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財務モデルの視覚的対話型操作インターフェースと，その意思決定の品質への作用

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広範に利用されている表計算ソフトは，事業計画における財務モデルの設計や操作においても，重要な道具となっている．意思決定や将来の環境条件に応じて財務モデルの数値を変更したり戻したりする試行錯誤は，「What-If（もしこうなったら）分析」と呼ばれる，表計算ソフトの意思決定支援システムとしての利用である．しかし，表計算ソフトは多くの数値の変更や復帰，退避などを効率的に行うことが困難である．筆者は，スライダーなどのグラフィカルウイジェットを用いてセル上のデータを視覚的かつ対話型に操作することを可能にする“VI (Visual Interactive)-What-If Analysis”という，表計算ソフトの拡張を設計・実装した．この研究の目的は，この機能拡張が，財務モデルの操作を用いて事業計画をする際の意思決定に，どのような作用をもたらすかを，ユーザー実験を通じて調査するものである．実験は，58 人の大学院生および 23 人の現役社会人を被験者として 2 回実施された．その結果，この機能拡張が，リスク認識，意思決定に対する自信，およびバイアスの回避といった面で，意思決定の品質を向上する作用が認められた．

Visual and Interactive User Interface for Financial Model Manipulation, and Its Effects in Decision Making

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People rely on Spreadsheet for design and manipulation of financial models. In most of the business planning examples, users work on the “What-if” type of operation, creating many scenarios according to their strategies and uncertain conditions. Spreadsheet has not been able to support much efficient changing numbers, saving values and resuming of previous values. The author designed and implemented a software, with an extended spreadsheet function, called “VI (Visual Interactive)-What-If Analysis”, which allows users to manipulate data on cells interactively and visually through graphical widgets, such as sliders. The purpose of this study is to examine the effects of the software for decision making in business planning via the manipulation of financial models. Two experiments were conducted with 58 business school students and 23 business individuals. Results has indicated that “VI-What-If Analysis” is effective in improving decision quality, with greater accurate risk cognition, greater confidence and avoids bias amongst users in their decision making with financial model manipulation.

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1. Introduction

Financial analysis is the crucial part of quantitative analysis in business planning in order to make a decision for more profitable business outcome. A decision is a choice made from available alternatives in order to achieve the objective. Miyagawa[10] described a decision making process as using the following comprehensive model. A decision maker searches x by estimating movement of y and chooses a particular x which maximizes u.

$$\mathbf{z} = f(\mathbf{x}, \mathbf{y}),$$
$$\mathbf{u} = g(\mathbf{z}).$$

where z denotes “result valuable”, which is a set of factors indicating the business performance; x denotes “decision valuable”, which is a set of factors that the decision maker can control; y denotes “environment valuable”, which is a set of environmental factors that the decision maker cannot control; u denotes “utility valuable”, which is a set of decision maker’s preferences.

A rational decision can be made from all factors of x, y, z, and u are defined. Function f and g are completely generate results and utilities, and all alternatives of x are tested under the complete probability distribution of y. However, according to Simon’s bounded rationality, people are bounded by their ability to process information[13]. Therefore, in realty, a decision maker does not try to maximize the outcome but try to find a “satisfying” outcome within a limited combination of options with uncertainties tested. As per the interpretation by Miyagawa’s model, a decision maker tested limited number of x under limited number of y, with incomplete factors in x, y, z, u and defective functions f and g, in order to reach a satisfying result and utility.

Miyagawa’s model can also be applied to a financial analysis in business planning, with f as the financial model, factors of x as price, marketing budget, and etc., and factors of y as market size, market share, and etc. Result elements of z as net profit, NPV, and so on. Generally, utility is not considered in business planning, so it can be assumed that $u = z$.

