The application of fuzzy logic for profit optimization to contractor project cash flow

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Abstract. Profit has become the main goal for a contractor without neglecting other aspects in the content of contract. According to previous empirical studies, profit has been optimized. However, it was optimized not as an output variable. Therefore, in this study we were going to try to position profit as an output variable using Fuzzy logic. The research aimed to: 1) describe cash in and cash out to prepare empirical Project Cash Flow (PCF) statement, 2) develop Fuzzy Mamdani set model on PCF 3) formulate manual method and Fuzzy Mamdani computational programming on PCF, 4) validate the results of manual simulation using computation, and 5) make profit which can be simulated. The results of the study were: 1). Fuzzy Mamdani set model with 4 input variables (%), those were: Direct Cost (7-75), Indirect Cost (2-25), Informal cost (1-15) and Progress (0-100) and single output which was profit (0-10); 2). The manual method consisted of 4 stages: (1) creating a fuzzy set of 4 input variables and 1 output variable, (2) making the Application Function Implications based on 2 rules, (3) Composing all output variables with the MAX operation, and (4) Defazzification using the method of centroid of area, 3). computational way with indicators: Trapezoid membership function, two-type linguistic set (minimum - maximum) and (slow - fast), MISO (Multiple Input Single Output) implication functions, "MAX - DOT" operation system, fuzzy rules (if ... and ... then) = 16 rules, 4). The output of the manual method and computational method resulted the same profit of 4.46, so it was declared valid, and 5). The simulation revealed that minimum profit can be made if the cash out allocation and progress on input variables are not balanced and in contrast, we will obtain maximum profit if the allocation of cash out and progress are balanced with input variable.

1. Introduction
The condition of PCF in every construction contractor varies especially buildings owned by the government which is pretty costly. In contrast, in private-owned buildings informal cost is relatively small. Despite, the offering nomenclature is strict, the quality demands is high, and moreover, tenders are done on every type of work [1]. As a result, contractors experience difficulties in making optimal profit [2]. Other factors of PCF vary, such as material raising prices, unexpected cost overrun, weather factors, and construction failures, so that those lead to progress delay which causes profit to fall or even the contractor fails in making any [3].

Profit is the primary goal of entrepreneurs in general and construction contractors in particular. This is because profits are used for company survival, development, trust and working capital to get the next project [4]. Profit is also a reward for contractors during and after completing their works [3].
Various ways to get optimal profit include: (1) using fuzzy sets, it must be detailed in identifying the duration of the project main cost, calculating cash flow periodically and cumulatively, and drawing a progress curve precisely which, if those are applied, can increase profits by 2-3% [5], (2) Using fuzzy PCF: material and builder salary overrun increases by 7% and so as not to decelerate the profit rate, the allocation of non-technical funds must be minimized [6], (3) In complex construction company, applying fuzzy logic approach helps make decision easier for work priority, thus can save expenses up to 2% [7],, (4) application of fuzzy nets in project scheduling optimizes construction progress and minimizes the risk of cost overrun [8], (5) by working with fuzzy project cash flow approach, project costs are easily evaluated starting from the feasibility study, planning, and execution [9], (6) by using fuzzy Mamdani cash flow cycle, a contractor company can minimize human error to 2% [10], (7) by adopting Fuzzy Mamdani, optimization of partial productivity of furniture companies can increase profits up to 2.5% [11], (8) With fuzzy mamdani ready-mix concrete delivery setting can be optimized up to 2.7% of the plan capacity [12], (9) With fuzzy Mamdani, procurement of goods is based on what is sold, so that buildup and damage can be avoided, risk factors can be minimized to 4% and productivity/ progress increases [13], (10) With Fuzzy Mamdani, PCF process management can be controlled and save cost to 2% [14], (11) Fuzzy Mamdani simulation on large-scale project work utilities saves 4% of the planned time [15], and (12) Mamdani optimization simulation on raw, semi-finished, and finished materials at the project site saves 3.4% of the total material expenses [16].

