

VALUING REAL OPTIONS WITH SIMULATION SOFTWARE

Eyler Coates
University of Southern Mississippi
P.O. Box 5137
Hattiesburg, Mississippi 39406 USA
E-mail: Eyler.Coates@usm.edu

Jon Juneau
Fulcrum and Lever
920 Sioux Lane
Hattiesburg, MS 39402 USA
Email: jonjuneau@fulcrum-lever.com

Rita Schweickert Endt
University of Southern Mississippi
P.O. Box 850
Gautier, Mississippi 39553 USA
Email: Rita.Endt@usm.edu

KEYWORDS

Real options, financial risk analysis.

ABSTRACT

Traditional engineering economic analysis concerns itself mainly with deterministic inputs, even though deterministic data seldom occur in business. Additionally, traditional net present value methods used to evaluate potential projects make no allowance for flexibility by management and assume a static environment. Practitioners often assume that risk analysis and real options are too complicated to include in their analyses. The simplified approach is less accurate and managers often intuitively adjust the results to reflect their understanding of the risks and potential rewards. This paper demonstrates the ease that engineering economic analysis with risk analysis and real options can be valued by simulation software that is readily available to owners of personal computers. This novel approach to modeling real options may also encourage more sophisticated and realistic engineering economic analysis.

INTRODUCTION

In order to deal with the variability issues of real business projects, risk analysis is necessary. Unfortunately, the risk analysis approach is one aspect of economic analyses that is commonly ignored during project evaluations. Ristroph points out that errors in estimates of cash flows are the rule rather than the exception. He also states that the primary question involving most cash flows is not whether they will be correct, but rather by how much will they be incorrect (Ristroph 2000). Including risk analyses in engineering economy solutions is an important step for acquiring more information to make better management decisions. Ho and Pike report that "proponents of risk analysis argue that increased risk information improves management's understanding of the nature of risks, helps identify the major threats to project profitability and reduces forecasting errors." (Ho and Pike 1998) They also report "the risk analysis approach provides useful insights into the project, improves decision quality and increases decision confidence."

There are several approaches used to handle economic risk. One approach is scenario analysis. However, as

Park has pointed out, the worst-case and best-case scenarios are not easy to interpret and do not provide probabilities of occurrence of those possibilities. He continues to point out that these scenarios normally do not provide additional information such as the probability of losing money on a project or the probability of other possibilities (Park 2002). However, multi-scenario analysis, used in conjunction with probability descriptions of input variables, forecasts the relative impact and interaction of all the uncertain factors simultaneously. The result of the study is a distribution of the desired answer. The distribution of the possible outcomes in itself provides a clear picture of the range and variability of the possible outcomes of the project. The use of simulation software to conduct multi-scenario analyses makes the approach practical. As Ristroph states, simulation provides insight into the variability of a project's potential performance and hence its risk, so that an informed, albeit subjective, decision can be made (Ristroph 2000).

Given that there is imperfect information when we make a financial decision in the planning and beginning of a project, we need to determine what happens when the information becomes certain as the project progresses. Is there an option to bail out of a bad deal or is the organization committed to finishing a project? Are there other alternatives at different stages of the project that would yield better results? If the organization can "cut its losses" and perhaps recoup some losses by recovering some of its investment in the event that a project goes sour, then the organization has some flexibility in regards to the execution of the project. In other words, there is an "option" for alternative project direction once the project is underway. Evaluating these 'options' ahead of project execution or during project execution gives management more information to make better decisions about a project.

INTRODUCTION TO REAL OPTIONS

By definition, "a real option is the right, but not the obligation, to take an action (e.g., deferring, expanding, contracting, or abandoning) at a predetermined cost called the exercise price, for a predetermined period of time – the life of the option." (Copeland and Antikarov 2001) The ability to adjust a project gives an organization real options. Recently, the evaluation of

real options in project analysis includes the methods developed for evaluating financial options (Herath and Park 1999) (Herath and Park 2000) (Nembhard et al. 2000). For example, deciding to prematurely abandon a project can be modeled in a similar manner as modeling a put option on a stock.

A financial stock option is a contract between the option writer, who sells the option, and the option owner, who buys the option. If the option owner decides to exercise the option, the option writer must execute the transaction specified in the contract. Since the option contract can be bought and sold, they have a market value. The factors that determine the value of an option include the price of the publicly traded stock and the specifics of the option.