2. VI-What-If Analysis

2.1 Issues of spreadsheet

Spreadsheet is one of the most popular applications. People rely on it for design of financial tables, such as cash flow statement. One of the useful utilizations of spreadsheet as a DSS (Decision Support System) is “What-if Analysis”, which allows decision makers to evaluate alternative scenarios and explore the task/problem space in the spirit of interactive marginal optimization[6]. On the other hand, there are some issues that arise during decision making

because spreadsheet can only manage and maintain the data set one at a time. As mentioned above, the financial model has many factors in *x* and *y*, and people tend to test on many scenarios by changing the values in each factor. By means of this subjunctive operation, it gives rise to three important issues. Firstly, spreadsheet does not have relevant functions that are useful for scenario analysis. Lunzer and Hornbæk[8] noted that examining scenarios with repeated parameter changes would be decidedly laborious. Smedley et al.[14] also argued that current spreadsheets provide little support for What-If type of interaction. Secondly, it is difficult to observe "changes". In business planning, people sometimes do not care about a specific result value due to a specific input values, but care about the "changes", in other words "sensitivity". As spreadsheet requires data to be completely entered, the users must perform hundreds of data entry in order to observe changes. Finally, initial values stored in spreadsheet cells may possibly result in the issue of "anchoring bias". Anchoring refers to different starting points which yield different estimates which are biased towards the initial values. This is because people make estimation by starting from an initial value that is adjusted to yield the final answer[15]. In decision making situation, the decision maker's testing may be "anchored" to the initial values in the financial models on spreadsheet. For example, initial values derived from the business environment may mislead the decision maker into recognizing lesser risk as he/she only tested on the scenarios that were close to the initial values.

2.2 VI-What-If Analysis

The author has designed and implemented a software as an extended spreadsheet function, called "VI (Visual Interactive)-What-If Analysis", which allows users to manipulate data on cells interactively and visually through graphical widgets, such as sliders. To use this function, the user will declare assumptions and goals in the financial model. Assumptions are cells containing decision valuables or environment valuables. Goals are cells containing expressions to calculate results or utilities. A range with maximum and minimum values in which the decision maker can select is given to each decision valuable. A 90% probability interval with maximum values, minimum values and probability distribution type is given to each environment valuable. Upon starting the "VI-What-If Analysis", the "What-If" control panel will be displayed above the given financial model as shown in Figure 1. The control panel consists of two portions, which are the assumption list and the result valuable graph. The former includes an assumption name, a minimum value, an initial value, a maximum value, a current value, a slider, and a scenario storage area in a row corresponding to each assumption. The initial value, which the user believes to be most likely, will be the value on the financial model. The current values are changed by moving the corresponding slider, and the result valuable graph dynamically synchronizes with the change, like animation. The both ends of each slider are set by the minimum and maximum values as defined previously so that the users can easily change or continuously vary the current values. Users can also temporally save a set of current values into one out of the five scenario storage areas, and retrieve values at any time. The result valuable graph will show a set of bars corresponding to each goal. These bars reflect the goal values at the initial and the current values (decision and environment).

Users are able to test more combinations of decision factors and uncertain factors by "VI-What-If Analysis", which provides more efficient changing values in cells and effective cognition of results. Under the Simon's bounded rationality theory, it is expected the more values the user tests, the greater satisfaction he/she gains.