According to the empirical studies above, profit was optimized not as an output variable. Therefore, in this study profit would be tested as a single output variable using MISO system of Fuzzy Mamdani model [17]. While the input variables were: Direct Cost, Indirect Cost, Progress and Informal cost. Continued to compile a manual and computational model of the Fuzzy Mamdani MATLAB R2017b program including: (1) input and output variables, (2) membership functions, (3) rules making, (4) the relationship among inputs and outputs and 3 dimensional 3 surfaces [10]. The input and output variables were in the form of empirical data/ PCF of construction contractors in East Java (Surabaya, Malang and Nganjuk). For this reason, the study was considered important to be done so that the profit which status was fuzzy in the project cost plan for the wholesale project is not allocated explicitly [1], so that profit can be optimized without neglecting other aspects.

![Figure 1. Model PCF [1]](image)
PCF is the flow of cash in and cash out per period of time in a project work [18]. Furthermore, cash in consists of: 1. Own capital, 2. Loan funds, and 3. Initial and terms funds [3]. Meanwhile, cash out consists of: (1) Indirect cost, (2) Direct costs, and (3) Mark Up (contractor’s profits and informal costs) [19,1]. The preparation of PCF can be done with 2 (two) methods, those are: (1) Table Method, and (2) Graphical Method. One of the graphical methods is the PCF model [1] as shown in Figure 1.

Profit is the main goal for entrepreneurs, particularly, construction contractors. This is because profits are used for company survival, development, trust and working capital to get the next project [4]. Profit is also a reward for contractors during and after completing their work [3]. The explicitly fuzzy profit is not allocated in the project budget plan (PPP) [20].

S curve is a type of time schedule or PCF in the form of linear graphical correlation between percentage of work and time allocation which creates letter-S form [21]. Time schedule and S curve become one unit which is easier to do and function on the construction project to make sure that the contractor is doing right according to what is planned by comparing with the progress curve which can be seen in Figure 2 [20].

**Figure 2.** Time Schedule, S-Curve and Progress Curve [20]

Notes:
1. ) = The S curve is made by a planning consultant
2. - - - - - - - = The progress curve is made by a supervisory consultant

**Figure 3.** Defuzzification Process [17]
Fuzzy Mamdani Logic is an approach to map an input space into the output space using IF-THEN rules [22]. According to Kusumadewi and Purnomo [10], it takes 5 steps to get an output: (1) Fuzzy sets making which consists 2 attributes: linguistic and numerical attributes, (2) application of Implication Functions that is IF x is A THEN y is B, (3) Composition of Rules which consists of 3 methods (max, additive and probabilistic (OR)), (4) If the implication function used is MIN, then this composition (MAX-MIN) and (5) Affirmation (Defuzzification) results in numbers in the fuzzy set domain which can be achieved in 5 ways as shown in Figure 3.

According to [10], fuzzy systems consist of: 1) Fuzzy variables, variables to be discussed, for instances: input variables (direct cost, indirect cost, informal cost, progress) and output variables (profit), 2) Fuzzy sets are groups which represent a condition of fuzzy variables (input variables, fuzzy variables, linguistics and symbols), 3) Value talks universe (min-max), 4) Domain which means all values allowed in the universal set and may be operated [0 0 7 75].

Software used in this research is MATLAB R2017b. According to [23], MATLAB (Matrix Laboratory) is a program for numerical analysis and computation, an advanced mathematical programming language created with the principle of properties and matrix form use. MATLAB language supports vector operations which are basics of data technique scientific problems. Fuzzy Logic toolbox provides Graphical User Interface (GUI) facility to make building fuzzy system easier. GUI consists of 5 tools which can be seen in Figure 5.

2. Method
TResearch samples were determined purposively [25], those are buildings in three cities in East Java: Surabaya, Malang, and Nganjuk, with 30 samples in total. Data collection methods used are: 1) Interview which aimed to get informal cost and profit information and 2) Documental study which aimed to get information about PPP, time schedule, progress, S curve, cash in and cash out.

