# FUZZY TECHNIQUE APPLICATION IN PRODUCTION PLANNING AT PT. XYZ

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***ABSTRACT***

*Decision making is the important matter which often faced to a plant manager. With some alternatifs available, the manager should be able to create priority scale to which alternatif should be taken according to company development concept. PT. XYZ is also experiencing this matter as a small to medium industry which produces soybean ketchup. To deal with the competition, company should have a production planning to survive in a competition. Production planning that will be done is according to two alternatives: Production Capacity Planning and Revise the Facility Layout. And to decide which plan would be taken, this paper uses Non-Numeric Expert Multi-Criteria Decision Making approach. Asking for two experts judgment from this company, and one expert is a senior lecturer at Industrial Engineering Department of Bina Nusantara University. To execute the alternatives, production capacity planning will use the fuzzy linear programming, and to revise the facility layout is using fuzzy facility layout. Software LINDO is use to find the optimal solution from the usual linear programming and the fuzzy linear programming. While the fuzzy set is use to solve the fuzzy facility layout problem. Trapezoidal fuzzy number (TrFN) is used for expressing the membership function of fuzzyfication process, and geometric mean is used for defuzzyfication process. Fuzzy value ($\chi$) gained from LINDO is 0,89. According to the result of Fuzzy facility layout, there are two alternatives of facility layout; first is to move the facility without adding with total cost Rp.919.590,- and second is to move and add the facilities with total cost Rp.1.033.631,-. For further research, it's possible to design a warehouse to separate the soyabean warehouse with supporting goods.*

*Key words: Fuzzy facility layout problem, Fuzzy linear programming.*

## 1. INTRODUCTION

### 1.1. Background

Capacity production planning is one of the problems that need to be solving by PT.XYZ. From the PPIC (Production Planning and Inventory Control) annual report, it shows production capacity planned is greater than the actual production capacity. There are a lot of contributing factor; one of it is there is no demand prediction therefore the company didn't know how many basic material and product needed accurately. And if there is a rising in demand, often the company is not prepare with the right amount of employee, or if they have to work over time, how long is the over time, there fore the company often does the production capacity planning which is not irrelevant with market demands. There fore the market demands couldn't be utilized as maximum as it could be.

The efficient factory placement planning is tightly connected with production planning. This company has a big area to produce its product (3052 square meter). This company is inefficient. They didn't use its area to its fullest capacity. For example the area that should have been use as a label stockroom, is misused as empty/dirty bottle storage. These empty bottles are stored here because the original empty/dirty bottle storage is full and couldn't hold any more empty bottles.

### 1.2 Purpose

1. Deciding important production planning alternatives to be suggest (prioritize) based on Non Numeric ME MCDM

2. To give production planning suggestions based on alternative chosen with fuzzy applications:
   a. Suggesting Facility placement improvement.
   b. Suggesting planning production capacity.

### 1.3 Problem Formula

The problem that has successfully formulated from production planning activity for PT.XYZ is:

1. The company is unable to meet consumer's demand, which means that the company tends to hardly achieve product capacity planning that has been planned.
2. Facility placement in this company is inefficient; this factor contributes a lot in product planning.

### 1.4 Outcome and Usefulness

1. The outcome expected from the research is: Production Capacity Planning, therefore the company will be wiser in production planning which is tightly connected with working hours and production target.
2. To give suggestions on Facility Placement Improvement, therefore the company will work well with material removal, which will be more efficient and the condition of the company will be cleaner and more work friendly. Therefore will increases working speed of the operator so the targeted production will be achieved.

## 2. RESEARCH METHOD

### 2.1 Thinking Framework

The first thingking flow is to decide the priority of action production planning which use Non Numeric ME.MCDM approach.

