PURCHASE ORDER SELECTION MODEL AT CV. ROOESMAN INDONESIA USING ANALYTIC NETWORK PROCESS

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ABSTRACT

The research in this paper was done in CV. Rooesman, a small scale shoes and bag manufacturer company located in Yogyakarta Indonesia. Their strategy to response the demand is *make-to-order*. This company receives many purchase orders from several countries such as Japan, South Korea, and USA. Each purchase order is unique for example in term of design, complexity of the production process and raw material needed. Currently CV. Rooesman has difficulty to select which purchase order should be accepted. Ideally, all purchase orders from the customers have to be accepted. However due to the some factors such as limitation of resources that the company have i.e. human resources (number of workers and skill of workers needed) and other factor such as characteristic of the purchase order the company have to select which purchase order should be accepted. It happened in the past that the company accepted the purchase order without considering those factors then the order was not be able to deliver on time and the quality of the products did not meet the expectation of the customer. As a result, the company paid the penalty and the products were rejected by the customer. The research in this paper therefore tries to model purchase order selection problem using Analytic Network Process. There are four clusters considered in the model which are: Characteristic of the Purchase Order (Design of the Product, Quantity Order, Characteristic of the Customer, and Expected Quality), Complexity of the Production Process (Number of Workers Needed, Ability to Make the Prototype, Manufacturing Lead Time, Skill of the Worker), Economical Value (Production Cost, Selling Price and Price of Raw Material), and Alternative Purchase Order (Purchase Order 1, Purchase Order 2, Purchase Order 3).

Keywords: Make-To-Order Manufacturer, Purchase Order Selection Model, Analytic Network Process

1. Introduction

CV. Rooesman is one of the small scale shoes and bag manufacturer made from leather located in Manding Village, Yogyakarta. Recently, the company employs 25 workers. The products are exported overseas and the strategy to response their customer is *make-to-order*. Usually, CV. Rooesman receives purchase orders from several countries such as Japan, South Korea and USA. In the past, they tended to accept all of the consumer orders without considering their ability to fulfill the order such as the number of workers needed. When the company accepted the orders without considering the output capacity of the workers, it happened that the capacity was not sufficient for fulfilling the consumer orders. Then, in order to do so, they hired temporarily workers which tend to produce lower quality products than the products of regular workers. As a result, the products were rejected as the quality did not meet the specification. In addition, usually the rate of output of the temporarily worker is slower than that of the regular workers. Therefore, it happened that the company had to pay the penalty as they were not able to meet the order on

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time. To prevent all those things will happen in the future, as a small scale industry CV. Rooesman that has some limitation in term of such as human resources and financial resources, therefore they need to decide which order has the highest possibility of having successfully fulfilled, in the sense that consumers orders can be delivered on time with the quality that meet the specification so that it can give the maximum profit to the company. The purchase order selection model is then needed by the company.

According to the result from the interview and discussion process that was done with the owner of CV. Rooesman, it was known that in order to decide which purchase orders should be selected they consider several criteria. Those criteria are Characteristic of the Order (Design of the Product, Quantity Order, Characteristic of the Customer, and Expected Quality), Complexity of the Production Process (Number of Workers Needed, Ability to Make the Prototype, Manufacturing Lead Time, Required Skill of the Worker), Economical Value (Production Cost, Selling Price and Price of Raw Material). In addition, there are dependencies among criteria for example: the skill of worker affects the ability to make prototype.

Problem on determining which purchase orders should be accepted by industry have been investigated by many researchers in the past. The common criterias used for determining which order should be accepted are maximizing profit (Rom and Slotnick, 2009; Martinez and Arredondo, 2010; Huang et al., 2011; Mestry et al., 2011), maximizing revenue (Arredondo and Martinez, 2010; Oğuz et al., 2010; Cesaret et al., 2012; Wang et al., 2013), and minimizing late delivery (Wester et al., 1992). The techniques proposed for solving the order acceptance problem in past including integer programming (Huang et al., 2011), mixed integer linear programming solved by various approach such as branch and price algorithm (Mestry et al., 2011) and heuristic algorithm (Oğuz et al., 2010), intelligent decision rule (Martinez and Arredondo, 2010; Arredondo and Martinez, 2010), and modern meta heuristics such as genetic algorithm (Rom and Slotnick, 2009), tabu search (Cesaret et al., 2012), and modified artificial bee colony algorithm (Wang et al., 2013). It is noted that majority of the proposed order acceptance approach in the past used only single criteria for the optimization problem.