To introduce the ideas of stock options, assume that XYZ Corporation has publicly traded stock and stock options. An option on XYZ Corporation's stock would specify an exercise price (or strike price) and an expiration date. The exercise price is the cost to the option owner to exercise the contract. The expiration date is the last date that the owner can exercise the option.

Calls and puts are the two types of stock options. A call option on XYZ stock might have an exercise price of \$100 and an expiration date of July 20. This option would allow the owner to buy XYZ stock from the option writer for 100 dollars per share on or before July 20. (Note: European options can only be exercised on the expiration date and American options can be exercised on or before the expiration date. We assume here that the option is an American option.) The owner of an American put option on XYZ stock with an exercise price of 100 and an expiration date of July 20 can sell XYZ stock for 100 dollars to the option writer on or before July 20. Stock options have an intrinsic value. For example, if the market price of the stock grew to 125 dollars, the call option owner can buy the stock for 100 dollars (option exercise price) instead of the market price of 125 dollars and the intrinsic value of the option would be 25 dollars. If the stock of XYZ corporation stock has a market price less than 100 dollars, the option to buy XYZ stock for 100 dollars becomes worthless. Likewise, the put option owner can sell the stock to the option writer for \$100 dollars. Thus, if the market price of XYZ stock is 85 dollars, the owner could buy the stock for 85 dollars and then exercise the option to receive 100 dollars making an instant profit of 15 dollars. Therefore, the intrinsic value of this put option would be 15 dollars. If the market price of XYZ stock rises above 100 dollars, then the put option will become worthless.

Because of the possibility for large profits, a great deal of work has been done to learn methods to value options. On the expiration date, an option's value will

equal its intrinsic value, with no uncertainty. The European option is the easiest to evaluate because it can only be exercised on the expiration date. The value of the European option before expiration involves adjustments for both the time value of money and the uncertainty in the final stock price. An analysis on a binomial lattice is used when the situation is modeled with a discrete time periods and discrete changes in price. The Black-Scholes formula for the European call option is the continuum limit, with the time periods and the price changes becoming very small, of a binomial lattice. Brealy and Meyers hint at how to adjust the value of the European call to determine the value of other options (Brealy and Myers 2000). The value for real options can be approximated when the methods of evaluating financial options are applied to the choices an organization makes in a project.

SIMPLE REAL OPTIONS

If an organization can show that their choices, or the real options, are similar to financial options, then they can use the financial option evaluation methods to evaluate the real options. In this paper, the authors examine an organization's real option to prematurely abandon a project when expectations are not being met.

The option to abandon is often modeled like a put option. When the organization decides to abandon a project, they might sell their capital equipment investment. The cash flow from this sale could be modeled as the exercise price of the put option. (Note: If expectations are better than expected, the organization might also have the real option to expand their production capability. This could be analyzed like a call option with the exercise price being the investment amount required for the expansion.) Only the option to abandon, the put option, will be modeled in this paper.

The next section presents the financial option approach to modeling the premature abandonment of a project. Then the simulation approach is demonstrated for the same project. Since real options are often more complicated than the European call option, simulation is a powerful tool for evaluating these real options.

EXAMPLE PROBLEM

The problem presented in this paper is a three-phase project with incoming cash flows in each phase and an option of abandoning the project at the end of the first two phases. This type of problem is becoming more prevalent in today's business because projects are becoming more and more complex, longer in duration and more costly. Most companies cannot afford to financially back a long-term project without receiving some feedback (cash flows) at several stages throughout the duration of the project.

Below is the description of the problem presented in this paper:

A company has a project that requires a \$30,000 investment. The \$30,000 investment is the best estimate but there is an uncertainty about the amount. The company's minimum attractive rate of return (MARR) can be calculated based on the capital structure of the firm using the weighted-average cost of capital (Park 2002). The degree of project variability is captured by the probability distributions of the cash flows and the timing. So, the discount rate can be set to the risk-free rate. For our example, we are using $i = 15\%$. Each phase of the project could have a duration between 1 and 2 years and incoming cash flows for each phase is estimated to be \$15,000. From past experience, the company knows that the estimated cash flows are somewhat variable and that they are also correlated to each other (a typical time series). That is, if the first cash flow is low, then the remaining cash flows are also likely but not necessarily low. Could the company lose money doing this project?