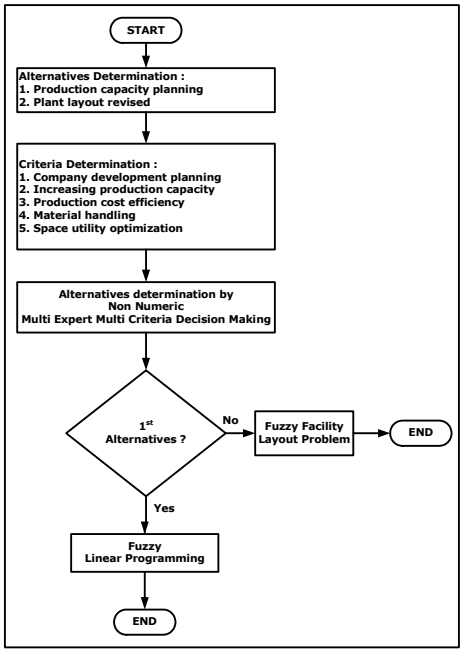


*Figure 1. Thinking Framework*

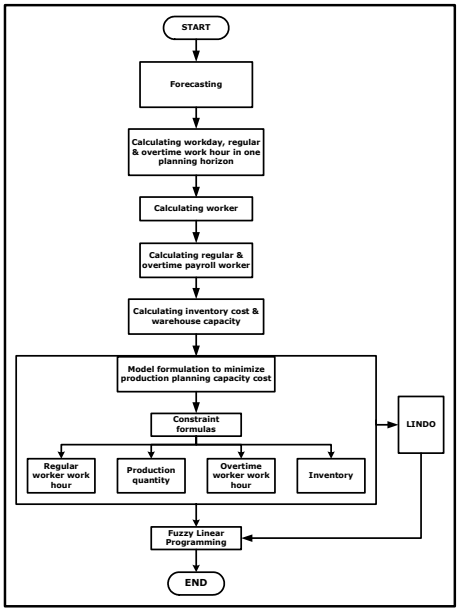


*Figure 2. Fuzzy Linear Programming*

### 2.2 Operational Plsnning Analysis

Demand data collected is for the period January 2002 until December 2003.

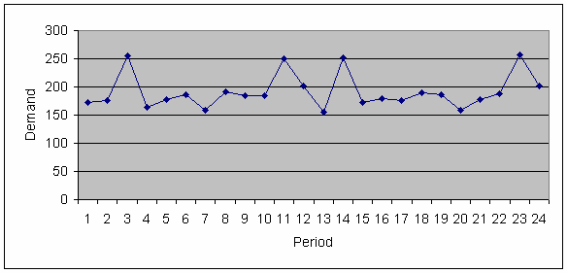


*Figure 3 Data Period January 2002 – Dedember 2003*

## 2.3 Product Data

PT.XYZ owns 3 products which they produce everyday. The first product from this company is soy sauce. Additional product is chilly sauce and shrimp crackers. Soy sauce as the main product has 5 taste; sweet, regular sweet, sweet satay, barbecue, and original taste.

Soy sauce and the chilly sauce produce is packaged in five different packages that is suited with the demand. Which are;

1. 150 ml Plastic Bottle
2. 300 ml Plastic Bottle
3. 625 ml Plastic Bottle
4. 5 kg jar
5. 20 kg jar

The basic ingredient is black soy, from information collected the soy is collected from IPB, Solo and Jember University.
Additional ingredients are collected from local distributor. Additional ingredients include: palm sugar, salt, benzoate natrium, vinegar, MSG, lemon grass, laos, bay leaves, lemon leaves, garlic, adas and cinnamon stick.

According to the interview, It is known that selling price for soy sauce with the size of 625 ml is Rp.8.975,-. Therefore if its sell in one packaging box is Rp.107.700,-

Employment data collected for the PPIC sector and direct observation in the factory.

*Table 1. Employment Data*

| Fasilitas | Jumlah |
|---|---|
| Soy warehouse | 4 |
| Fermentation | 7 |
| Fermentation area | 4 |
| Dirty bottle storage | 2 |
| Washing bottle area | 14 |
| Label storage | 1 |
| Extraction tank | 7 |
| Cooking tank | 2 |
| Filling area | 20 |
| Transite warehouse | 2 |
| Warehouse (product) | 2 |

Take home pay=manday x longest day in one planning horizone
= Rp.22.000,-/day x 27 day
= Rp.594.000/month

$$\text{Upah Tenaga Kerja Reguler} = \frac{\text{Rp.594.000,-/bulan}}{\text{196 jam/bulan}} \text{ x 63 tenaga kerja}$$
$$= \text{Rp.190.928,-/jam - tenaga kerja}$$

Regular Cost = Rp.190.928/hour-worker
Overtime Cost = Rp.286.392/hour-worker

Supply cost that has been established is as big as 25% from product selling price, which is Rp.2.243,75,-/box/month or if rounded up Rp.2.244,-/box/month

Soy sauce product that is packaged in bottles is repackaged into a 32x24x30cm box. This is the same with the other *bongsang* packages with the same size. Each packaging cannot be stacked more than 8 stacks. Production Storage Capacity is 7192 boxes.