In this paper, a purchase order selection model is constructed especially for CV. Rooesman using Analytic Network Process in order for the company to decide the order they have to accept.

2. ANP Methodology

As there are many decision problem that cannot be structured hierarchically i.e., there exist dependencies among criteria (Saaty, 1996), therefore the AHP no longer can be used. A method called Analytic Network Process (ANP) is then used for the decision problem that involves dependencies among criteria. There are five steps of ANP as it is explained below:

Step 1: Formulating decision network.
In this step the problem is formulated in to the network structure. The structure can be constructed either by formal method or informal method such as discussion group with the decision maker. The purpose of this step is that to understand the nature of the problem so that the researchers and the decision maker might able to identify the criteria that influence the decision problem and the dependencies among criteria. The more understand the researcher and the decision maker about the problem, the more valid the decision network formulation will be.

Step 2: Building the structure of supermatrix.
Supermatrix is a stochastic matrix in which its elements are also matrices (Saaty, 1996). The value of the matrix represents the priorities from the paired comparisons appear in the appropriate column of the supermatrix. Each matrix represents the dependency between clusters (outer dependency) and or

dependency among element within one cluster (inner dependency). The matrix will be valued 0 if there are no dependencies among clusters and elements within one cluster. The 0 value means that there is no need to do the pairwise comparison in the associated matrix (Saaty, 2009). The structure of the supermatrix is presented in the following Figure 1.

$$W = \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1N} \\ W_{21} & W_{22} & \cdots & W_{2N} \\ \vdots & \vdots & \cdots & \vdots \\ W_{N1} & W_{N2} & \cdots & W_{NN} \end{bmatrix}, \qquad W_{ij} = \begin{bmatrix} w_{i1}^{(j1)} & w_{i1}^{(j2)} & \cdots & w_{i1}^{(jn_j)} \\ w_{i2}^{(j1)} & w_{i2}^{(j2)} & \cdots & w_{i2}^{(jn_j)} \\ \vdots & \vdots & \cdots & \vdots \\ w_{in_i}^{(j1)} & w_{in_i}^{(j2)} & \cdots & w_{in_i}^{(jn_j)} \end{bmatrix}$$

Figure 1. The Supermatrix of a Network (*W*) and Detail of Matrix in it (W_{ij})

Step 3: Obtaining cluster weight matrix.
This step is done to measure relative importance of one cluster to another cluster. The pairwise comparison is done in this step. Once the pairwise comparison is finished then the value is normalized and synthesized to find relative priority for each cluster. The approach to find the relative priority is the same as AHP approach and can be found detail in Saaty (2009). This relative priority is the basis to form the Cluster Weight Matrix.

Step 4: Obtaining Unweighted Matrix
In this step pairwise comparison is conducted to measure relative importance among node and its controlling clusters or relative importance of nodes to another within a cluster. With similar step as it was mentioned in Step 3 above, the relative priority are found then those values will be the basis to form the Unweighted Matrix.

Step 5: Obtaining Weight Matrix and Limit Matrix
In this step the unweighted matrix is multiply by cluster weight matrix to get weight matrix. Then Limit matrix is obtained by raising this matrix to powers until the value in the weight matrix has converged.

Step 6: Synthesis
In this step, the limit matrix is converted into raw values, which are represented the priority of each alternative order, then, the raw values are normalized to get the normal values. After that, the normal values are idealized to get the ideal values.

3. Purchase Order Selection Model

As it was mentioned in the previous section, the research in this paper was done in CV. Rooesman, a small scale shoes and bag manufacturer company located in Yogyakarta that are facing a problem in deciding whether a purchase order from consumer should be accepted or not. As according to the result from the discussion between the researchers and the owner of CV. Rooesman it is known that there are several criteria that affect the decision of the company whether they have to accept the purchase order or not and there are dependencies between clusters and also between elements within a cluster, therefore in the research in this paper purchase order selection problem in CV. Rooesman is modeled using ANP methodology then is solved by using Super Decisions Software with the following steps.

