The Group Strategic Knowledge Mining Model for Telecom Power Infrastructure

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***Abstract*—The telecom industry faces many changes of competitive environments and challenges of technological innovations. Many companies make efforts to solidify their technological superiority and maintain the market share. Making the best use of limited resources and efficient resource allocation are the most important tasks. Among all resources, the power infrastructure of telecom rooms plays an increasingly critical role in broadband infrastructure and it is the heart of telecom resources. This study develops a group strategic knowledge mining model based on knowledge discovery and mining to clearly elicit the criteria and evaluate the strategic values of the alternatives. Furthermore, by uncovering the clusters knowledge rules and generating the decision tree, the decision makers' knowledge will be mined. The contributions of the proposed model may support the planners and managers to develop more effective power management strategies for telecom rooms.**

Keywords-telecom power infrastructure; fuzzy modified Delphi method; multiple criteria decision making; fuzzy aggregation method.

I. Introduction

Taiwan has one of the more advanced telecom networks in the region of Asia Pacific. Since the privatization and liberalization of Taiwan's telecom markets in 2005, the telecom industry faced many changes of competitive environments and challenges of technological innovations. Telecom companies need to find new ways to obtain competitive advantages. According to the administrative plan of 2013 proposed by the National Communications Commission (NCC), enhancing the monitoring mechanism of high-speed broadband network, and amending guidelines for fixed-line network service quality are part of the telecom supervision plan in Taiwan [1]. Chunghwa telecom (CHT) company is the largest telecom operator in Taiwan, and no one can compare with its rich talented personnel, facilities, fund and network construction [2]. The CHT's 2014 guidance also reported "Facing market saturation and competition on broadband business, we will continue to support growth through offering attractive convergence plans and facilitating higher-speed migration. Lastly, we plan to launch ground-breaking 300Mbps speed services, helping us solidify our technological superiority and maintain our market leading position." [3]. Therefore, the telecom infrastructure plays an important role in CHT's broadband strategic management.

The telecommunications room (telecom room) gathers all connectivity from customers or business, such as broadband networks, data communications, and fixed line. Due to the needs of customers and the market share, the telecom infrastructure needed to provide more diversification of services. The telecom rooms play an increasingly critical role in broadband infrastructure, among these all, power infrastructure is the heart of telecom resources. In terms of management and operation, CHT has some inborn inferiorities because it has been a monopoly for 40 years [2]. To make the best use of limited resources and efficient resource allocation, CHT needs to develop more effective management strategies for power infrastructure to meet increasing demand for broadband network performance in the business market.

With the advent of the Internet and the development in the telecom industry, in selection of telecom alternatives for the power system protection and control applications, greater emphasis is usually placed on reliability than cost [4]. Additionally, the management of telecom power infrastructure based on knowledge discovery from domain experts were however less discussed. Therefore, this study developed a group strategic knowledge mining (GSKM) model for telecom power infrastructure. The objectives of this paper are to clearly elicit the criteria and evaluate the strategic values of the alternatives. Furthermore, by uncovering the clusters knowledge rules and generating the decision tree, the decision makers' knowledge will be mined. The contributions of the proposed model may support the planners and managers to develop more effective power management strategies for telecom rooms. The existing methodologies in the GSKM model include: (1) Eliciting criteria for knowledge discovery by using the modified Delphi method; (2) Evaluating the weights and alternatives to get strategic values by using fuzzy MCDM method; (3) Integrating the group experts' opinions by using two fuzzy aggregation method; (4) Clustering the telecom rooms for mining the experts' knowledge and advice appropriate management strategies of power infrastructure.

II. Background

A. Knowledge elicitation

The Delphi method is a set of procedures and methods for formulating a group judgment toward a subject matter in which precise information is lacking, and relies on soliciting individual (often anonymous) answers to written questions by survey or other type of communication [5]. A series of iterations provide each individual with feedback on the responses of the others in the group. The final responses are

 ISBN: 978-1-61208-364-3

evaluated for variance and means to determine which questions the group has reached consensus about, either affirmatively or negatively.

Murry and Hammons defined that the modified Delphi method is a technique to arrive at a group consensus regarding an issue under investigation [6]. It was used to rate the indicators. This process consisted of one round of anonymous ratings of the indicators by the panel, a face-to-face panel discussion, and a second round of anonymous ratings immediately after the panel discussions. It is a structured approach to expert panel deliberations that does not require consensus.