Due to the small storage room, it is only able to hold over production not more than 8%.

## 2.4 Data Procesing

After data is successfully collected, the overall data processing can be done based on the thinking scale that has been planned before.

There are two alternatives
- Alternative1 = Production capacity planning
- Alternative2 = Facility placement improvement

There are 5 criterias
- Criteria 1 = Factory development planning
- Criteria 2 = Increasing production capacity
- Criteria 3 = Production cost efficiency
- Criteria 4 = Material handling
- Criteria 5 = Area optimize used

There are 5 marking scale
- VI = Very Important
- I = Important
- A = Average
- NI = Not Important
- VNI = Very ot Important

Non Numerik ME-MCDM counting result is as follow:

| Bobot Nilai | A | I | VI |
|---|---|---|---|
| Negasi Bobot Kriteria | VNI | NI | VNI | A | NI |
| Hasil Agregasi Kriteria | Alt 1 | NI | NI | A |
| | Alt 2 | I | I | I |
| Hasil Agregasi Pakar | Alt 1 | A |
| | Alt 2 | I |

*Figure 4. Non Numeric ME-MCDM Result*

**Priority I: Facility Placement Improvement**

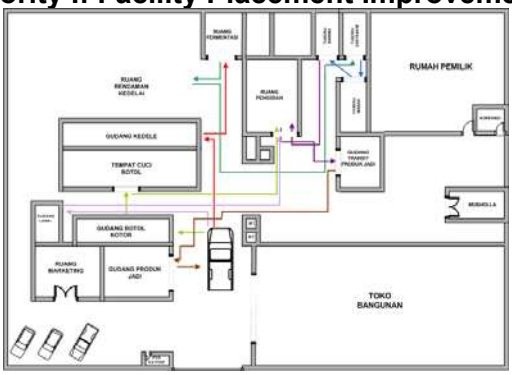


*Figure 5. Facility placement at the moment*.

The material handling cost that has to be used according to the PT.XYZ placement facility at the moment is Rp.1.966.500,-

To make a placement facility, the approaches used is fuzzy-ing and defuzzy-ing. Fuzzy-ing stage using *Trapezoidal Fuzzy Number* (TrFN). And for the defuzzy-ing stage in order to achieve the single mark (*crips*) with geometry average.

*Table 2. Trapezoidal Fuzzy Number*

| Linguistic Scale | TrFN |
|---|---|
| VI | (1, 1, 5,5 , 10) |
| I | (8, 11,67 , 15,34 , 19) |
| A | (17, 21, 25, 29) |
| NI | (27, 30,67 , 34,34 , 38) |
| VNI | (36, 39,67 , 43,34 , 47) |

There are two alternatives that are going to be proposed in this research:

1. Facility arrangement by moving it, but without adding any of it. For this alternative, the total cost of the *material handling* is Rp. 919.509,-