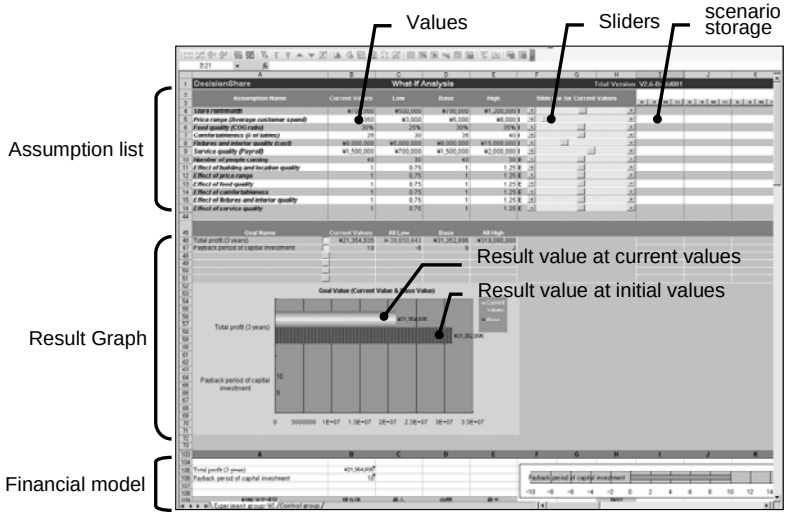


Fig. 1 VI-What-If Analysis

3. Related Research

There seems to be no exact same software being developed so far, except for some which share certain similarities in visual or interactive user interface. Ahlberg et al[1] designed and implemented a concept called "Dynamic queries" for database manipulation, which allowed users to retrieve graphical widgets, such as sliders. The database query language SQL has been the standard application till today, but it needs expert skills to use, less interactive and requires conventional batch processing. In contrast, Dynamic query enables the user to interactively control visual query parameters that generate a rapid (100 millisecond update),

animated visual display of database search results. Shneiderman[12] examined an empirical study of Dynamic query effectiveness by comparing with natural-language queries of the same real estate database. The result suggested that Dynamic query offered significant speed advantages and greater users' satisfaction. The similar functionality can be widely seen today on the internet, such as Google map.

VIS (Visual Interactive Simulation) is the use of simulation model where the user starts, pauses, and resumes the simulation execution, and modifies the model and data even when the execution is at the pause mode. All operations are interactive and visual aided by graphic display and iconic animation[2]. Hurrion and Secker[4] first developed VIS concept for job shop scheduling problems in manufacturing. Many VIS software products were developed in later years, and some had achieved commercial successes. Kirkpatrick and Bell[5] interviewed engineers who had designed the models, with 80% of them who answered that the visual operation of VIS had been useful in understanding problems and mathematical technologies. Chau and Bell[3] examined efficacy of VIS by using three types of DSS (Decision Support System), such us (1) traditional (non-graphic) simulation status expressions, (2) VIS model with only graphical expressions, and (3) "Paired-systems" with both numeric and graphical expressions in the interactive interface. They found that the paired-system was most effective and efficient for the problem solving task, and VIS was more effective than traditional simulation. In spite of the studies by VIS proponents who have shown benefits in decision making, there has been no clear evidence to support the benefits[3].

However, most VIS researches have been conducted in engineering application areas. Parker[11] examined its effect in financial decision making using spreadsheet software. As the spreadsheet technology was a basic tool at that time, data change was performed by typing the keyboard and graphical expression was limited to character combination, such us "*******". The result showed that the subjects using graphical expression made better decision than the subjects using tabular expression, even though the tabular subjects may produce more alternatives than graphical.

4. Experiment

Two experiments were conducted with subjects assigned to the experimental group which utilized the "VI-What-If Analysis", while the control group which utilized Excel spreadsheet. In both experiments, participants were asked to read a case study regarding the planning for a restaurant business operation, such as costs estimation, decision making and judgment under uncertainties. Evaluation was done based on their decision making process.

4.1 Experiment 1

4.1.1 Participants and financial model

Participants were 58 business school students who had more than three years of working experience. They were randomly placed into the control group (34 subjects) or the experimental group (24 subjects). Each participant received printed copies of the case study and an Excel spreadsheet with a three-year cash flow projection (financial model) on it. However, participants in the experimental group received the "VI-What-If Analysis" as the additional add-in software to Excel. The financial model had two result values, six decision values, and seven environment values. The result values reflecting the business performance were the total profits over three years and the payback period for the initial investment. Each of the decision values including store rent/month and price range, had a given range in which decision maker could pick up a scenario as according to his/her strategy. As the case study had uncertainties, each of the seven environment values including number of people coming and effect of price, was given a range with a 90% probability interval as the designated risk. Therefore, the task was to make a decision under uncertainty, so that the subject could not search the optimum set of decision values.