Iggland applied fuzzy Delphi method in coupling of customer preferences and production cost information [7]. Ishikawa et al. implemented experts' judgments with group fuzzy integration based on fuzzy Delphi method (FDM) [8]. Applying fuzzy set theory to the Delphi group decision method seems attractive as demonstrated by Cheng who utilized fuzzy Delphi method to adjust the fuzzy rating of each expert [9]. Therefore, the fuzzy modified Delphi process was used to develop consensus in the proposed model.

B. Getting the Fuzzy Weights for criteria

Because an evaluator always perceives the weight with their own subjective evaluation, an extra or precise weight for a specified criterion was not given. This led to the use of the fuzzy weights of criteria. In decision analysis, pairwise comparison of alternatives is widely used [10]. Usually, decision makers express their pairwise comparison information in two formats: multiplicative preference relations and fuzzy preference relations. The analytic hierarchy process (AHP) with multiplicative preference relations has been applied extensively in telecom fields [11][12][13][14]. However, the decision makers may also use fuzzy preference relations to express their preference due to their different cultural and educational backgrounds, personal habits, and the vague nature of human judgment. There are some common research issues between multiplicative preference relations and fuzzy preference relations, as both are based on pairwise comparison. Therefore, research progress in multiplicative preference relations can benefit research in fuzzy preference relations [15].

The fuzzy preference relations method provides some advantages, including a consistency indicator, simplicity of computation, high precision and preservation of ranks. The method constructs the decision matrices of pairwise comparisons using an additive transitivity. Only comparisons are required to ensure consistency for a level with criteria. The method is simply and practically provides ranking choices in decision-making problems [15][16][17].

Current approaches for group decision-making analysis support different preference formats, but their computational procedures are very complicated. Usually, they consist of three steps: (1) uniform the preference information given by decision makers through a transformation function, (2) aggregate the uniformed preference information into a collective one by means of the aggregation operators, and (3) rank alternatives or select the most desirable alternatives by the selection methods [18].

The multi-granular linguistic methodology permits the unification of the different linguistic domains to facilitate the calculus of consensus degrees and proximity measures on the basis of experts' opinions. The consensus degrees assess the agreement amongst all the experts' opinions, while the proximity measures are used to find out how far the individual opinions are from the group opinion [17]. Therefore, this study assumed that there exist several experts who may have different background and knowledge to solve a particular problem and, therefore, different linguistic term sets (multi-granular linguistic information) could be used to express their opinions.

C. Aggregating linguistic labels into a group opinion

1) FLOWA (Fuzzy Linguistic Ordered Weighted Average): At present, many aggregation operators have been developed to integrate information. The aggregation function, ranking method, and consensus measure are the main problems to be solved for a fuzzy group decision-making issue. The existing main aggregation operators can be briefly classified into the following three categories: (1) One contribution of the methodology presented herein is that the result of this aggregation approach is a collection of linguistic labels with a calculated degree or membership function, presenting a more informative aggregation. (2) A two phase model developed by Herrera and Herrera-Viedma [19]. (3) The operators, which can only be used in situations where the arguments are exact numeric variables, such as Linguistic Ordered Weighted Averaging (LOWA) operators that is based on the OWA and the convex combination of linguistic labels [20]. Ben and Chen proposed a new linguistic-label aggregation operator incorporated fuzzy set theory into LOWA that call the fuzzy-LOWA (FLOWA) operator. FLOWA organized OWA and LOWA aggregation algorithms and individual linguistic opinions into a group opinion. These aggregation methods operate directly on the linguistic labels and allow each expert to represent an optimistic or pessimistic predilection [21].

2) EFWA (Efficient Fuzzy Weighted Average): When the environment is vague, the rating criteria and the weights of their corresponding importance are often evaluated as a fuzzy number. In order to obtain the weighted sum of those criteria evaluated by fuzzy numbers in terms of rating and importance, this study use the fuzzy weighted average for the calculation. There has been some research involved in the field of fuzzy weighted average [22][23][24]. Lee and Park proposed an efficient algorithm, named the Efficient Fuzzy Weighted Average (EFWA), to compute a fuzzy weighted average, which was an improvement over the previous methods by reducing the number of comparisons and arithmetical operations [22]. The computational algorithm of EFWA is based on the α-cut representation of fuzzy sets and interval analysis. The managerial meaning of α-value can be explained as a confidence level [23]. Because of the above-mentioned advantages, this study will adopt the EFWA algorithm to aggregate decision makers' opinion.