The traditional engineering economy analysis solution to this problem, using end-of-year cash flow conventions, yields a risky answer because it is not designed to handle variable progress payments and the other uncertain parts of the problem. The method presented in this paper provides an easy way to solve this more complex problem using simulation software. Simulation software can estimate the distribution of the possible net present values (NPV) for the project. Arena, a readily available PC based simulation software, was used to solve this problem. The following steps should be used when using simulation software to solve this type of economic decision problem:

1. Determine the input variables
2. Create a flowchart for a single scenario
3. Identify the entity for the simulation
4. Determine the appropriate attributes and global variables that are required for the final result
5. Design and enter the network diagram to generate multiple scenarios according to the flowchart
6. Verify the model
7. Run the simulation
8. Analyze the output

Each of the above steps is described in the following paragraphs. The given data for this problem are the distributions for the initial investment, discounting rate, the cash flows at the completion of each phase, the duration of each phase of the project and the late penalty for missing the deadline.

Step 1 - Determine Input Variables

The simulation solution requires that we input the initial investment, the minimum attractive rate of return (i.e., the discounting rate), the amounts of the individual

progress payments, the timing of these progress payments, the project deadline and the late penalty for missing the deadline. The values of all of these inputs can be deterministic or stochastic according to the requirements of the problem. For this problem, the initial investment by the company to begin the project is assumed to be normally distributed with a mean of \$30,000 and a standard deviation of \$333, denoted in this paper as NORM(30000, 333). Given that plus or minus three standard deviations in a normal distribution tend to encompass 99.73% of the possible data points, essentially it is assumed that the investment will be likely be around \$30,000 but could even be as low as \$29,000 and as high as \$31,000. Likewise, the cash flow at the completion of the first phase is NORM(15000, 2000) dollars and the duration of each phase of the project is estimated to be NORM(1.5, 0.2) years. The time duration is given in years to match the time units of the discount rate, which is 15% per year. Note that unique cash flows and time durations could easily be assumed for each phase. The details on how to determine what distributions to use for a variable are covered in Coates and Endt (Coates and Endt 2000).

Note that the cash flows for the last 2 phases follow a first-order auto-correlated series based upon the first cash flow. For this example we will assume an 80% correlation coefficient although this figure should be based on past experience. So, this means that if the first cash flow is low, then the remaining cash flows are likely (but not necessarily) to be low also and the management might decide to abandon the project.

Step 2 – Create Flowchart

A good intermediate step to solving the overall problem is to generate a flowchart for calculating an individual scenario. The flowchart for this problem is shown in Figure 1. Once the basic steps to generate a single scenario are worked out, the transition to a simulation flowchart is rather simple.

Step 3 – Identify Entity

Each entity, in the simulation run, will represent a single replication (scenario) of the net present value calculation. After an entity is created, the stochastic variables are selected via sampling from the appropriate distribution.

Step 4 – Determine Attributes and Global Variables

Several variables are needed in order to calculate the net present value for an individual scenario. These would be assigned as attributes since they would be unique to a scenario (entity). From the flowchart in Figure 1, these attributes would be Interest, Investment, Timing, Payment and NPV. The auto-correlation of 80% could also have been a global variable.

Step 5 – Design And Enter The Network Diagram

There is almost a one-to-one relationship between the Arena simulation network diagram and the flowchart given in Figure 1. The simulation network is rather elegant but well within the grasp of the average student.