4.1.2 Task and design

The experiment consisted of following parts:

- Practice (experimental group only): "VI-What-If Analysis" software training (20 min.)

Each subject in the experimental group practiced using the "VI-What-If Analysis" software on each PC by answering checklists based on distributed paper material.

- Part 1: Individual decision making (30 min.)

Each respective subject in both groups made a decision by manipulating the financial model and answered the decision values which are considered as the most appropriate strategy. Then, the subjects estimated the risk caused by the environment values, and answered 90% probability intervals using maximum and minimum of the result values (for example total profit). Finally, the subjects answered with confidence to their decisions on a scale from 1 to 9 (9=high).

- Part 2: Group decision making (30 min.)

In both the experimental and control groups, participants were randomly placed into group of three members respectively. Each three-member group was asked to make a decision as the group on the same procedure as part 1, using the financial model.

- Part 3: Post-task questionnaire (10 min.)

The three-member groups were further separated and assigned with a post-task questionnaire, which includes each subject's support level for the group decision on a scale from 1(No support as the best decision) to 9 (Fully support as the best decision).

4.1.3 Results

In both individual and group decisions, the two-sided Mann-Whitney's U test was applied to medians of confidence and support levels in both groups. However, it indicated no significant difference between the groups. On the other hand, the Student's t test indicated that the absolute width between maximum and minimum values of estimated profit were wider in the experimental group than the control group ($P<0.1$). This was perceived that "VI-What-If Analysis" has fostered risk recognition.

4.2 Experiment 2

Based on the statistical results from experiment 1, the second experiment was designed and performed. It was different from the previous experiment in two major points; (1) The participants were business individuals and (2) Direct estimation of environment values was added to the task. Experiment 1 did not show significant differences in decision confidence. One possible explanation for it was that the subject from business school did not know "What-If Analysis" in the first place. Therefore, this experiment had chosen to target at business individuals with 5 to 10 years of project financial analysis experience. The another result of experiment 1 was that "VI-What-If Analysis" has shown meaningful effect in fostering risk recognition based on the given uncertainty, as well as motivated the author to examine the effects for direct estimation of unknown quantities. Specifically, the subjects were asked to estimate some environment values in the financial model and to answer as probability intervals.

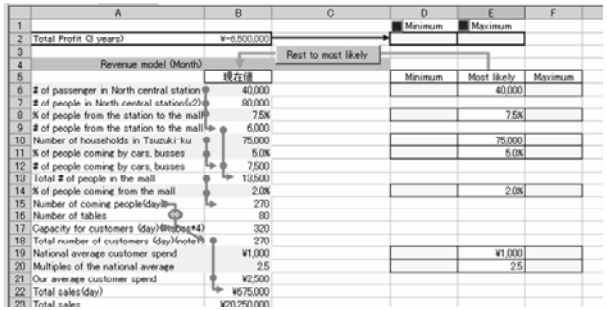
4.2.1 Participants and financial model

There were 23 business individuals who had been randomly assigned to the experimental group (11 subjects) and controlled group (12 subjects). The case study used in this experiment had small differences from experiment 1. The decision making task was changed to be easier. Thus, the subjects were asked to select one out of the three sets of decision values given in the case study, in contrast to the decision made on a set of decision values within the given possible intervals in experiment 1. The participants received the test package, including the case study and the answer form by e-mail, because active business individuals were unable to gather in an experiment room at the same time. Thus, the experiment did not include group decisions.

The experiment consisted of two parts. In part 1, the subjects were asked to estimate seven values in environment valuables using 90% probability interval. These valuables were selected as the subjects did not know the exact values but could estimate them. Figure 2a showed the spreadsheet model that was provided for control group and Figure 2b showed the one that was provided to experimental group. Both sheets had the initial values in the cells but subjects were informed the values were not true but just initial, and asked not to pay much attention to the values. This was intended to examine how initial values affected subjects as the "anchoring bias". The control group subjects input upside (maximum) and downside (minimum) values to appropriate cells by typing on the keyboards. The experimental group subjects varied values using each slider and clicked the small buttons on appropriate cells to set the estimated values.

