VALIDATION OF A SUPPORT SYSTEM ON BUILDING SYSTEM SELECTION IN CONSTRUCTION

by Christiono Utomo[a]

ABSTRACT

Decisions for multi-person on building system selection are very complicated since many parties involved. Where a number of stakeholders are involved in choosing single alternative from a set of alternatives, there are different concern caused by differing preferences, experiences, and background. Therefore, a support system is required to enable each stakeholder to evaluate and rank the solution alternatives before engaging into negotiation. This paper presents a validation process of the negotiation support system in building system selection. A case study was carried out in a real estate company in Indonesia. Validation was conducted to a framework of coalition formation as a basis algorithm of negotiation support for building system selection in construction. Two methods of validation were conducted in a group decision to select building roof system. These methods are decision result validation by similarity index and stakeholder preferences validation by canonical correlation analysis and a set of descriptive statistic analysis. Two others conventional model were compared with the coalition formation algorithms. This validation process reveals that the algorithms proposed is better than single weight factor and aggregation method in terms of closely to the best fit option, stakeholder satisfaction, and performance of the model.

KEYWORDS: *building system; similarity index; statistic analysis; support system; validation.*

INTRODUCTION

The validation process presented in this paper is the last stage of the research[1] that is developing a conceptual model of negotiation support for building system selection in construction. As a process of multi disciplines and teamwork, negotiation becomes an important role in the process of building system decision of a component or an element. Decision techniques applied to determine the relative value of the solutions and trade off between function and cost for the best value of design of a building system. The research methodology is based on a theoretical approach that consists of value-based decision nature in construction, multi criteria group decision making, game theory, negotiation theory, and agent-based development[2].

The methodology combines value analysis method by Bytheway[3] group decision analysis method based on Analytical Hierarchy Process[4] and Game theory-based agent system[5] to develop a negotiation support. As the last stage of the research by Utomo[1], the work presented on this paper presents the validation of the work earlier. The validation was conducted for coalition formation algorithms as main core of negotiation support proposed for building system selection in construction.

RESEARCH SIGNIFICANCE

The significance of achieving the objectives and its contributions are to provide an approach for a better decision-making which will improve the value of construction projects; to provide a framework to facilitate automated negotiation in a collaborative negotiation between all parties in building system decision; to contribute to the body of knowledge in the decision-making science domain by initiating an advanced tool for negotiation; and to provide an advanced method in building system selection process since the practice of the knowledge is teamwork-based.

The result from the application on building system selection also contributes to the group decision and negotiation process of the American Society for Testing and Materials (ASTM) Standard, Book of Building Economics[6]. The coalition algorithms developed in this research can be used for any development research on group decision and negotiation in construction industry. Negotiation support model arising from this research gives contribution for a better application of multi-discipline and teamwork on practice. As the area of the research covers the domain of building system, construction, operation research and Artificial Intelligence (AI), this validation to the support model proved the contribution of the support system to the development of research on these areas.

The negotiation support system proposed in the validation process will also bridge the gap between automated design on the construction domain in relation to automated negotiation in Information Technology (IT) domain.

METHODOLOGY FOR VALIDATION

The objectives of this validation is to determine how much the primary goal of the coalition formation algorithms was achieved by pointing out the differences among three decision models of technical solution selection method, and by determining the user satisfaction and confidence in the results of the decision model with respect to each model. The model of validation can be illustrated in Fig. 1.