Other paragraphs are indented (BodytextIndented style).
**Table 1. Profit optimization variables breakdown**

| No | Concept | Variable       | Sub Variable     | Indicator                                                                 | Instrument                   |
|----|---------|----------------|------------------|----------------------------------------------------------------------------|-------------------------------|
| I  | Arranging empirical PCF | 1.1. Cash in | 1.2.1. Indirect cost | 1. Own capital                                      | 1. Interview guideline          |
|    |         |               |                  | 2. Loan                                                    | 2. questionnaire               |
|    |         |               |                  | 3. Initial capital from owner                   |                               |
|    |         |               |                  | 4. Term                                                   |                               |
|    |         |               |                  | 5. Tax and formal cost                                   |                               |
|    |         |               |                  | 6. Operational cost                                      |                               |
|    |         |               |                  | 7. Material cost                                         |                               |
|    |         |               |                  | 8. Salary                                                 | Recapitulation                 |
|    |         |               |                  | 9. Equipment + rental/ quality test cost                 |                               |
|    |         | 1.2. Cash Out| 1.2.2. Direct cost| 10. Paying sub-contractor                                 |                               |
|    |         |               |                  | 11. Unforeseen cost                                      | S-curve                       |
|    |         |               |                  | 12. Contractor’s profit                                   | Progress curve                 |
|    |         |               |                  | 1.2.3. Pro In                                            |                               |
|    |         |               |                  | 13. Informal cost                                         |                               |
| II | Arranging Fuzzy app MAMDANI For Profit Optimization | 2.1. Direct cost | 2.1.1. Value [min–max] empirical data |                               |
|    |         |               |                  | 2.1.2. Indirect cost                                     |                               |
|    |         |               |                  | 2.1.3. Informal cost                                     |                               |
|    |         |               |                  | 2.1.4. Progress                                          |                               |
|    |         |               |                  | 2.2. Output Profit                                       |                               |
|    |         |               |                  | 2.2.1. Tax and formal cost                               |                               |
|    |         |               |                  | 2.2.2. Operational cost                                  |                               |
|    |         |               |                  | 2.2. Material expense                                    |                               |
|    |         |               |                  | 2.2. Salary                                               |                               |
|    |         |               |                  | 2.2.3. Cost of equipment + rent / quality test            |                               |
|    |         |               |                  | 2.2.4. Paying sub-contractor                             |                               |
|    |         |               |                  | 2.2.5. Unforeseen expenses                               |                               |

Research analysis was done by validating output [10, 14] which is comparing the manual method output with computational method output. If those results are in the same number, it is considered valid.

3. Results and discussion

Data obtained through this study is shown in Table 2 below.

**Table 2. Cash in and cash out in construction contractor**

| No | PCF | Min – Max (%) |
|----|-----|---------------|
| I  |     | 10 – 30       |
|    | 1. Own capital | 0            |
|    | 1.2. Loan       | 0            |
|    | 1.3. Initial capital | 10 – 30   |
|    | 1.4. 1st Term   | 15 – 25      |
|    | 1.5. 2nd Term   | 20 – 25      |
|    | 1.6. 3rd Term   | 10 – 15      |
|    | 1.7. 4th Term (retention) | 5        |
|    | 2. Cash out     | 0 - 100      |
|    | 2.1. Indirect cost | 2 – 25   |
| II |     | 11.5 – 13     |
|    | 2.1.1. Tax and formal cost | 5 – 10   |
|    | 2.2. Direct cost | 7 – 75     |
|    | 2.2.1. Material expense | 50 – 60 |
|    | 2.2.2. Salary   | 10 – 20     |
|    | 2.2.3. Cost of equipment + rent / quality test | 0.5 – 2  |
|    | 2.2.4. Paying sub-contractor | 10 – 30  |
|    | 2.2.5. Unforeseen expenses | 2 – 5     |
2.3. Profit and Informal cost