In part 2, subjects were asked to select one of the three sets of decision values as their best strategy, and asked to score their confidence level. To assess risks during decision making, subjects in the control group had to perform "What-If Analysis" by typing and those in the experimental group performed "VI-What-If Analysis" by moving the sliders.

(a) Control group



(b) Experimental group

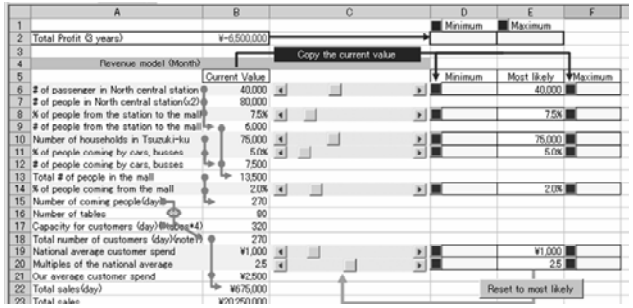


Fig.2 Financial models

4.2.2 Results

Table 1a has compared the number of estimated intervals which included and excluded the initial values. It showed that the estimation included the initial values which were lesser in the experimental group, however it was not a meaningful difference ($p>0.1$) by Fisher's exact test. On the other hand, in Table 1b, "Symmetric interval" was produced in the experimental group,

and was significantly less than the control group ($p<0.01$). A "symmetrical" interval means that it has the initial values which was closer to the center of the estimated intervals, thus

(Initial Value) – (Downside Value) = (Upside Value) – (Initial Value).

Another meaningful result was found in subjects' confidence level from 1 to 5 (1=most confident) across groups. The experimental group was perceived to have more confidence (median=2.0) than the control group (median=3.0) in their decisions by the two sided Mann-Whitney's U-test ($p<0.1$).

Table 1 Estimated intervals

	(a) Number of intervals		(b) Number of intervals	
	Include initial value	Not include initial value	Asymmetric	Symmetric
Control group	81	2	43	40
Experimental group	72	5	59	18
Fisher's exact p value	p=0.26>0.1		p=0.001<0.1	

5. Discussion

5.1 Risk recognition

The results of experiment 1 suggested that "VI-What-If Analysis" would possibly foster risk recognition when making a decision using a financial model with environment values given as probability intervals. In other words, "VI-What-If Analysis" has possibly inhibited overconfidence. To verify the positions of estimated interval in both groups in actual probability distribution, the Monte-Carlo simulation was performed on the same financial model with the same environment values. Figure 3 has shown two estimated intervals along the probability distribution. The median of intervals by the experimental group was 71,479,102 yen, which was 74% of the probability interval. In contrast, the median of intervals by the control group was 30,931,172 yen, which was 37% of the probability interval. This can be taken as the evidence that "VI-What-If Analysis" may provide more efficient and effective manipulation of financial models as noted earlier. Therefore, when maximum and minimum values are given to environment values, they are preset onto sliders' both ends in "VI-What-If Analysis". More scenarios can be tested in a particular time by efficient change values and effective recognition of the result value changes. Thus, the more scenarios the user has tested, the higher the probability that the user will reach the best and the worst result values.

5.2 Confidence

As mentioned previously, "VI-What-If Analysis" has effects in increasing confidence level in experiment 2, but that was not found in experiment 1. A potential explanation for this result is the application of "VI-What-If Analysis" caused by the task difference and participant difference. For the former difference, the decision making task in experiment 1 was to make one set of decision values from a given range. In contrast, experiment 2 was to select one out of the three preset combinations of decision values. In order to make the best decision, it is important to analyze risks by testing effect of environment values carefully. For experiment 2, it was much easier to select the decision values. Thus participants could pay more attention in risk analysis with the application of "VI-What-If Analysis". As for the latter difference, the business participants in the experiment 2 were experts in financial analysis and familiar with "What-If Analysis" through using spreadsheet, in contrast, the student participants were not. The research by Lee et al.[7] showed that individuals, who had recently learned how to use the DSS (Decision Support System) were confused or restricted by the set of functions provided by the system and would not plan well for their usage of the DSS. It could be understood as the subjects in experiment 2 had utilized "VI-What-If Analysis" more effectively than the ones in experiment 1.