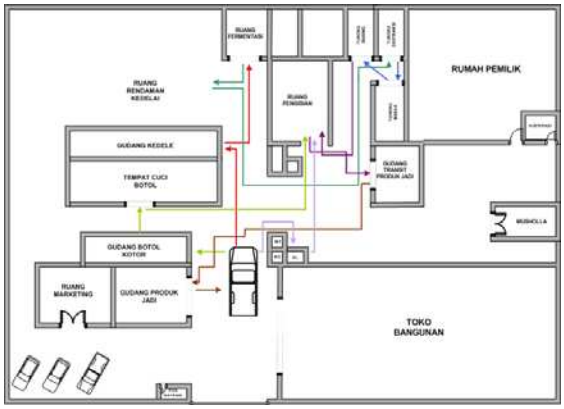


*Figure 6. TLF Alternative I Proposal*

2. Facility arrangement by adding or moving the location of the facilities inside the factory.. These locations are :
   - **Label Factory**. The label factory is much related to the *Receiving area* and the filling up room. It is so not efficient to put the label factory on the corner of the whole factory because it is not related to the other facilities around it. The label factory itself should be around (2,5 x 2,5) m. If we move the label factory, the new distance between the label factory and the filling up room is only 8 meter, compare to the distance before which is 38,1 m.
   - **Soy Washing Room**. For now, the fermentation room is in the same room as the soy washing room. It would be a good idea to add some screen between them so the operator can work more comfortably. Because it confuses the operator at some times to work two different things in the same room. Of course it would add some amount on the material handling cost.
   - **Clean Bottle Warehouse**. For now, bottles that are already cleaned were put on the side of the filling up room and there is no exact location for it. The suggestion for it is to add a warehouse near the filling up room for those clean bottles to be put. It will organize the production process and the operator can work more comfortably.
   - **Used Bottle Warehouse**. As seen so far, the used bottle warehouse does not manage to retain anymore used bottle that are waiting to be washed. In this case, there are a lot of used dirty bottle outside the factory itself. It is very uncomforting for the work of the operator.

Since the label factory are going to be moved, there is a space to expand the used bottle warehouse so it can be larger than it used to.

Based on the total facility cost plus the allocation of the new facility, the total cost of the *material handling* is Rp.1.033.631,-

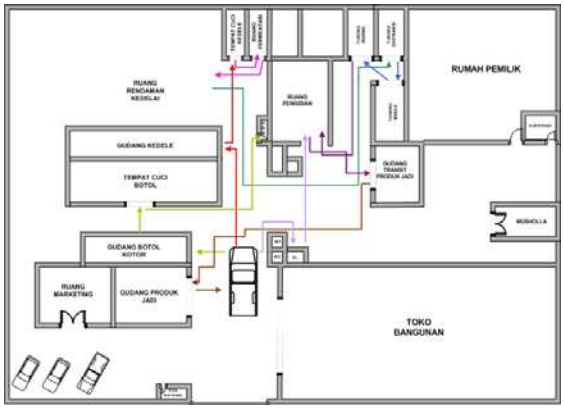


*Figure 7. Facility Layout Second Alternatives Proposal*

The difference between these two alternatives are only Rp.114.122,-. But if we see from the readiness between these two alternatives, maybe the owner would rather choose alternative one than the alternative two.

**Priority II : Production Capacity Planning Forecasting**

To forecast the demand for the soy sauce, it can be done with 4 different *forecasting* methods in a quantitative way. The result from these four different methods can be seen on the attachment.

The methods that are going to be used to calculate the future forecast for Januari 2004 to Desember 2004 period are:

1. *Double Moving Average* method Every four months
2. *Double Exponential Smoothing* 1 method Parameter from Brown
3. *Double Exponential Smoothing* 2 method Parameter from Holt
4. *Triple Exponential Smoothing* 1 method Parameter from Winter.

## 2.5 Production Capacity Planning Formula

From collecting data, therefore processing data is necessary to do in order to carry out production capacity planning.

The formula will be done with stating the minimal cost for capacity production planning as a purpose function. With problems as follow:

Jumlah produksi

1. Production total
2. Total regular working hours
3. Total over time working hours
4. Ingeredient supply

Purpose Function: (Bedworth, 1987)

$$\text{Minimize } Z = \sum_{t=1}^{T} A_{p,t}P_t + A_{r,t}R_t + A_{o,t}O_t + A_{i,t}I_t$$

