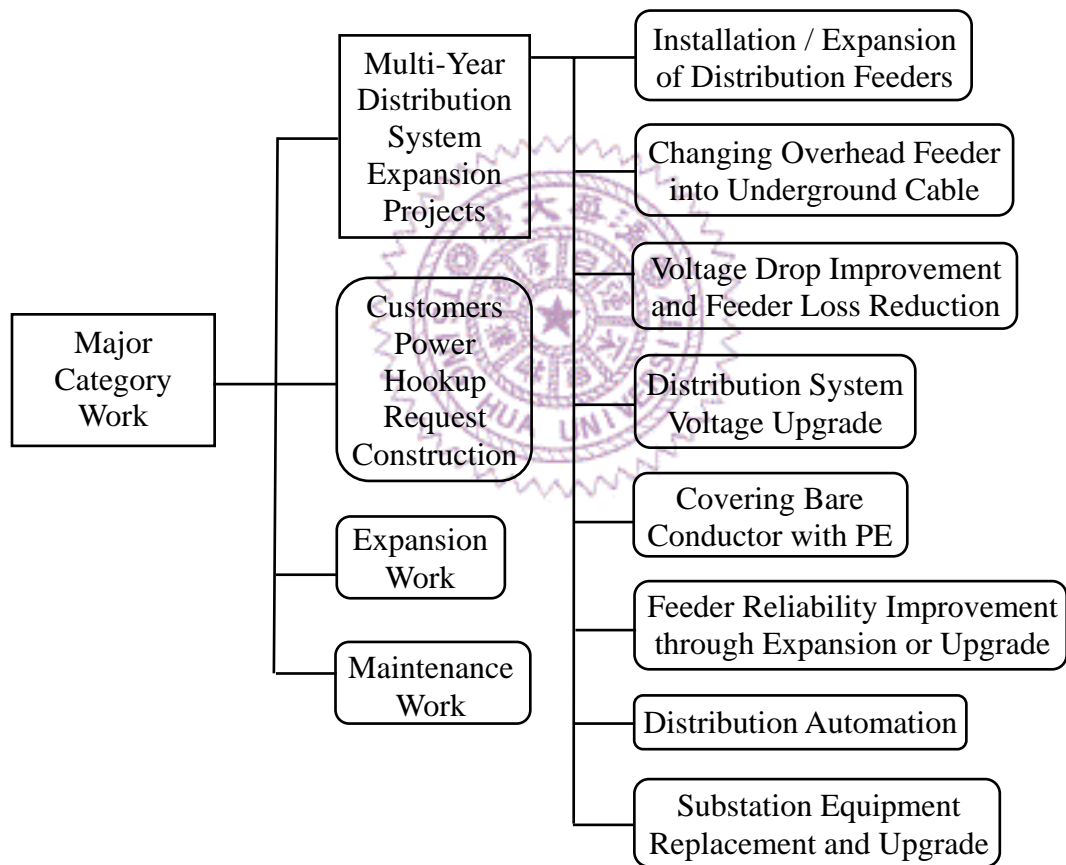


Fig. 4.7 The contents of major category work of Fig. 4.4 and Fig. 4.5.

- Maintenance Work

The multi-year distribution system expansion projects are categorized into following 8 kinds of work:

- Installation / Expansion of Distribution Feeders
- Changing Overhead Feeder into Underground Cable
- Voltage Drop Improvement and Feeder Loss Reduction
- Distribution System Voltage Upgrade
- Covering Bare Conductor with PE
- Feeder Reliability Improvement through Expansion or Upgrade
- Distribution Automation
- Substation Equipment Replacement and Upgrade

These works have their own characteristics on construction which will affect both the frequency and duration of service interruption.

Miscellany work refers to the interim or small scale works. Though each is of small scale, the total amount of budget for miscellany works sometimes exceeds that of major category works. There are 3 kinds of work are included in this category.

- Small-Scale Construction
- Miscellaneous Work
- Maintenance Work

A larger work volume would tend to increase the scheduled power interruption frequency. While some work requires power interruption, such as voltage upgrade work, whereas some can be conducted through hot-line operation without resorting to power interruption. Therefore, the work type could also affect the power interruption frequency and duration.

(2) Feeders' Peak Load Rate

Excessive feeder load factor invariably leads to a higher probability of engineering work for feeder maintenance, notwithstanding a larger number of customers will be affected during the construction or maintenance period.

(3) Total Circuit Length

The longer the distribution feeders, the more likely the incidents, hence are requiring a greater probability of construction or maintenance.

(4) Overhead /Underground

Duration of service interruption required by construction works of underground feeders is generally longer than of overhead feeders.