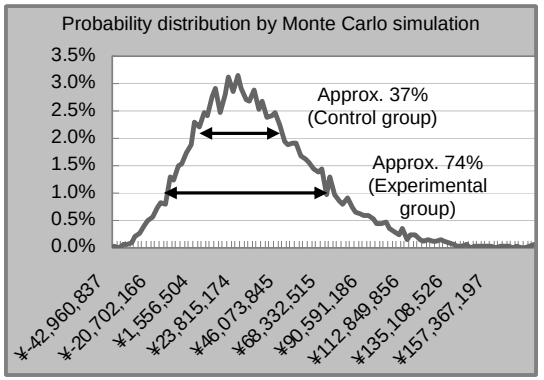


Fig. 3 Intervals on Probability distribution by Monte Carlo simulation

5.3 Bias avoidance

As mentioned above, the subjects in the experimental group estimated significantly less "symmetric intervals" than the control group. This reflected that "VI-What-If Analysis" has affected users towards avoiding "anchoring bias". One explanation for the avoidance is that "VI-What-If Analysis" reduces user's cognitive load. People estimated risk as a probability interval by two different ways, such as thinking of low and high values independently, or a certain value plus and minus a displacement (or a ratio). It is reasonable that the former way almost produces "asymmetric" intervals, and the latter way always produces "symmetric" intervals. Noted that the former way requires to memorize two sets of digits in mind, however

the latter way requires to memorize only one set on digits (displacement) when using the initial value. The active human's short-term memory has the capacity for holding a small amount of information in mind. A commonly-cited capacity is 7±2 elements[9]. It could be understood as the subjects in the control group tended to save short-term memory by using the latter process, while the subjects in the experiment group had more memory capacity as supported by "VI-What-If Analysis" through using the former way. This interpretation can be observed in figure 4, as estimation with more digits, such us 40,000 and 75,000 were more symmetrical in the control group, but less symmetrical in the experimental group. It is reasonable to infer that "VI-What-If Analysis" is effective in decreasing cognitive load.

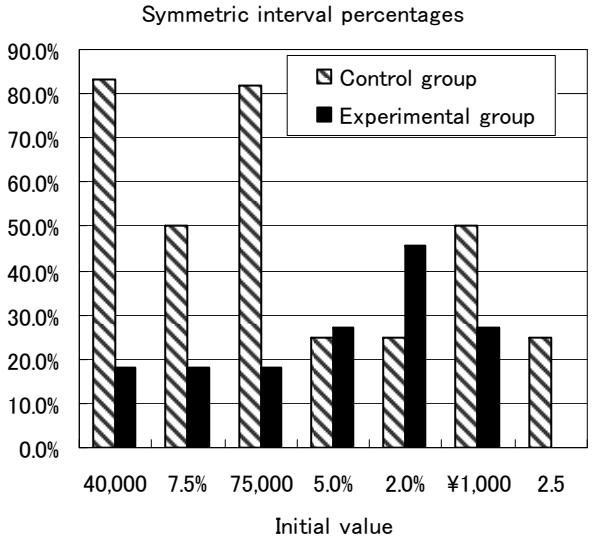


Fig. 4 Symmetric interval percentages of initial values

6. Conclusion

This paper has proposed a functional design of visual and interactive "What-If Analysis" as an extension of the spreadsheet application. It also reported the results of the experiments, with regards to its effect of utility. The results suggested that "VI-What-If Analysis" has been effective in improving decision quality, with greater accuracy in risk cognition, greater confidence and avoided anchoring bias amongst users in their decision making through financial model manipulation. Although, the findings may be limited in this study, the result suggests an opportunity to enhance spreadsheet in decision support application.

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