Step 1: Formulating decision network
In this research, network formulation was done by using an informal method where the researchers and the owner of CV. Rooesman discussed about the criteria that affect the decision of selecting purchase order. In addition, during the discussion the dependencies among criteria were investigated. Based on the

result from interview and discussion process with the owner of CV. Rooesman, it was found that there are several criteria that affect the decision whether the company should accept or reject purchase order from consumer. As it was in the previous section, those criteria are Characteristic of the Order (Design of the Product, Quantity Order, Characteristic of the Customer, and Expected Quality), Complexity of the Production Process (Number of Workers Needed, Ability to Make the Prototype, Manufacturing Lead Time, Required skill of the Worker), Economical Value (Production Cost, Selling Price and Price of Raw Material). And in addition, there are dependencies among criteria for example: the skill of worker affects the ability to make prototype. The criteria are then classified into clusters and elements as it is shown in Table 1.

Table 1. Cluster and Element

Clusters	Elements
Characteristics of the Order (CO)	Design of the Product (DP)
	Quantity Order (QO)
	Characteristic of the Consumer (CC)
	Expected Quality (EQ)
Complexity of the Process (CP)	Number of workers needed (NW)
	The ability to make prototype (AP)
	Manufacturing Lead Time (MLT)
	Required Skill of the Worker (SW)
Economical Consideration (EC)	Production Cost (PC)
	Selling Price (SP)
	Raw Material Price (RWP)
Alternative Order (AO)	Purchase Order 1
	Purchase Order 2
	Purchase Order 3

It is noted that Purchase Order 1 is the purchase order from the consumer from Japan, Purchase Order 2 is the purchase order from South Korea and the Purchase Order 3 is the purchase order from USA. Each purchase order has its own characteristics from example: Purchase Order 1 require the simple design with high quality standard and intolerable to nonconforming product. They will reject the whole lot, if they find that the product that does not meet specification. However, this consumer is also willing to pay the product with the highest price, so the margin profit of CV. Rooesman if this purchase order is accepted is the highest among that of two other purchase orders. Purchase Order 3 usually require more complicated design, however they more tolerable to nonconforming product, in the sense that if this consumer find a nonconforming product, then they will only return back that nonconforming product and ask for replacement. In addition, usually the quantity order for each Purchase Order is also different. There exists consumer whose quantity order is usually larger than that of other consumer.

Once the criteria are observed then the structure of the decision problem is constructed by observing the inner dependencies and outer dependencies, and the decision network is presented in Figure 2. Based on Figure 2 it can be seen that there are inner and outer dependencies such as Design of the Product (DP) affects the Skill of Worker Needed (SW) and Quantity Order (QO) affects the Number of Worker Needed (NW).