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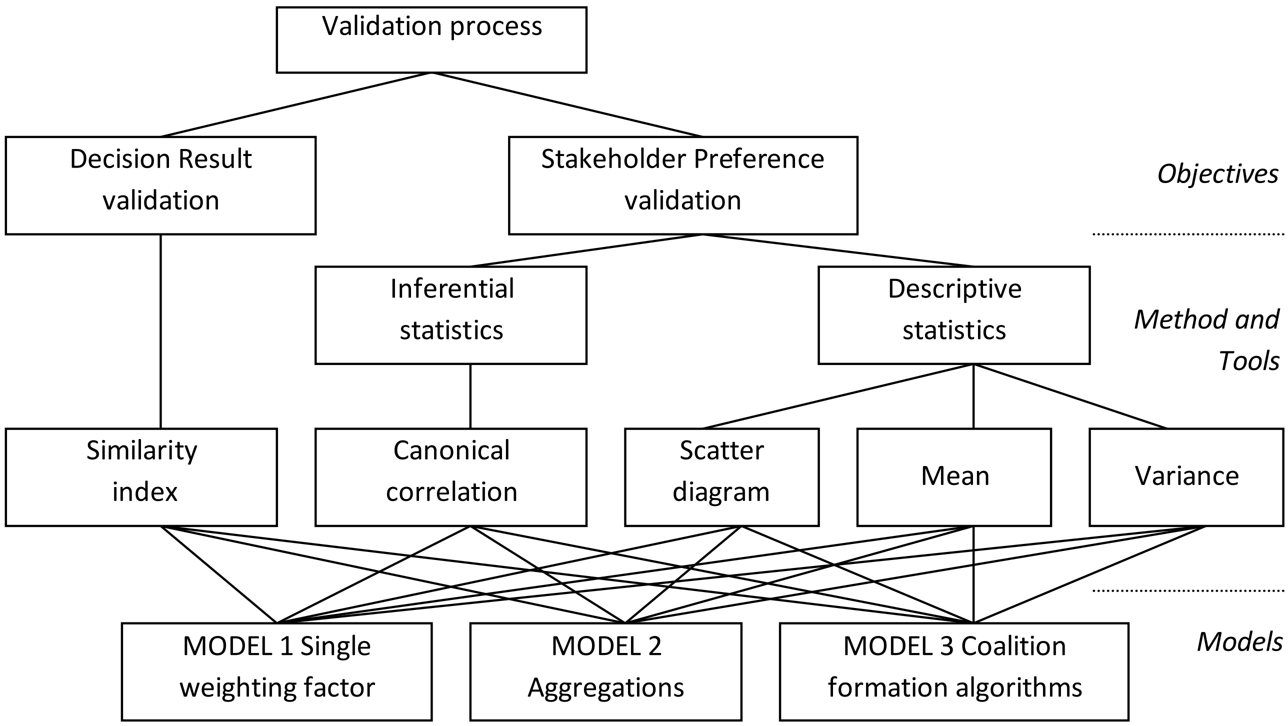

Fig. 1. The model of validation.

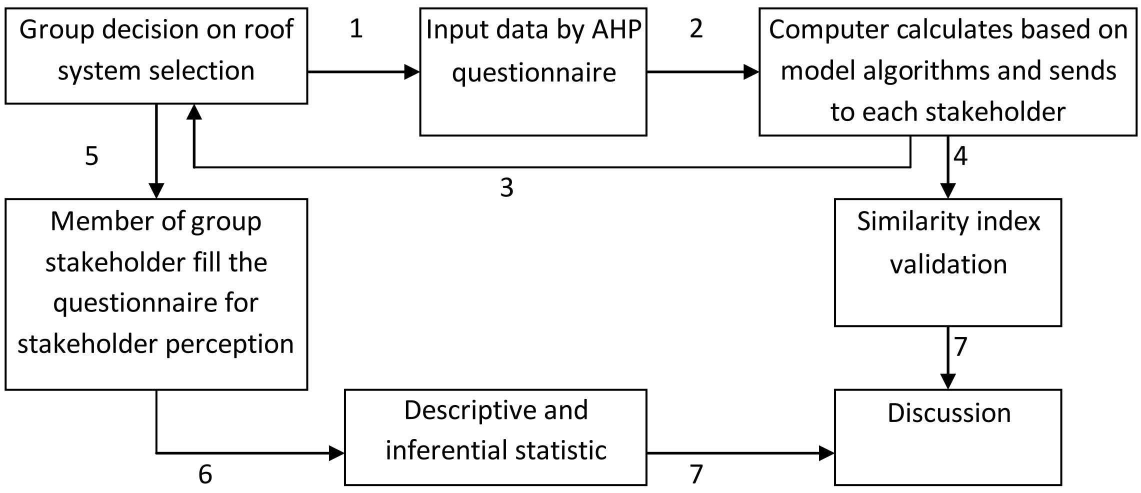

Fig. 2. Validation process.