$P_t$ = Jumlah produksi yang terjadwal pada periode t
$A_{p,t}$ = Biaya produksi perunit di luar biaya tenaga kerja pada periode t
$R_t$ = Jam kerja untuk produksi waktu regular pada periode t
$A_{r,t}$ = Biaya tenaga kerja pada waktu regular pada periode t
$O_t$ = Jam kerja untuk produksi lembur pada periode t
$A_{o,t}$ = Biaya tenaga kerja pada waktu lembur pada periode t
$I_t$ = Persediaan pada akhir periode t
$I_{t-1}$ = Persediaan pada periode sebelum t
$A_{i,t}$ = Biaya persediaan perunit pada periode t
$T$ = Planning horizon
$F_t$ = Hasil peramalan/prakiraan (*forecasting*)
$k$ = Faktor konfensi
$U_t$ = Waktu menganggur
$h_t$ = Jumlah hari kerja pada periode t
$J_t$ = Total jam kerja pada periode t

Therefore purpose function of minimize Z :

$$\text{Minimize } Z = \sum_{t=1}^{T} A_{p,t}P_t + A_{r,t}R_t + A_{o,t}O_t + A_{i,t}I_t \quad \ldots 1)$$

$$= \sum_{t=1}^{T} 83.916P_t + 190.928R_t + 95.464O_t + 2.244I_t$$

1. Production quantity constraint :

$I_t - S_t = I_{t-1} - S_{t-1} + P_t - F_t$
$I_t - I_{t-1} - P_t + F_t = 0$
$F_t = P_t + I_{t-1} - I_t$
or :
$P_t + I_{t-1} - I_t = F_t$ …2)

Therefore :

$P_1 + I_{1-1} - I_1 = 207.458$
$P_2 + I_{2-1} - I_2 = 210.442$
$P_3 + I_{3-1} - I_3 = 212.427$
$P_4 + I_{4-1} - I_4 = 214.411$
$P_5 + I_{5-1} - I_5 = 216.395$
$P_6 + I_{6-1} - I_6 = 218.379$
$P_7 + I_{7-1} - I_7 = 220.363$
$P_8 + I_{8-1} - I_8 = 222.347$
$P_9 + I_{9-1} - I_9 = 224.332$

$P_{10} + I_{10-1} – I_{10} = 226.316$
$P_{11} + I_{11-1} – I_{11} = 228.300$
$P_{12} + I_{12-1} – I_{12} = 230.284$

2. Regular work hour capacity constraint :
$R_t + U_t = J_t$ …3)

Therefore :
$R_1 + U_1 = 4375$
$R_2 + U_2 = 4128$
$R_3 + U_3 = 5292$
$R_4 + U_4 = 4500$
$R_5 + U_5 = 4400$
$R_6 + U_6 = 4500$
$R_7 + U_7 = 4941$
$R_8 + U_8 = 4500$
$R_9 + U_9 = 4888$
$R_{10} + U_{10} = 4758$
$R_{11} + U_{11} = 1428$
$R_{12} + U_{12} = 4775$

3. Regular work hour utility constraint :
$O_t – U_t = kP_t – R_t$
$O_t – U_t = k(F_t – I_{t-1} + I_t) – R_t$
$O_t – U_t = kF_t – kI_{t-1} + kI_t - R_t$

Therefore :
$O_t – U_t + R_t + kI_{t-1} – kI_t = kF_t$ …4)

Therefore :
$O_1 – U_1 + R_1 + 0.3I_{1-1} – 0.3I_1 = 62537$
$O_2 – U_2 + R_2 + 0.3I_{2-1} – 0.3I_2 = 63133$
$O_3 – U_3 + R_3 + 0.3I_{3-1} – 0.3I_3 = 63728$
$O_4 – U_4 + R_4 + 0.3I_{4-1} – 0.3I_4 = 64323$
$O_5 – U_5 + R_5 + 0.3I_{5-1} – 0.3I_5 = 64918$
$O_6 – U_6 + R_6 + 0.3I_{6-1} – 0.3I_6 = 65514$
$O_7 – U_7 + R_7 + 0.3I_{7-1} – 0.3I_7 = 66109$
$O_8 – U_8 + R_8 + 0.3I_{8-1} – 0.3I_8 = 66704$
$O_9 – U_9 + R_9 + 0.3I_{9-1} – 0.3I_9 = 67299$
$O_{10} – U_{10} + R_{10} + 0.3I_{10-1} – 0.3I_{10} = 67895$
$O_{11} – U_{11} + R_{11} + 0.3I_{11-1} – 0.3I_{11} = 68490$
$O_{12} – U_{12} + R_{12} + 0.3I_{12-1} – 0.3I_{12} = 69085$