(5) Load Transfer Inability

A surplus in feeder loading capabilities guarantees a stronger load transfer capability, which in turn warrants a scaled-down range of in-maintenance power interruption or no interruption at all. On the contrary, a limited surplus in feeder loading capabilities, or the inability to provide any load transfer capability would often lead to a scheduled power interruption. Feeder' peak load rate and radial circuit ratio are the factors which affect load transfer capabilities. Their impacts are as explained as in section 4.2.

(6) Average Customers per Feeder

Customers per feeder naturally influence the number of customers affected by service interruption during the period of construction.

4.4 Design of Evaluation Indices

Referring to the disparity factors depicted in the 3 AHP sub-models of Figs. 4.1~4.3 for evaluating the SAIDI of distribution forced service interruption, the design of evaluation indices corresponding to the disparity factors shall be presented in the following paragraphs:

(1) Total Circuit Length

The value refers to the total circuit length in kilometers.

(2) Feeders' Peak Load Rate

The value refers to the annual peak load divided by the total number of distribution feeders.

(3) Overhead Circuit Ratio

The value refers to the percentage of overhead feeders in circuit length out of the total circuit length.

(4) Geographical Condition

The value refers to kilometer squares for urban, suburban and mountainous areas or the percentage of urban, suburban and mountainous areas out of total areas respectively.

(5) Weather Environments

The value refers to the number of power service interruption times caused by thunderbolt, salt or fog with occurrence at district distribution system.

(6) Overhead /Underground

The value refers to the percentage of overhead and underground feeders in circuit length out of the total circuit length respectively.

(7) Automated Feeder Ratio

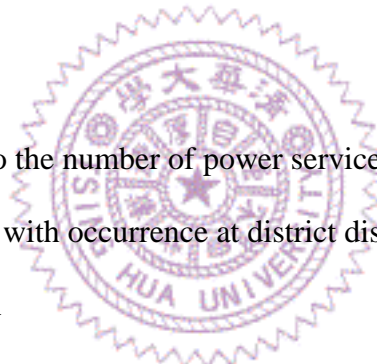
The value refers to the percentage of automated feeders out of the total feeders.

(8) Radial Circuit Ratio

The value refers to the radial circuit percentage in circuit length out of the total circuit length.

(9) Average Customers per Feeder

The value refers to the total number of customers served divided by the total



number of distribution feeders.

The above disparity factors and their corresponding evaluation indices are summarized in Table 4.1.

Table 4.1 Evaluation Index Designed to Measure Regional Status on Disparity Factors of SAIDI for Distribution Forced and Scheduled System Interruption

Disparity Factors	Evaluation Index
Geographical conditions	Kilometer squares or percentage for urban, suburban and mountainous areas
Weather environments	The number of power service interruption times caused by thunderbolt, salt or fog with occurrence at district distribution system
Total circuit length	The total circuit length in kilometers
Overhead/underground circuit ratio	The percentage of overhead and underground feeders in circuit length out of the total circuit length respectively
Radial circuit ratio	The radial circuit percentage in circuit length out of the total circuit length
Automated feeder ratio	The percentage of automated feeders out of the total feeders
Feeders' peak load rate	The annual peak load divided by the total number of distribution feeders
Customer density	The total number of customers served divided by kilometer squares for area of district
Customers per feeder	The total number of customers served divided by the total number of distribution feeders
Major category work	The budget approved for the major category works that include 4 categories
Miscellany category work	The budget approved for the miscellany category works that include 3 items of work

For the disparity factors of SAIDI of distribution scheduled service interruption, their corresponding evaluation indices referring to the AHP sub-models of evaluation as shown in Figs. 4.4~4.7 are described in the following paragraphs.

(1) Major Category Work Volume

The value refers to the budget approved for the 4 items of work listed in major category.

(2) Feeders' Peak Load Rate

Same as the value collected for forced service interruption mentioned in previous paragraph.

(3) Miscellany Work Volume

The value refers to the budget approved for the 3 items of work listed in miscellany category.

(4) Total Circuit Length

Same as the value collected for forced service interruption mentioned in previous paragraph.

(5) Overhead /Underground

Same as the value collected for forced service interruption mentioned in previous paragraph.

(6) Radial Circuit Ratio

Same as the value collected for forced service interruption mentioned in previous paragraph.

(7) Average Customers per Feeder

The value refers to the total number of customers served divided by the total number of distribution feeders.

The above disparity factors and their corresponding evaluation indices are summarized in Table 4.1.



4.5 Questionnaire Design

Eight regional survey meetings have been conducted for Taipower's 22 distribution districts. Four experienced engineers who are either the section chief or the department head of the operation or maintenance department in the same distribution district are surveyed; thus total 44 engineers have been surveyed for the distribution forced and scheduled service interruption respectively.

Similar to the questionnaire designed for transmission service interruption, in the questionnaires designed for forced and scheduled distribution service interruption, the same question for evaluation of the relative importance of disparity factors have been asked three times each in a different form so to ensure the effectiveness of the answers from respondents, which has been detailed in Section 3.4.