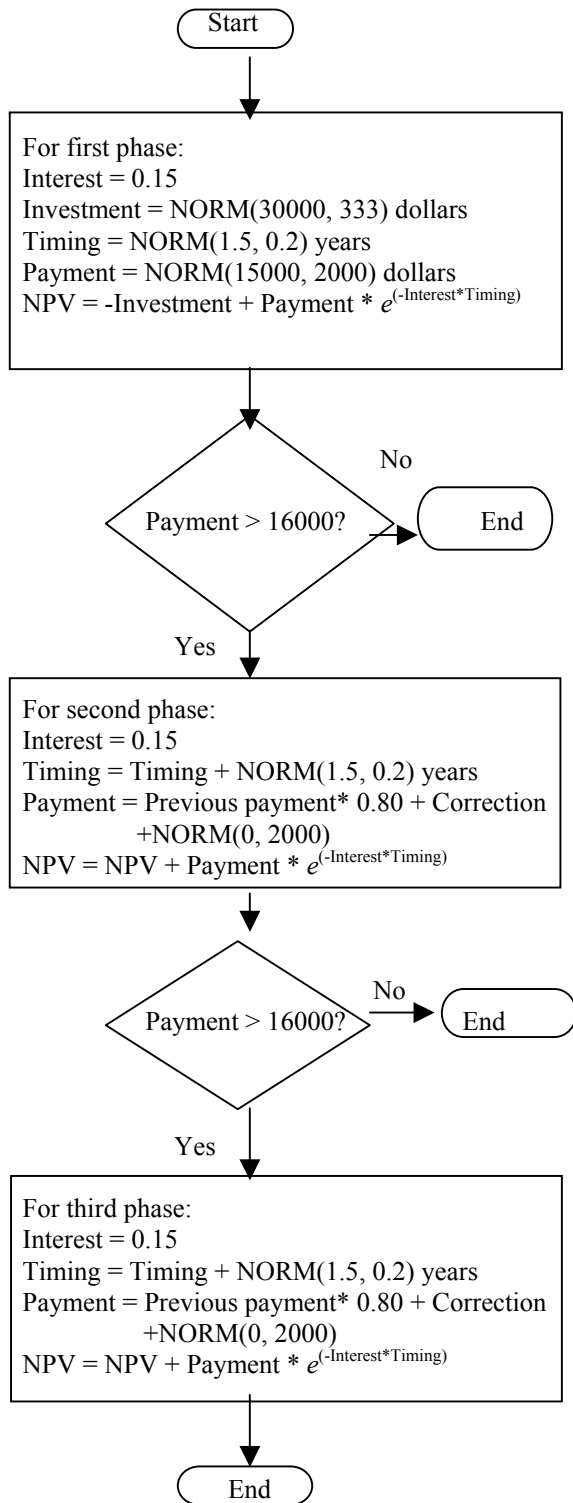


Figure 1: Individual Scenario Flowchart

The Actions Modules perform the iterative calculations to generate the value of the NPV attribute. The first phase Action Module calculates the NPV up to the point of the first progress payment. The details for that module are given in Figure 3. The details of the other action modules for the remaining progress payments are very similar to Figure 3.

The Arrive module, labeled New Scenario, allows for the creation of entities. Each entity represents one scenario. Detail of the Arrive Module is given in Figure 2.