This research applied two stages for validation of the negotiation model for agreement option. The first was result validation while the second was stakeholder preference validation. In the first stage, results on the best choice alternative for technical solution from the case study on floor system selection would be validated by similarity index. The stakeholder preference validation was conducted using a questionnaire. Two methods, which were descriptive statistics and analytical statistics, were applied to analyze a set of result from survey questionnaire. The questionnaire asked a group of stakeholders in order to compare three methods of group decision making, including the proposed method from this research. The questions consisted of two variables, which were 'the satisfaction of stakeholders on every group decision method' and 'the perception of stakeholders on the performance of every group decision method'.

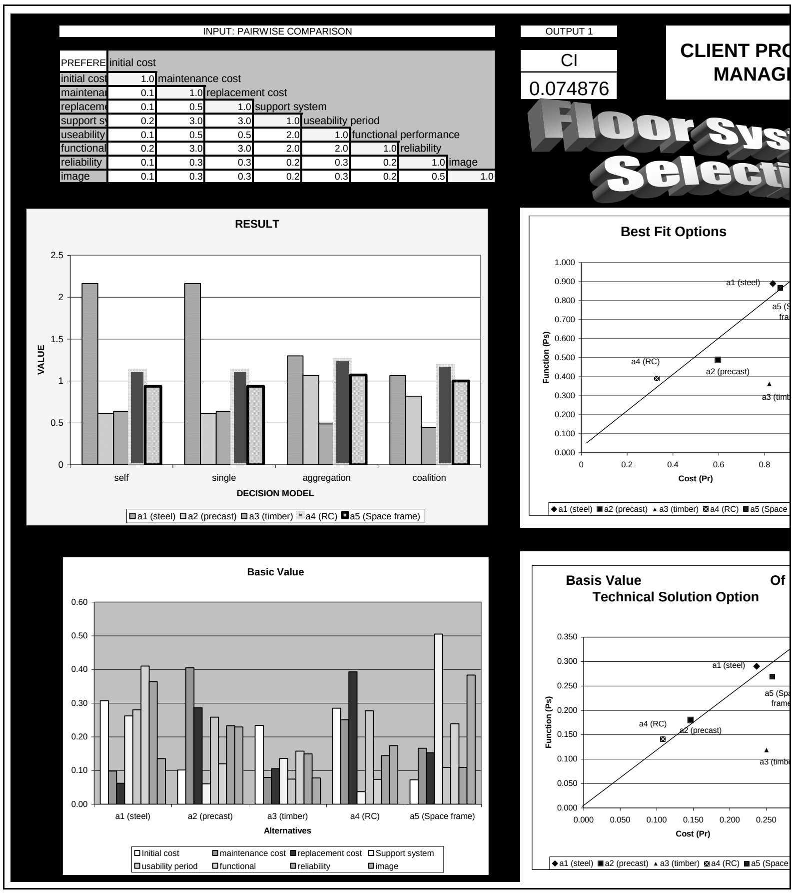

Fig. 3. A screen shot of the validation tool.

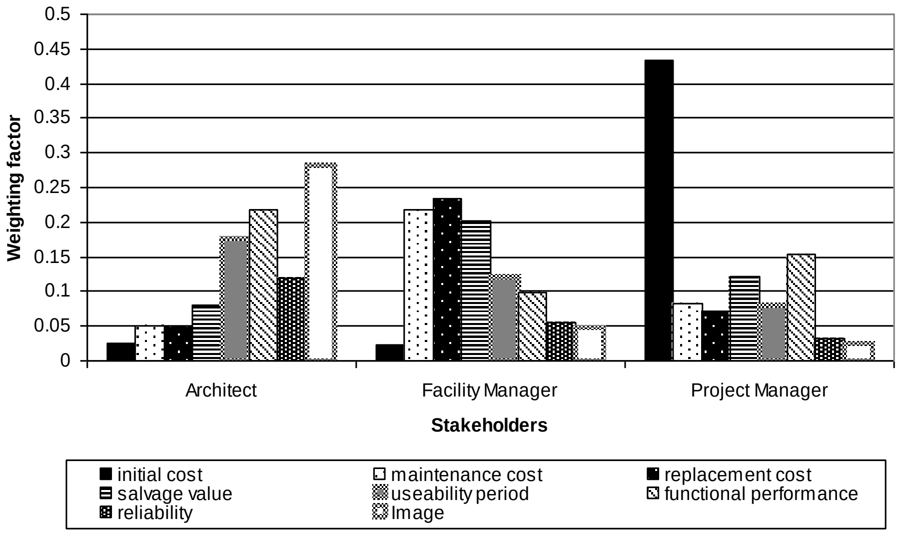

Fig. 4. Weighting factor of criteria for each stakeholder.