III. THE GROUP STRATEGIC KNOWLEDGE MINING MODEL

This section proposes the GSKM model. It includes three phases, as shown in Figure 1. Phase I is the process of criteria elicitation and weights assessment for telecom knowledge discovery. Phase II is to evaluate and aggregate the alternatives, namely telecom rooms, to get strategic values and ranks. Phase III is the process of clustering the telecom rooms and mining the decision tree for the power infrastructure.

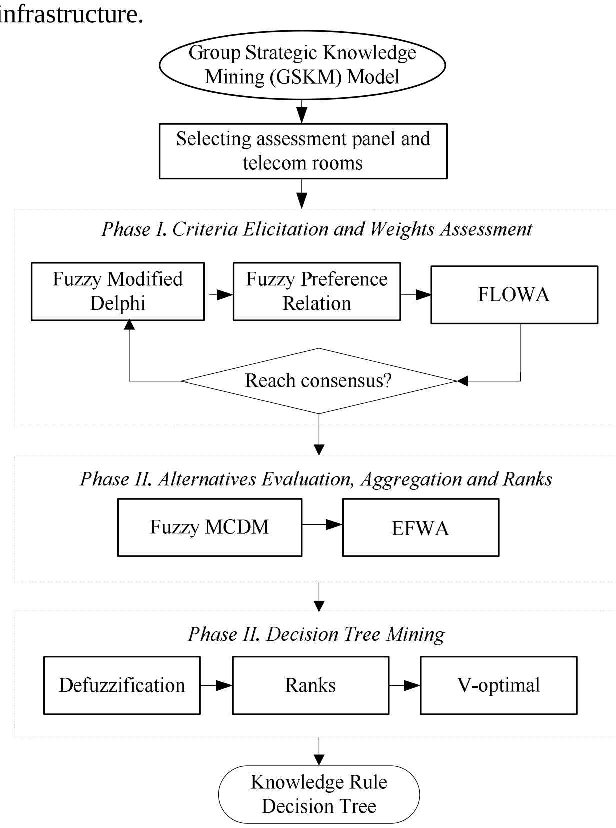

Figure 1. The GSKM model.

A. Phase I. Criteria Elicitation and Weights Assessment

To identify the important criteria for the operation strategies in power infrastructure of telecom rooms, the fuzzy modified Delphi method is used to elicit implicit knowledge of decision makers and assess criteria for deciding weights. The decision makers are invited to take part in a series of rounds to identify, clarify until reaching consensus on this issue.

This process consisted of the first round of anonymous ratings of the indicators and a face-to-face discussion, and then generated an impact assessment form for power infrastructure of telecom rooms. The decision makers investigated that MCDM problem with preference relations could assess the relative importance weights of criteria. Moreover, human thoughts are uncertain, fuzzy theory could be used to express their preference relations in linguistic terms. To integrate the decision makers' opinions, the FLOWA method was used to aggregate all criteria. This way, the decision makers' valuable domain knowledge can be acquired and shared in an effective and efficient manner. In the following rounds, a series of discussion are provided feedback to the decision makers, the appropriate thresholds are also restricted to achieve the goals by cognitive subjective view until consensus is reached. Finally, criteria and weights are decided in this phase.

B. Phase II. Alternatives Evaluation and Aggregation

To evaluate the alternatives with respect to criteria, the MCDM method consists of two steps: (1) collecting the individual confidence level, define the linguistic terms and corresponding triangular fuzzy numbers, and (2) aggregating all decision makers' opinions and integrating the scores of weighing the criteria for each alternative.

The first step should utilize fuzzy set theory to deal with the uncertain problem of linguistics, and the linguistic terms are replaced by suitable triangular fuzzy numbers that are used for arithmetical operations. Each decision maker defined their different confidence levels and corresponding triangular fuzzy numbers in terms of VH (very high), H (high), M (medium), L (low), VL (very low) to score the importance of alternatives that collected with respect to the criteria elicited. When the scores finished assessing completely, the strategic values will be obtained, and then a decision matrix is established for the decision makers.