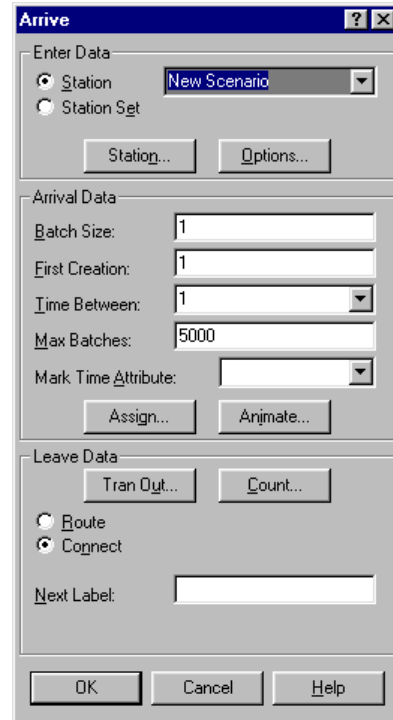


Figure 2: Detail of Arrive Module

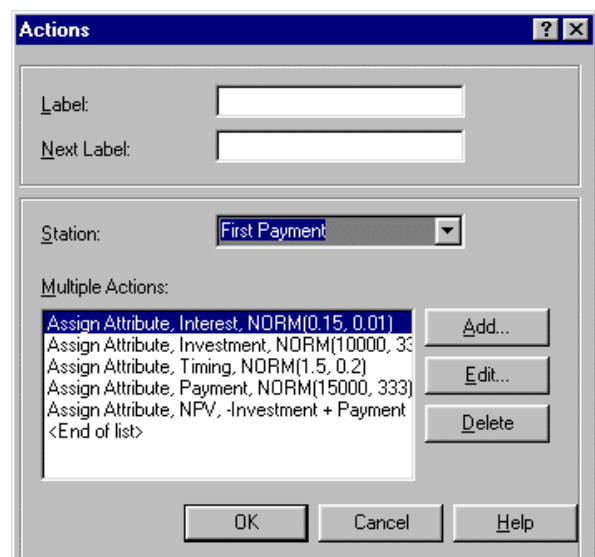


Figure 3: Detail of Action Module for First Phase

The Depart module allows the attribute NPV to be tallied before the entity is destroyed. The Arena network requires two additional modules. The Simulate module is required only to enter the title of the report and the name of the analyst. The Statistics module is required to tell the simulation software to save the output data, namely NPV, into a file for later analysis. There are several methods for stopping the simulation. The method chosen was to limit the number of created entities in the Arrive module. For this example, the number of entities (scenarios) was 5000. See Figure 2.

Step 6 – Verify The Model

There are a couple of ways to verify this simulation model. A relatively easy method is to replace all the stochastic variables with constants. Then run the simulation program (only one scenario is needed). Compare the results with a manual calculation. For this problem, the simulation, using all deterministic inputs such as the means of the distributions yields and allowing no flexibility to terminate the project, yields a point estimate of -\$821. This is verified by the manual NPV calculation, which yields a point estimate of a negative \$820.49.

Step 7 – Run The Simulation

The NPV associated with the particular scenario (entity) is calculated from the cash flows from all 3 phases of the project. This NPV is stored as an attribute of the entity. Before the entity leaves the system, the NPV is collected as a statistic and tabulated by the simulation software. Five thousand scenarios are run by the simulation program. It only takes 0.07 minutes to run the simulation. Thus, the number of scenarios can be increased greatly with little strain on a personal computer's resources. For this paper, the simulation was run with no option to abandon and then again with the option to abandon.

Step 8 – Analyze The Output

An excerpt of the text output of the simulation program is given in Figure 4. When there is no option to abandon, then the project has a greater variability. One can see that the net present value of the 5000 scenarios ranges from \$-15,040 to \$14477. Also, the average NPV for the project with no option is \$-860.60. By comparison, the net present value of the 5000 scenarios of the project with an option to abandon ranges from \$-2822 to \$16761 and the average NPV is \$3067.1

For additional comparisons, histograms of the outputs, when there is no option to abandon and when there is an option to abandon are given in Figures 5 and 6. Based on the histograms, the analyst can determine any prediction (tolerance) interval. For example, on the project with no option, the middle 90% of the

observations fall between \$-8000 and \$6000. By contrast, when there is an option to abandon, it appears that the middle 90% of the observations fall between \$0 and \$7,000. Therefore, the option to abandon has removed most of the risk. Incidentally, if we had used deterministic estimates of the input values and no allowance for flexibility to cancel the project (a real option), the NPV calculation would yield a point estimate of -\$860.49 with no indication whatsoever of the probable range of the risk associated with this project.

CONCLUSION

This paper demonstrated that commonly available simulation software that runs on personal computers can:

- easily be used in engineering economy analysis to explain the risk associated with a project
- give the present worth distribution of a project when there is uncertainty about the future timing of cash flows, particularly in those projects that have progress payments which involves the uncertainty of the amount of the cash flows, an uncertain interest rate as well as uncertain timing.
- easily incorporate a discontinuous function such as a decision to cancel a poor performing project (a real option)
- handle problems with a number of replications that that can not be handled by spreadsheet software

```

ARENA Simulation Results
Project: 3-phase project with option to
abandon
Replication ended at time      : 5000.0

Identifier      Avg      Half Width      Obs.
-----
NPV w/option    3067.1      40.368          5000
NPV no option   -860.603    131.16          5000

Simulation run time: 0.07 minutes.
Simulation run complete.