Fig.1 shows the two model validations with five methods. These are "Decision Result" validation using similarity index method[7, 8], and "Stakeholder Preference" validation using statistical analysis[9] which are canonical correlation analysis[10, 11] and descriptive statistic[12] (mean, variance, and scatter diagram). The case study for this validation was a group decision to select the best technical solution for a floor system. Five alternatives of floor system as ~~a~~ possible solution were selected and evaluated by eight criteria and three stakeholders. The schematic for the validation process is presented in Fig. 2 and a screen shot of the validation tools is presented in Fig. 3. In phase 1, every stakeholder input their preferences. Automatically, the computer calculated (phase 2) and sent the result for the best-fit solution for every method to every stakeholder (phase 3).

In phase 3, the computer calculated the input data on each three decision models which are:

MODEL 1: Single Weighting Factor (SWF) 13.

MODEL 2: Aggregation Value (AV) 14, 15.

The aggregation combines the performance ratings for all attributes with respect to each alternative16.

MODEL 3: Coalition Formation Algorithms (CFA) 17,18,19,20. It consists of the two stages and algorithm which are determination of optimal solution (payoff optimum) and fitness factor of an alternative solution.

At the same time with phase 3, the computer calculated the similarity index for all three decision models (phase 4). After receiving the result from computer, each stakeholder filled the questionnaire as respondent to give their perception on the satisfaction and performance of the models (phase 5). The input data from questionnaire was analyzed by statistical method (phase 6), and together with the result from similarity index, they are discussed for the result of the validation process (phase 7).

DATA ANALYSIS

Results from computer calculation became the input on three kinds of result analysis for validation. The input data was presented by computer into three types of information:

Determining weighting factor (weight of preferences) of criteria for each stakeholder. Fig. 4 indicates that each stakeholder has their own preferences.

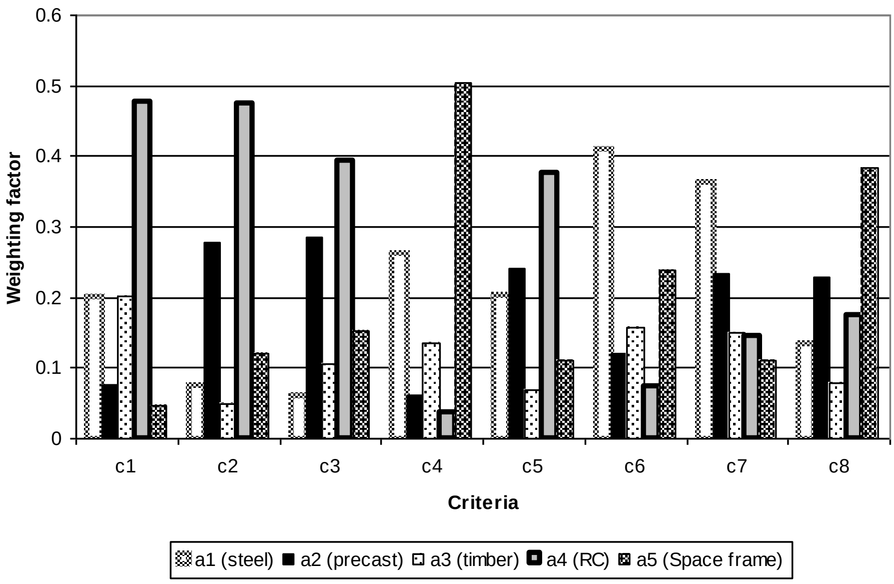

Fig. 5. Weighting factor of alternative for each criteria.