2.3.1. Informal cost
2.3.2. Contractor’s profit

III Progress

Based on the data presented in Table 2, fuzzy variables were arranged in Table 3

| No | Function | Variable | Grouping | Symbol | Universal set (%) | Domain (%) |
|----|----------|----------|----------|--------|------------------|-----------|
| 1  | Input    | Direct cost | minimum | min    | 7 - 75           | 0 7 75 75 |
|    |          | maximum   | max      |         | 75 75 75         |           |
|    |          | minimum   | min      |         | 0 0 7            |           |
|    |          | maximum   | max      |         | 75 75 75 75      |           |
|    |          | Indirect cost | maximum | max    | 2 - 25           | 2 25 25 25 |
|    |          | minimum   | min      |         | 0 0 1            |           |
|    |          | maximum   | max      |         | 25 25 25 25      |           |
|    |          | Informal cost | minimum | min    | 1 - 15           | 1 15 15 15 |
|    |          | maximum   | max      |         | 0 0 0            |           |
|    |          | slow      | slow     |         | 15 15 15 15      |           |
|    |          | fast      | fast     |         | 0 0 0 0          |           |
|    |          | Progress  | slow     | slow   | 0 - 100          | 0 100 100 100 |
|    |          | fast      | fast     |         | 0 100 100 100    |           |
| 2  | Output   | Profit    | minimum | min    | 0 - 10           | 0 0 0 10 |
|    |          | maximum   | max      |         | 0 10 10 10       |           |

Output validity was tested by [10]: 1) The Manual method using Fuzzy Mamdani set and defuzzification using the method of centroid of area. Figure 6 illustrates results of the test

\[
\sum \text{Moment} = M1 + M2 + M3 = 0.798 + 5.332 + 6.157 = 12.28 \\
\sum \text{Area} = A1 + A2 + A3 = 0.745 + 1.230 + 0.745 = 2.72 \\
Z = \text{Profit} = (\sum \text{Moment of area})/(\sum \text{Area}) = 12.28/2.72 = 4.56.
\]

Calculation using the computational method with Fuzzy Mamdani MATLAB 2017b software obtains profit output as shown in Figure 7.
Manual calculation = computational calculation = 4.56 (valid).
Based on data presented in table 3, we obtained simulation result as shown below.

**Example 1**: Progress position simulation results = 25% and profit = 6.16%

![Figure 8](image8.png)

**Figure 8.** 6.16% Profit rate simulation result

**Example 2**: Progress position simulation results = 50% and profit = 5%

![Figure 9](image9.png)

**Figure 9.** 5% Result of Profit rate simulation

**Example 3**: Progress position simulation results = 75% and profit = 5.75%

![Figure 10](image10.png)

**Figure 10.** Result of profit Value simulation = 5.75%

**Example 4**: Progress position simulation results = 100% and profit = 4.67%

![Figure 11](image11.png)

**Figure 11.** Result of simulation of profit = 4.67%
Example 5: Progress position = 100 % and profit = 5 %

![Diagram showing the example simulation results](image)

Figure 12. Result of simulation of profit = 5 %

The example simulation results 1, 2, 3, 4 and 5 above are summarized in Table 4

| No | Direct cost (%) | Indirect cost (%) | Informal cost (%) | Progress (%) | Profit (max) (%) | Notes     |
|----|-----------------|-------------------|-------------------|--------------|-----------------|-----------|
| 1  | 17              | 6                 | 2                 | 25           | 6.16            | Realistic |
| 2  | 37              | 10                | 3                 | 50           | 5               | Realistic |
| 3  | 60              | 15                | 5                 | 75           | 5.75            | Unrealistic |
| 4  | 70              | 15                | 10                | 100          | 4.67            | Unrealistic |
| 5  | 70              | 17                | 8                 | 100          | 5               | Realistic |

On the Table 4 row 1, on the input variable, some certain values are added orderly such as direct cost value = 17%, indirect cost value = 6%, informal cost value = 2% and progress value = 25%, then on the output variable was obtained profit value = 6.6%. Which means that with the progress value = 25% the contractor in the qualified position to get the first term. At the same time obtaining profit / profit = 6.16% is relatively high and unrealistic due to the long work journey and the informal cash cost is relatively small, so that the contractor can enjoy it or be prepared for further work costs. Profit is relatively easy to obtain, because construction work is not yet complex, informal costs are small and costs are borne by the DP or if there is a delay in DP payments, the contractor can use a letter of work order (LWO) to guarantee a short-term loan with low interest [1]

On the Table 4 row 2, on the input variable, some certain values are added orderly such as direct cost = 37%, indirect cost = 10%, informal value = 3% and progress value = 50%, then the output variable is obtained the profit = 5%. Which means with the progress value = 50% of the contractor are in the qualified position to get the term II (second), while the contractor gains profit = 5%. This simulation is more realistic that the contractor gets profit = 5% which is the maximum profit that must be achieved as their target progress = 50%. If the contractor able to reach progress as target (50%, 75% and 100%) and get a profit of 5%, and the maintenance period plus retention payment is 5%, the contractor will get a maximum profit of 10% according to empirical data, namely maximum profit = 10%. Such realistic and ideal conditions according to [3] are called better progress.