In the second step, in order to obtain the weighted sum of those criteria evaluated by fuzzy numbers in terms of rating and importance, we used EFWA method to aggregate the weighted scores that are from individual decision-makers to become the group results. Therefore, the alternatives can be ranked according to the group scores.

C. Phase III. Decision Tree Mining

This phase included defuzzification and data analysis. By clustering for discovering the knowledge rules and feedback to the decision makers, two algorithms are employed. One is center of gravity for defuzzifing and ranking the alternatives, and another one is V-optimal for uncovering the clusters knowledge rules and generating the decision tree. Therefore, the results may help decision makers to more effectively manage the telecom power infrastructure, and thus obtain competitive advantages.

IV. A CASE ILLUSTRATION

In order to illustrate the practicability and usefulness of the proposed model, we implemented it in the power infrastructure of telecom rooms for the largest telecom company in Taiwan. We convened three decision makers who are the most knowledgeable in power technologies and services. The processes of evaluating the strategies can be expressed as follows.

 ISBN: 978-1-61208-364-3

A. Identification of selecting criteria and deciding weights

In the first phase, the fuzzy modified Delphi method was applied to reach consensus on the importance of each of the identified criteria for evaluating operation strategies toward the power infrastructure of telecom rooms. During the first round, the decision makers were provided the fault research, cause analysis, accident causation and process and the choice of UPS of the telecom rooms' electric power system to understand practical implementation, planning and management. Based on the decision makers' deep domain knowledge about the related geographical information, facilities, personnel allocation and future investment plan of the telecom rooms, they were elicited the criteria and suggested criteria through brainstorm technique. After discussing in the first round, this study analyzed the priority ranking of criteria is as follows: staffing ＞ room features ＞ initial load ＞ power supply ＞ growth forecast ＞ maintaining support, and included 266 telecom rooms in Southern Taiwan.

The decision makers used fuzzy preference relations to assign the strategic values for criteria. The value represents the important degree of the preference for the first criteria with respect to the second one. The decision matrix, which is based on Saaty's 9 point scale, is constructed. Therefore, the decision makers used the fundamental 1–9 scale defined by Saaty to assess the priority score [21]. To combine the scores of fuzzy preference relation that each decision maker assessed, the FLOWA method is applied to get final weights of each criterion. Herein, the matrix and the weight factors of 6 evaluation criteria for group opinions are shown in Table I.

TABLE I. THE WEIGHTS OF CRITERIA

	Staffing	Room features	Initial load	Power supply	Growth forecast	Maintaining support	Weight
Staffing	0.50	0.57	0.71	0.75	0.87	1.00	0.24
Room features	0.43	0.50	0.63	0.68	0.79	0.93	0.22
Initial load	0.29	0.37	0.50	0.54	0.66	0.79	0.18
Power supply	0.25	0.32	0.46	0.50	0.62	0.75	0.16
Growth forecast	0.13	0.21	0.34	0.38	0.50	0.63	0.12
Maintaining support	0.00	0.07	0.21	0.25	0.37	0.50	0.08

In Table I, the criteria "maintaining support" was "extreme unimportance" and ranked last. In the next round, the decision makers decided to give up it for satisfying the threshold condition, and then regenerated the matrix of five evaluation criteria. According to Table II, the weight set on C_1: staffing, C_2: room features, C_3: initial load, C_4: power supply, and C_5: growth forecast respectively were 0.3, 0.26, 0.29, 0.16 and 0.1.

B. Assessment of telecom rooms

In phase II, the three decision makers, who have the basic knowledge about fuzzy theory are then introduced to the basic concepts of common linguistic term set (LTS) by the facilitator. After a brief introduction, the decision makers defined their linguistic terms and corresponding triangular fuzzy numbers according to their subjective judgments within a scale of 0-10. The LTS {VH, H, M, L, VL} indicates very high, high, medium, low, and very low, respectively. See Table III.