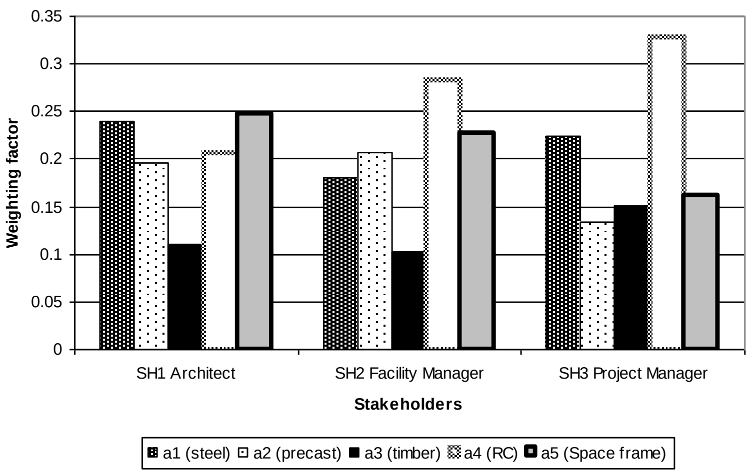

Fig. 6. Weighting factor of alternatives for each stakeholder.

Table 1. Similarity Index Result.

	Model 1	Model 2	Model 3
Stakeholder 1	>1 =1	>1=1	0.691
Stakeholder 2	>1 =1	0.94	0.566
Stakeholder 3	<1 =0	0.713	0.366

Grading of each alternative for each evaluation criteria. Fig. 5 presents that a4 was the 'best-fit' for c1, c2, c3, and c5. The 'best-fit' solution for c4 and c8 was a5; meanwhile a1 was the 'best-fit' for c6 and c7.

Grading of every alternative for every stakeholder. Fig. 6 shows that stakeholders have different best option as a solution alternative.

RESULTS AND DISCUSSION

Similarity Index

In this research, the index was used to measure how closely the best-fit option in the first negotiation matches the expectations of each stakeholder. The criterion value $P = \frac{X_i - B_a}{B_b - B_a}$ was normalized into a range between 0 and 1. The data can be converted by:

$$P = \begin{cases} 0, & if \quad P < 0 \\ 1 & if \quad P > 1 \\ \frac{X_i - B_a}{B_b - B_a} & if \quad 0 \le P \le 1 \end{cases} \qquad (1)$$

Where, B_a is the lowest criterion value, B_b is the highest criteria value, X_1 is the best fit solution for all stakeholders. The result of similarity index is presented in Table 1. The closer is the value of an individual stakeholder to the best-fit of the group; the more satisfactory is the model to every stakeholder.

The result reveals that Model 1 did not satisfy all stakeholders, Model 2 satisfied two stakeholders and Model 3 satisfied all stakeholders.

Descriptive Statistics

This analysis used means, variance and scatter diagram to show the comparison between three models.

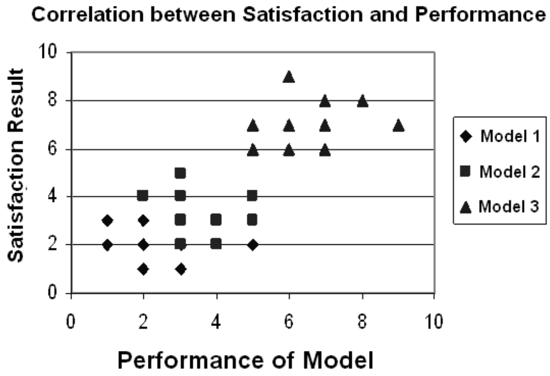

Fig. 7. Scatter diagram on respondent satisfaction and performance of model.

There were two criteria to present the difference between decision methods, which are (a) satisfaction of respondent (stakeholders) as measured by three questions: understand, confident, and helpful, (b) performance of model as measured by three questions: reliability, full information, and collaborative. The result can be seen in Table 2 and Fig. 7.

The result from descriptive statistic reveals that Model 3 fulfilled the highest satisfaction of stakeholder and performance of the model. This can be seen clearly from the scatter diagram in Fig. 7.

Canonical Correlation Analysis

Multivariate technique is concerned with determining the relationships between groups of variables. Therefore, the data set of canonical correlation was split into two groups; x_1, x_2, …,x_n and y_1, y_2, …,y_n, based on some common characteristics. In this case x_1 is satisfaction to Model 1, x_2 is satisfaction to Model 2 and x_3 is satisfaction to Model 3. The y_1 is performance of Model 1, y_2 is performance of Model 2 and y_3 is performance of Model 3. The purpose of Canonical analysis is then to

Table 2. Descriptive statistic analysis.