```

Figure 4: Text Output of the Simulation Program

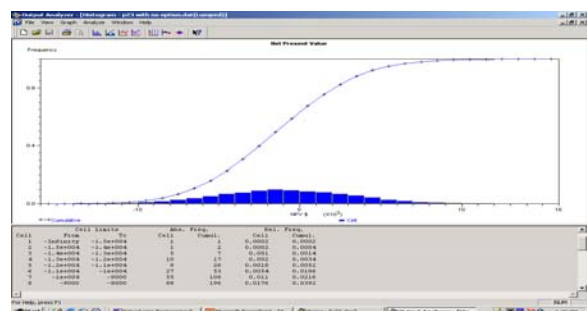


Figure 5: Project NPV with No Option to Abandon

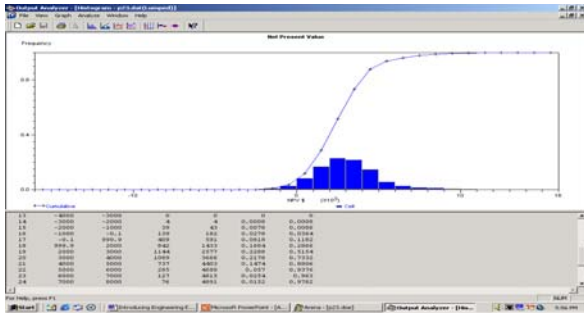


Figure 6: Project NPV with Option to Abandon

REFERENCES

- Brealy, R.A. and Myers, S.C., [2000], *Principles of Corporate Finance*, 6th Edition, Irwin McGraw-Hill.
- Coates, E.R., and Endt, R.L., Making Engineering Economy 'Real' With Simulation Software, *Proceedings of the 2000 ASEE Annual Conference* – St. Louis, MO, June, 2000.
- Copeland, T.E., and Antikarov, V., [2001], *Real Options, A Practitioner's Guide*, TEXERE Publishing Limited, New York, New York.
- Goyal, A.K., J.M. Tien, and P.A. Voss, [1997], Integrating Uncertainty Considerations In Learning Engineering Economy, *The Engineering Economist*, 42(3), 249-257.
- Herath, S.B.H., and C.S. Park, [1999], Economic Analysis of R&D Projects: An Options Approach, *The Engineering Economist*, 44(1), 1-35.
- Herath, S.B.H., and C.S. Park, [2000], Exploiting Uncertainty: Investment Opportunities as Real Options: A New Way of Thinking in Engineering Economics, *The Engineering Economist*, 45(1), 1-36.
- Ho, S.S.M., and R.H. Pike, [1998], Organizational Characteristics Influencing The Use Of Risk Analysis In Strategic Capital Investments, *The Engineering Economist*, 43(3), 247-268.
- Nembhard, H.B., Shi, L., and C.S. Park, [2000], Real Option Models for Managing Manufacturing System Changes in the New Economy, *The Engineering Economist*, 45(3), 232-258.
- Park, C.S., [2002], *Contemporary Engineering Economics*, 3rd Edition, Prentice Hall, Upper Saddle River, New Jersey.
- Ristroph, J.H., Economic Simulations for Risk Analysis, *Proceedings of the 2000 ASEE Annual Conference* – St. Louis, MO, June, 2000.

AUTHOR BIOGRAPHIES



EYLER COATES was born in Baton Rouge, Louisiana, USA. He is an Associate Professor of Engineering Technology at The University of Southern Mississippi in Hattiesburg. He has 12 years of industrial work experience with manufacturers performing industrial engineering functions. He received a B.S. degree in Industrial Engineering (1979), a M.S. degree in Engineering Science (1996), and a Ph.D. in Engineering Science (1998) all from Louisiana State University in Baton

Rouge. His Web-page can be found at <http://www.set.usm.edu/bcoates>.



JON JUNEAU was born in Dallas Texas, USA. He is a management consultant in Hattiesburg, Mississippi. He has 13 years electric utility experience in nuclear fuel management. He has a B.S. degree in Nuclear Engineering (1978), a M.S. degree in Nuclear Engineering (1980) and a M.S. degree in Mathematics (1981) from Texas A&M University. He has a Ph.D. in Engineering Science (1996) from Louisiana State University. He is a licensed professional engineer and certified in production and inventory management. His email is JonJuneau@fulcrum-lever.com



RITA SCHWEICKERT ENDT was born in Detroit, Michigan, USA. She is an Assistant Professor of Engineering Technology at The University of Southern Mississippi in Gautier. She has 27 years of work experience with several large corporations and the US Navy. Her research interests lie in life-cycle costing. She has a B.S. degree in Industrial Engineering (1977), and an M.S. degree in Industrial Engineering (1979) from Wayne State University. She is currently completing her Ph.D. in Industrial Engineering at Mississippi State University. Her email is Rita.Endt@usm.edu