On the Table 4 row 3, on the input variable, some certain values are added orderly such as direct cost value = 60%, indirect cost = 15%, informal value cost = 5% and progress value = 75%, then the output variable obtained profit value = 5.75 %. This simulation, according to the comments of some
respondents, is unrealistic, because in the progress position 75% of the informal cost expenditure = 5% is too small, and not according to the facts in the field. The results of the study, in the progress position 75% informal cost of minimum expenditure 7% [1].

On the Table 4 row 4, on the input variable, some certain values are added orderly such as direct cost value = 70%, indirect cost = 15%, informal value = 10% and progress value = 100%, then the output variable obtained profit value = 4.67%. This simulation contrasts with table 4 line 3 above, that is the informal cost expenditure is increased by 10%, so that the profit gain decreases by = 4, 67% <5%, namely the maximum profit that must be sought and maintained by the contractor, especially on the final target of 100% progress, if they want get maximum profit. This less ideal allocation of PCF according to [26] is called indicates a negative cash flow.

On the Table 4 row 5, on the input variable, some certain values are added orderly such as direct cost = 70%, indirect cost = 17%, informal value = 8% and progress value = 100%, so the output obtained profit value = 5%. This simulation is in the same principle as table 4 row 2: the implementation of the work according to the target of progress = 100%, the contractor earns a profit of = 5% and the maintenance period is added plus retention payments = 5%. Total profit contractor becomes = 10% is the maximum profit [3].

The cash out value in table 4 line 2 and table 4 row 5 are just a simulation example so that the contractor's progress position is in accordance with the ideal progress, so that the contractor can get term payment and the amount of profit in ideal conditions. There is still the possibility of allocating variations in cash out without changing the purpose of the simulation, so that it will be controlled all time, and avoiding the contractor for experiencing a loss for no irregularities [10, 14].

4. Conclusion
The conclusion of this study can be stated that: 1) Fuzzy Mamdani set model for profit optimization has 2 functions, those are: 1) input function and 2) output function. Input function consists of 4 variables: (1) Direct cost with linguistic set (min-max) and universe of discourse (7-75%), (2) Indirect cost with linguistic set (min-max) and universe of discourse (2-25%), (3) Informal cost with linguistic set (min-max) and universe of discourse (1-15%) and (4) Progress with linguistic set (slow-fast) and universe of discourse (0-100%). Output function is only one variable, that is Profit with linguistic set (min-max) and universe of discourse (0-10%), 2) The manual way of Fuzzy Mamdani logic application for profit optimization consists of 4 stages: (1) Making fuzzy set 4 input variables (Direct cost, Indirect cost, Informal cost and Informal cost) and 1 output variable (Profit), (2) Creating Application Function Implications based on 2 rules (rules), (3) Making Composition of All Output variables with MAX and (4) operations Defuzzification uses the centroid of profit area method 3) Computation method for profit optimization with Mamdani MATLAB R2017b fuzzy software with indicators, (1) Trapezoid membership function, (2) Linguistic set (min-max) and (slow-fast), (3) MISO implication function (4 input variables; direct cost, indirect cost, informal cost, progress and 1 output variable, namely profit), (4) "MAX - DOT" and (5) operating systems. Fuzzy rule (if ... and ... then) consists of 16 rules, 4) The level of validation by manual method by computation method resulted the same that is profit = 4, 46 (valid) so that it can be used for simulation, and 5) Simulation results will be obtained by minimum profit if in allocating cash out and the progress of the input variable are not balanced and vice versa, it will be obtained maximum profit if the allocation of cash out and progress in the input variable are balanced.

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