Respondents	Respondents Satisfaction			Performance of Model		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Client PM team						
PM 1	2	4	7	1	3	6
PM 2	2	3	7	1	4	6
PM 3	1	3	5	3	3	6
Facility management team						
FM 1	3	5	9	2	3	7
FM 2	5	5	7	2	4	8
FM 3	2	3	9	2	2	7
FM 4	1	4	6	2	2	9
Architect and design management team						
DM 1	2	5	8	3	4	8
DM 2	2	2	8	1	4	8
DM 3	3	3	6	1	5	6
DM 4	2	3	7	2	3	7
DM 5	2	3	6	1	3	7
DM 6	2	3	5	3	4	7
Mean	2.2308	3.5385	6.923	1.8462	3.3846	7.0769
SD	1.0127	0.9674	1.321	0.8006	0.8697	0.9541

Table 3. Correlation matrix (r).

	x1	x2	x3	y1	y2	y3
Satisfy 1 (x1)	1.000	0.458	0.264	-0.158	0.459	0.066
Satisfy 2 (x2)	0.458	1.000	0.296	0.331	-0.069	0.313
Satisfy 3 (x3)	0.264	0.296	1.000	-0.170	-0.190	0.204
Performance 1 (y1)	-0.158	0.331	-0.170	1.000	-0.147	0.235
Performance 2 (y2)	0.459	-0.069	-0.190	-0.147	1.000	-0.239
Performance 3 (y3)	0.066	0.313	0.204	0.235	-0.239	1.000

Table 4. Correlation significance (P).

	x1	x2	x3	y1	y2	y3
Satisfy 1	-	0.116	0.384	0.606	0.115	0.830
Satisfy 2	0.116	-	0.326	0.269	0.824	0.299
Satisfy 3	0.384	0.326	-	0.579	0.535	0.505
Performance 1 (y1)	0.606	0.269	0.579	-	0.631	0.440
Performance 2 (y2)	0.115	0.824	0.535	0.631	-	0.431
Performance 3 (y3)	0.830	0.299	0.505	0.440	0.431	-

find the relationship between satisfaction and performance for every Model. From the result analysis presented on Table 3 and 4 for all correlation between satisfaction to models and performance of all models, only Model 3 gives positive value for all satisfaction.

FURTHER RESEARCH

Generally, it is important that research continues in the area of operation research and agent-based technology. There is an urgent need for a greater recognition of the validity and importance of naturalistic inquiry within the building economics and construction management research community. Within the specific field of building system selection, there is need for further research into the possible application of other methodologies of group decision support and negotiation support. In the domain of operation research, there are a lot of opportunities for mathematical proof research for optimization and satisfying decision in cooperative and incomplete information environments. A mathematical proof research for an unlimited multi-person decision maker in a project involving a whole community as in many infrastructure projects today will be an interesting research.

Future research in the field of agent-based negotiation and management will have a huge benefit from the development of a user-friendly software which uses a GUI (graphical user interface), but it will surely consume a lot of time and money for research. In future, the combination of many technologies such as Virtual Reality (VR) will help human and its agent to communicate, discuss and make decision for any type or stages of building system design with two main important preferences that are function and cost. As to further illustrate, a final building design decision can be made by an agent from all the project participants in a virtual reality environment simultaneously while being in a different geographical area. This research provides basic and conceptual algorithms to bridge automated design decision, and automated negotiation by applying a systematical design method in construction.

CONCLUSIONS

Based on the two validation processes using similarity index, descriptive statistic and canonical correlation analysis to compare three models of group decision, the proposed model of coalition formation algorithms was found to be better than the conventional method. It was measured in terms of stockholder's satisfaction and their perceptions on the model's performance, and the closeness of their preferences to the group's best options (technical solution). This method of validation was applied to the group decision of a building system selection. The negotiation support was based on the coalition algorithms which adopts the value criteria as validated through the feedback of questionnaire survey on the stakeholder preferences and through the analysis of similarity index. The validation result indicates that the framework for negotiation support by coalition algorithms is acceptable and practical and therefore improving the satisfaction level of all the stakeholders on group decision making. Therefore, it is concluded that the proposed model provides a structured methodology which can lead to a systematic support system and automated negotiation process.

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