4. Overtime work hour constraint :

$kO_t – kU_t + kI_{t-1} – kI_t \leq kF_t$ ….5)

Therefore :
$0.0046O_1 – 0.0046U_1 + 0.0014I_{1-1} – 0.0014I_1 \leq 286$
$0.0043O_2 – 0.0043U_2 + 0.0013I_{2-1} – 0.0013I_2 \leq 270$
$0.0033O_3 – 0.0033U_3 + 0.0010I_{3-1} – 0.0010I_3 \leq 210$
$0.0039O_4 – 0.0039U_4 + 0.0012I_{4-1} – 0.0012I_4 \leq 251$
$0.0051O_5 – 0.0051U_5 + 0.0015I_{5-1} – 0.0015I_5 \leq 333$
$0.0039O_6 – 0.0039U_6 + 0.0012I_{6-1} – 0.0012I_6 \leq 256$
$0.0045O_7 – 0.0045U_7 + 0.0014I_{7-1} – 0.0014I_7 \leq 300$
$0.0039O_8 – 0.0039U_8 + 0.0012I_{8-1} – 0.0012I_8 \leq 260$
$0.0036O_9 – 0.0036U_9 + 0.0011I_{9-1} – 0.0011I_9 \leq 241$
$0.0047O_{10} – 0.0047U_{10} + 0.0014I_{10-1} – 0.0014I_{10} \leq 320$
$0.0061O_{11} – 0.0061U_{11} + 0.0018I_{11-1} – 0.0018I_{11} \leq 416$
$0.0027O_{12} – 0.0027U_{12} + 0.0008I_{12-1} – 0.0008I_{12} \leq 185$

5. Product safety stock quantity constraint :
$I_t \geq 0.08F_t$ ....6)

Therefore :
$I_1 \geq 16.677$
$I_2 \geq 16.835$
$I_3 \geq 16.994$
$I_4 \geq 17.153$
$I_5 \geq 17.312$
$I_6 \geq 17.470$
$I_7 \geq 17.629$
$I_8 \geq 17.788$
$I_9 \geq 17.947$
$I_{10} \geq 18.105$
$I_{11} \geq 18.264$
$I_{12} \geq 18.423$

**Fuzzy Linear Programming Formulation**

According to data processing that has been done in LINDO, it is acknowledge some factors which will be explained below:

1. From the first LINDO output it was achieved Z minimum score of 318.469.900.000
2. To settle a new problem for the second LINDO input therefore it is needed to decide, the decidingproduction total which is a crucial thing in the fuzzy linear program discussion.
   - *Right Hand Side* first problem is changed to become a difference between forecast result with forecast result with maximum capacity which is able to be achieved by PT.XYZ, which is 250.000 units.

- *Right Hand Side* first problem starting from January until December 2004 is process with the same procedures as above.
- Put this new problem with erasing the previous first problem.
- To do the execution in LINDO to achieve minimal score of Z.
- Minimal score of Z is 189.896.600.000

3. To achieve *fuzzy linear programming*, second processing is needed. It is achieve by:
   - Decide output score I as big as 318.469.900.000 as maximum level
   - Decide output score II as 189.896.600 as minimum level.
   - To search maximum and minimum leve, as bis as 128.600.300.000
   - To make a new purpose function, which is:
     Maksimasi Z = $\chi$ ….7)
   - New problem as followed :
     128600300000$\chi$ + 83916P1 + 83916P2 + 83916P3 + 83916P4 + 83916P5 + 83914P6 + 83914P7 + 83941P8 + 83914P9 + 83914P10 + 83914P11 + 83914P12 + 190928R1 + 190928R2 + 190928R3 + 190928R4 + 190928R5 + 190928R6 + 190928R7 + 190928R8 + 190928R9 + 190928R10 + 190928R11 + 190928R12 + 95464O1 + 95464O2 + 95464O3 + 95464O4 + 95464O5 + 95464O6 + 95464O7 + 95464O8 + 95464O9 + 95464O10 + 95464O11 + 95464O12 + 2244I1 + 2244I2 + 2244I3 + 2244I4 + 2244I5 + 2244I6 + 2244I7 + 2244I8 + 2244I9 + 2244I10 + 2244I11 + 2244I12 <= 318496900000 …8)
   - With execution from LINDO software maximum Z obtained is 0.8947933

## 3. RESULT AND DISCUSSION

### 3.1 FACILITY PLACEMENT SUGGESTION

According to operational planning essay it is shown that the receiving area to the soy storage area is 11.7 meter, mean while according to professionals it is acknowledge that the correlation between both is very important, where the biggest scale is wo meter, it means fixing both facility is needed. With maximum distance of 10 meter.