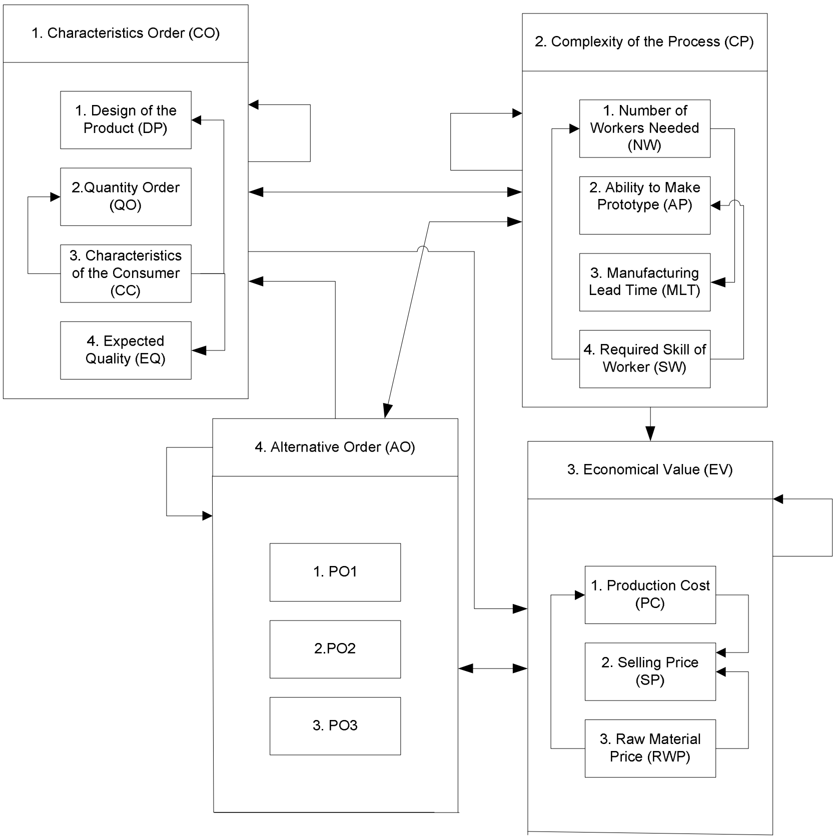

Figure 2. Structure of the decision problem

Step 2: Formulation of Supermatrix

Based on structure of the problem presented in Figure 2, then the structure of supermatrix can be formulated as it is shown in Figure 3.

$$W = \begin{bmatrix} w_{11} & w_{12} & 0 & w_{14} \\ w_{21} & w_{22} & 0 & w_{24} \\ w_{31} & w_{32} & w_{33} & w_{34} \\ 0 & w_{42} & w_{43} & 0 \end{bmatrix}$$

Figure 3. Structure of the Supermatrix

Step 3: Obtaining Cluster Weight Matrix

Cluster Weight Matrix can be obtained by doing cluster comparisons then its value is normalized and synthesized to get relative priority of each cluster. For example with respect to Cluster Characteristics of Order (CO), then the pairwise comparison is done as it is shown in Figure 4. The question was asked to the decision maker is for example "how strong is the importance of this Characteristic of Order (CO) compare to the criteria Complexity of the Process (CP)".

CO	9	8	7	6	5	4	3	2	1	**2**	3	4	5	6	7	8	9	CP
CO	9	8	7	6	5	**4**	3	2	1	2	3	4	5	6	7	8	9	EV
CP	9	8	7	6	**5**	4	3	2	1	2	3	4	5	6	7	8	9	EV

Figure 4. Cluster Pairwise Comparison with Respect to Cluster Characteristic of Order (CO)

Once the pairwise comparison is done then the value is normalized and synthesized to get relative priority of each cluster and the value is put in Cluster Weight Matrix as it is shown in Table 2.

Table 2. Cluster Weight Matrix

Cluster Node Labels	CO	CP	EV	AO
CO	0.3331	0.3637	0.0000	0.3196
CP	0.5695	0.4281	0.0000	0.5584
EV	0.0974	0.1019	0.5000	0.1220
AO	0.0000	0.1063	0.5000	0.0000

Step 4: Obtaining Unweighted Matrix
Unweighted matrix can be obtained by put the relative priority based on the pairwise comparison between elements that have dependencies each other. The result of the Unweighted Matrix is shown in Table 3.

Table 3. Unweighted Matrix

Cluster		CO				CP				EV			AO		
Node Labels		DP	QO	CC	EQ	NW	AP	MLT	SW	PC	RWP	SP	PO1	PO2	PO3
CO	DP	0	0	0.6250	0	0	1	0	0	0	0	0	0.3125	0.4948	0.2776
	QO	0	0	0.1365	0	0	0	0	0	0	0	0	0.0625	0.3333	0.1776
	CC	0	0	0	0	0	0	0	0	0	0	0	0.3125	0.0890	0.3916
	EQ	0	0	0.2385	0	0	0	0	1	0	0	0	0.3125	0.0829	0.1532
CP	NW	0	0.8333	0	0	0	0	0	0	0	0	0	0.1305	0.1276	0.1516
	AP	1	0	0	0	0	0	0	0.8333	0	0	0	0.3011	0.3828	0.3598
	MLT	0	0.1667	0	0.1667	1	0	0	0.1667	0	0	0	0.2002	0.1421	0.0577
	SW	0	0	0	0.8333	0	0	0	0	0	0	0	0.3682	0.3475	0.4309
EV	PC	0	1	0	0	1	0	1	0	0	0.8333	0	0.1571	0.3643	0.4664
	RWP	0	0	0.8333	0.8333	0	0	0	0	0	0	0	0.5936	0.5368	0.4331
	SP	0	0	0.1667	0.1667	0	0	0	0	1	0.1667	0	0.2493	0.0989	0.1005
AO	PO1	0	0	0	0	0	0.6666	0	0	0	0	0.7500	0	0	0
	PO2	0	0	0	0	0	0.1667	0	0	0	0	0.1250	0	0	0
	Po3	0	0	0	0	0	0.1667	0	0	0	0	0.1250	0	0	0

Step 5: Obtaining Weight Matrix and Limit Matrix
In this step the unweighted matrix is multiply by cluster weight matrix and normalized for each column to get weight matrix. Then, Limit Matrix is obtained by raising the matrix to powers until the value in the weight matrix has converged. The Limit Matrix is shown at Table 4.