TABLE II. THE WEIGHTS OF CRITERIA

	Staffing	Room features	Initial load	Power supply	Growth forecast	Weight
Staffing	0.50	0.60	0.78	0.84	1.00	0.30
Room features	0.40	0.50	0.68	0.74	0.90	0.26
Initial load	0.22	0.32	0.50	0.56	0.72	0.19
Power supply	0.16	0.26	0.44	0.50	0.66	0.16
Growth forecast	0.00	0.10	0.28	0.34	0.50	0.10

TABLE III. THE SUBJECTIVE PERCEPTION OF DECISION MAKERS OF THE FIVE LEVELS OF LINGUISTIC VARIABLES.

Linguistic Variables	Fuzzy Numbers		
	Decision maker 1	*Decision maker 2*	*Decision maker 3*
Very high	(8, 10, 10)	(9, 10, 10)	(8, 10, 10)
High	(5, 8, 10)	(5, 9, 10)	(5, 8, 10)
Medium	(3, 5, 9)	(1, 5, 9)	(2, 5, 8)
Low	(0, 3 ,5)	(0, 1, 5)	(0, 2, 5)
Very low	(0, 0, 3)	(0, 0, 1)	(0, 0, 2)

Each decision maker used their linguistic terms to evaluate the 266 telecom rooms with room features, staffing, initial load, growth forecast and power supply on power infrastructure of telecom rooms for the importance of operation strategies. To aggregate the evaluation results from the three decision makers, the EFWA method was used to calculate the weighted scores of the criteria. Through repeating the computational procedure of EFWA, the interval for α = 0, in which each point is corresponding to the end points of the triangle representing the membership function. The process is repeated for α =1, which corresponds to the center of the triangle. Consequently, with the intervals for α = 0 and α = 1, the aggregation results of EFWA for partial telecom rooms are shown in Table IV.

TABLE IV. AGGREGATE THE EVALUATION RESULTS USING EFWA

Room #	C_1			C_2			C_3			C_4			C_5		
	C_1L	C_1M	C_1R	C_2L	C_2M	C_2R	C_3L	C_3M	C_3R	C_4L	C_4M	C_4R	C_5L	C_5M	C_5R
1	5.33	10.00	10.00	8.44	5.33	10.00	10.00	8.44	7.33	9.33	10.00	8.89	6.00	2.67	6.33
51	0.00	1.00	5.67	2.22	0.00	1.00	5.67	2.22	0.00	1.00	5.67	2.22	0.00	1.00	5.67
101	6.00	5.00	5.67	5.56	6.00	5.00	5.67	5.56	6.00	2.67	6.33	5.00	0.00	2.00	5.00
151	6.00	2.67	6.33	5.00	6.00	2.67	6.33	5.00	0.00	1.00	5.67	2.22	6.00	1.67	7.00
201	6.00	5.00	5.67	5.56	6.00	2.67	6.33	5.00	0.00	1.00	5.67	2.22	0.00	1.00	5.67
251	6.00	2.67	6.33	5.00	6.00	1.67	7.00	4.89	6.00	2.67	6.33	5.00	0.00	1.00	5.67

C. Generating and exploring classification rules

The aggregation matrix, which is a linguistic term, should be transferred to non-fuzzy values; herein the Center of Gravity (COG) method are used to produce the Best Non-fuzzy Performance (BNP) value in given fuzzy sets and corresponding membership degrees. According to the BNP

 ISBN: 978-1-61208-364-3

value, 266 telecom rooms will be ranked. After determining the ranked result, the V-optimal histogram, which is suitable for clustering ordinary data, and based on the concept of minimizing the quantity of the weighted variance, clustered the telecom rooms into five groups. The numbers of each type of telecom room for class A, B, C, D, and E are 31, 68, 72, 32, and 63, respectively.

PolyAnalyst decision tree algorithm can generate classification rules to help the decision makers uncover knowledge for developing effective management strategies. The decision tree can grow each branch just deeply enough to perfectly classify the examples, as shown in Figure 2.