Based on the calculation, there is a correlation between facility with the criteria of NI, so it does not need to be fixed because the relation between them is not important.

Based from analysis above, the correlations that need to be checked are:

*Table 3. Facilities that need to be fied*

| Facility | | Distance | Scale Distance |
|---|---|---|---|
| From | To | | |
| Rec. area | Soy warehouse | 11.7 | (1, 1, 5.5, 10) |
| Rec. area | Label storage | 21.7 | (8, 11.67, 15.34, 19) |
| Soy warehouse | Fermentation area | 13.1 | (1, 1, 5.5, 10) |
| Soy fermentation area | Extraction area | 46.5 | (1, 1, 5.5, 10) |
| Washing bottle area | Filling area | 17.7 | (1, 1, 5.5, 10) |
| Label storage | Filling area | 38.1 | (1, 1, 5.5, 10) |
| Transite warehouse | Warehouse (product) | 24.7 | (1, 1, 5.5, 10) |

To solve the problems from the table above, the arrangement of these facilities has to be fixed. The operation of this arrangement was done in the last chapter.

When doing the material handling cost, the cost from the NI dan VNI criteria is not to be timed with the range factor because there is no material flow happening between these facilities on the factory. So there is no relation between them.

**Product Capacity Planning Suggestions**

Based on the manufacturing data done on the last chapter, the purpose of the *fuzzy* solution is:

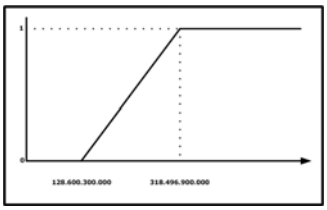


*Figure 8. Purpose of Fuzzy Linear Programming*

As the result, the *fuzzy* solution gives us the value of $\chi$ :

Value $\chi$ = 0,8947933 ≅ 0,89

With the value of 0,89 it means that the maximum revenue that can be reached is around Rp.318.469.900.000,-. So the production planning from January to December 2004 is :

*Table 4. Total Production*

| Period | Production | Period | Production |
|---|---|---|---|
| Jan | 59.219 | July | 64.736 |
| Feb | 73.070 | Aug | 63.070 |
| March | 71.402 | Sept | 61.403 |
| April | 69.736 | Oct | 59.736 |
| May | 68.070 | Nov | 58.069 |
| June | 66.403 | Dec | 56.403 |

## 4. CONCLUSION

1. The priority factors based on expert opinion are determined by *Non Numeric* ME-MCDM.
2. Two alternatives that are offered to solve the priority factors are the *fuzzy linear programming to* solve the production capacity planning, and the *fuzzy facility layout* to solve the arrangement of the factory places.
3. The first priority with the value of I is to do the production planning while fixing the arrangement and the location of the facility. Then the second priority with the value of A is to do the production planning itself. The production planning from fixing the facility gives the factory owner two alternatives, which are:
   a. Alternative I : Move the facility and not adding them more with the cost of Rp.919.509,-
   b. Alternative II : Move the facility and add some more with the cost of Rp.1.033.631,-
4. The value x that we get from the production capacity planning using the *fuzzy linear programming* is 0.89.

Suggestion

1. This factory has to fixed their used bottle and soy soaking stove arrangement because it is disturbing the work of their operator.
2. This factory soaking place.
3. The next step is to add a warehouse that can keep the main material and separate them from the secondary material warehouse.
4. The next step is to compare needs to add some toilet in the field next to the soy the *total cost* value that we got from the *fuzzy* and *Genetic Algorithm* solution.

## 5. REFERENCES

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