Step 6: Synthesis
There are 3 steps in the Synthesis part which are:
Step a. Take the all of values from Limit Matrix (see Table 4) in the Alternative Order (AO) part, in which those values represent the priority of each alternative order. In this case there are 3 values for each purchase order which are PO1 (0.0946), PO2 (0.0196), and PO3 (0.0196). These values are then put in the Raw column as it is shown in Table 5. Raw column is a column matrix with its size is *mx1,* where *m* is the number of alternatives.

Tabel 4. Limit Matrix

Cluster		CO				CP				EV			AO		
Node Labels		DP	QO	CC	EQ	NW	AP	MLT	SW	PC	RWP	SP	PO1	PO2	PO3
CO	DP	0.2579	0.2579	0.2579	0.2579	0.2579	0.2579	0.2579	0.2579	0.2579	0.2579	0.2579	0.2579	0.2579	0.2579
	QO	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064	0.0064
	CC	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250
	EQ	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388
CP	NW	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145	0.0145
	AP	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069	0.3069
	MLT	0.0359	0.0359	0.0359	0.0359	0.0359	0.0359	0.0359	0.0359	0.0359	0.0359	0.0359	0.0359	0.0359	0.0359
	SW	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556	0.0556
EV	PC	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570	0.0570
	RWP	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162	0.0162
	SP	0.0645	0.0645	0.0645	0.0645	0.0645	0.0645	0.0645	0.0645	0.0645	0.0645	0.0645	0.0645	0.0645	0.0645
AO	PO1	0.0946	0.0946	0.0946	0.0946	0.0946	0.0946	0.0946	0.0946	0.0946	0.0946	0.0946	0.0946	0.0946	0.0946
	PO2	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196
	PO3	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196

Table 5. Synthesis

Alternative Order	Ideals	Normalized	Raw
PO1	1.0000	0.7070	0.0946
PO2	0.2072	0.1465	0.0196
PO3	0.2072	0.1465	0.0196
∑		1.0000	0.1338

Step b. Normalization

In this step all of values in the Raw column (see table 5) are summed up, then each value in each row is divided by the sum of the Raw column, for example: the normalized value of PO1 is came from 0.0946 (the Raw value for PO1) divided by 0.1338 (sum of the Raw column).

Step c. Idealization

In this step, each normalized value is divided by the biggest normalized value. In table 5, the ideal value for PO2 is 0.1465/0.70707 = 0.2072 since the biggest normalized value is 0.7070. Based on the synthesis, it is found that the ideals values for order from PO1, PO2, and PO3 are 1.0000, 0.2072, and 0.2072, respectively. This result is visualized in Figure 5.

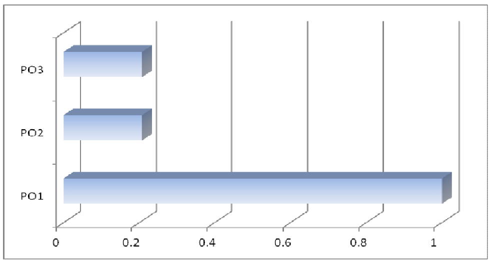

Figure 5. Purchase Order Acceptance Preference

4. Conclusion

The purchase order selection model using ANP for helping CV. Rooesman to select which Purchase Order should be accepted or not is proposed in this paper. It is consists of four clusters which are Characteristics of the Order (CO), Complexity of the Process (CP), Economical Value (EV), and Alternative Order (AO). The structure of the decision problem is presented in the Figure 2, and its corresponding structure of the supermatrix is presented in the Figure 3. Based on the synthesis, it is found that the ideals values for order from PO1, PO2, and PO3 are 1.0000, 0.2072, and 0.2072, respectively. This result shows that the preference to accept Purchase Order 1 from Japan is stronger than to accept Purchase Order 2 and 3.

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