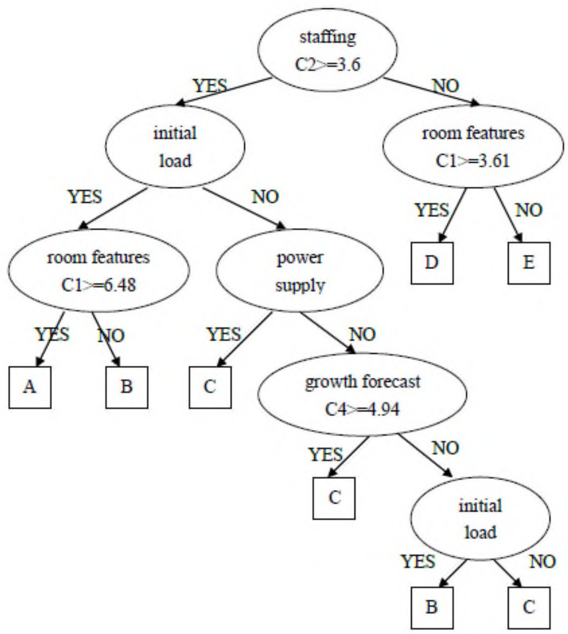

Figure 2. The decision tree.

D. *Administrative operational communication*

This study implemented and explored if it will enhance readability and simplify the decision-making task for the differences between the management modes and the types of power system. The features and strategies of each class of telecom rooms are shown in Table V.

TABLE V. THE FEATURES AND STRATEGIES OF EACH CLASS OF TELECOM ROOMS

Class	Location	Customer Type	Strategy
A	Metropolitan, commercial and industrial areas.	Enterprise, and leased lines with value-added potential customers	Provide a high standard of telecomm equipment for customer services.
B	Center of township district.	Many competitors are eager to enter such markets.	Keep the long-term customers and create revenue.
C	Center of small township district.	The customer revenue is declining.	Keep the long-term customers and raise value-added services
D	Low growth areas.	The low customer revenue growth	Need to fulfill the social responsibility
E	Negative growth or non-economic region.	The average telephone charges per user are not very high	Deploy the basic equipment on the business investments.

V. CONCLUSIONS

The privatization, liberalization and competition of telecom markets have created a really strong competition. In the new era of the digital economy, telecom resources lack effective management [25][26]. Many telecom companies and DGT pay more attention to the problem. If organizations can achieve performance of implementation of strategy, invest in telecom equipment accurately, and reduce operating costs, they will make optimal use of company resources. According to the classes of the telecom rooms (Table VI), CHT can apply the management modes to the planning stages of engineering works, particularly the initial stages or re-planning of power equipment to advance the effective use and resource development and utilization.

TABLE VI. OPERATIONAL MODES OF POWER PLANNING ADVISED FOR EACH CLASS OF TELECOM ROOM

Class	DC reserve capacity	Automatic Generation	Monitoring Equipment	Maintenance Personnel
A	Design capacity with more than three hours	Full power capacity, and two sets of automatic generation.	Installation and use of the automatic monitoring equipment to connect with main monitoring centrer.	Full-time and first-level maintenance personnel.
B	Design capacity with three hours	Full power capacity and one set of automatic generation.		Full-time and second-level maintenance personnel.
C	After blackout, the power backup system can be maintained two hours.			When failure occurs, second level maintenance personnel will take over the jobs.
D	After blackout, the power backup system can be maintained one hour	Basic power capacity and one set of automatic generation.		Centralized management by regional maintenance unit.
E		Automatic generation.		When failure occurs, delegate technicians will support based on the fault level.

This study proposed the GSKM model for power infrastructure to support maintenance strategies for telecom rooms. Group decision making with structured process is to improve the quality of decision-making and the results can be better judged. Followed by interviewing the decision makers, ascertain opinions by conducting knowledge discovery and drawing up evaluation criteria - staffing, office features, initial load, power supply and growth forecast. The GSKM model was based on knowledge discovery and mining generated the classification rules and decision tree through MCDM evaluation to develop an effective telecom

 ISBN: 978-1-61208-364-3

power infrastructure strategies. It will enhance readability and simplify the decision-making task for the differences between management modes and types of power system in each telecom room.

There are generally two main objectives in constructing GSKM model. The first objective concerns the improvement of the quality of the decisions taken. During the planning stages of engineering works, particularly the initial stages or re-planning of power equipment, power maintenance strategies can be integrated into the design-lifecycle to advance the effective use and resource development and utilization. The second objective of a formalized decision study is to supply technical documentation in support of decisions both in front of authorities and of public opinion.

Theoretically, most of scholars and experts studied the electric power transmission system, discussed how to solve the power distribution system, and trending econometric analysis. Because of different nature of each telecom room, this study may not be applied to plan telecom power infrastructure. Finally, the model will apply to other domain and compare with other group model in future work.

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