EQUIPMENT CRITICALITY CLASSIFICATION MODEL BASED ON AHP

Kadarsah Suryadi
Heri Setyanta
Industrial Management Research Group
Department of Industrial Engineering – Bandung Institute of Technology
Jl. Ganesa 10 Bandung, Tel./fax:62-22-2508141-Indonesia
kadarsah@bdg.centrin.net.id
heri_setyanta@yahoo.co.id

Abstract: *The objective of this research is to develop equipment classification model based on multi criteria approach and feedback loop mechanism. Model which is developed based on hybrid criteria, representing combination between serial criteria and parallel criteria. Serial criteria consist of "government regulation" and "public services", while parallel criteria consist of "safety", "production", "reliability", "spare availability", "frequency of failure", and "applicability of condition monitoring technique". Then both models are used to assess equipment criticality rating (ECR) by using real data of 125 equipments in a company. The results of ECR assessment are classified into four classes, those are: ECR1, ECR2, ECR3, and ECR4. It supports decision maker especially in prioritizing equipment monitoring when the number equipments are enormous. So, the decision maker could give more attention to equipment which are included in ECR1 class, those are equipment which has the highest criticality rating.*

Keywords: multi criteria, equipment classification, AHP, hybrid criteria, ECR, decision model.

1. Introduction

In equipment monitoring, company is facing many equipments in number and variation. Thus equipment classification is needed to ensure objectivity in equipment monitoring for maintenance process. Equipment monitoring needs rational and clear classification.

Nowadays, it has been developed a number of model for monitoring, such as model for material procurement by considering *safety stock*, inventory cost and material order cost aspect (Suryadi and Salim, 2003). The weakness of this model are: discussion is more focused on material level not equipment level, using for inventory management purpose, indicator assessment mechanism mostly based on perception, and can not be used to priority which equipment to monitoring, because this model used to monitoring is equipments support material.

Then data classification problem by using mathematical programming has been researched by Zhang *et al.*(2007). The weakness of this research is used for classification of data into two groups only, those are good and bad. This model using method that has not been discussed data classification more than two groups. Thereby, development of approach of multi criteria which can accommodate the alternative in a lot of number is needed.

Previously, Choi Et al. (2005) conducted research by using company data base and all expert opinion to prioritizing association rules by considering company business side based on data mining. The weakness from this research is data mining is difficult to detect the association or related inter criteria in a lot of number and not using feedback loop to accommodate of agree or disagree decision maker towards joint agreement. Thus it is needed to develop an approach by using feedback loop mechanism as a process to accommodate iterative consideration from all decision makers.

Research in classification problem using data mining has been conducted by Abascal *et al.* (2006). The weakness from this research is it used two criteria only. Thus it is needed to research about data mining using more than two criteria. Then Bohanec M. and Blaz Zupan (2002) in it research integrating between Decision Support (DS) with Data Mining (DM) by using decision model of Hierarchical Multi-Attribute to solve problem the data classification. Tools used are DEX and HINT. DEX is used to develop DS based on expert knowledge and HINT is used to develop DM based on data. The weakness from this research is indicator assessment mechanism more based on perception, so that it results less representative. Therefore indicator assessment based on fact is needed.

The propose of this research is to develop multi criteria approach by using feedback loop mechanism and criteria assessment based on fact by using decision table support to equipments classification in a company.

2. Model Development

2.1 Base Model

This research proposes a combination model of serial and parallel which aim to assess Equipment Criticality Rating or ECR. The principle which used is if equipments in condition do not function, how big affect that happened to company as a whole. Criteria which used in this model consist of serial criteria and parallel criteria. Serial criteria are criteria which it assessment based on yes or no answer.

If conditions from assumed criteria is fulfilled (yes answer), then assessed alternative to be assumed fulfilled condition to be selected. If conditions from criteria are assumed not fulfilled, then alternative assessed will be refused, and assessment to be continued at next criteria conducted serially after previous criteria is not fulfilled. Serial criteria consist of: government regulation and public services. While, parallel criteria are criteria which it assessment conducted concurrently with a number of other criteria and importance weight from each criteria. Decision towards alternative election conducted if all criteria have been assessed concurrently after considering value and importance weight from each criterion.

In this research, parallel criteria consist of: *safety, production, reliability, spare availability, frequency of failure,* and *applicability of condition monitoring technique*. The criteria is assessed one by one in serial and parallel, such as shown at Figure 1.

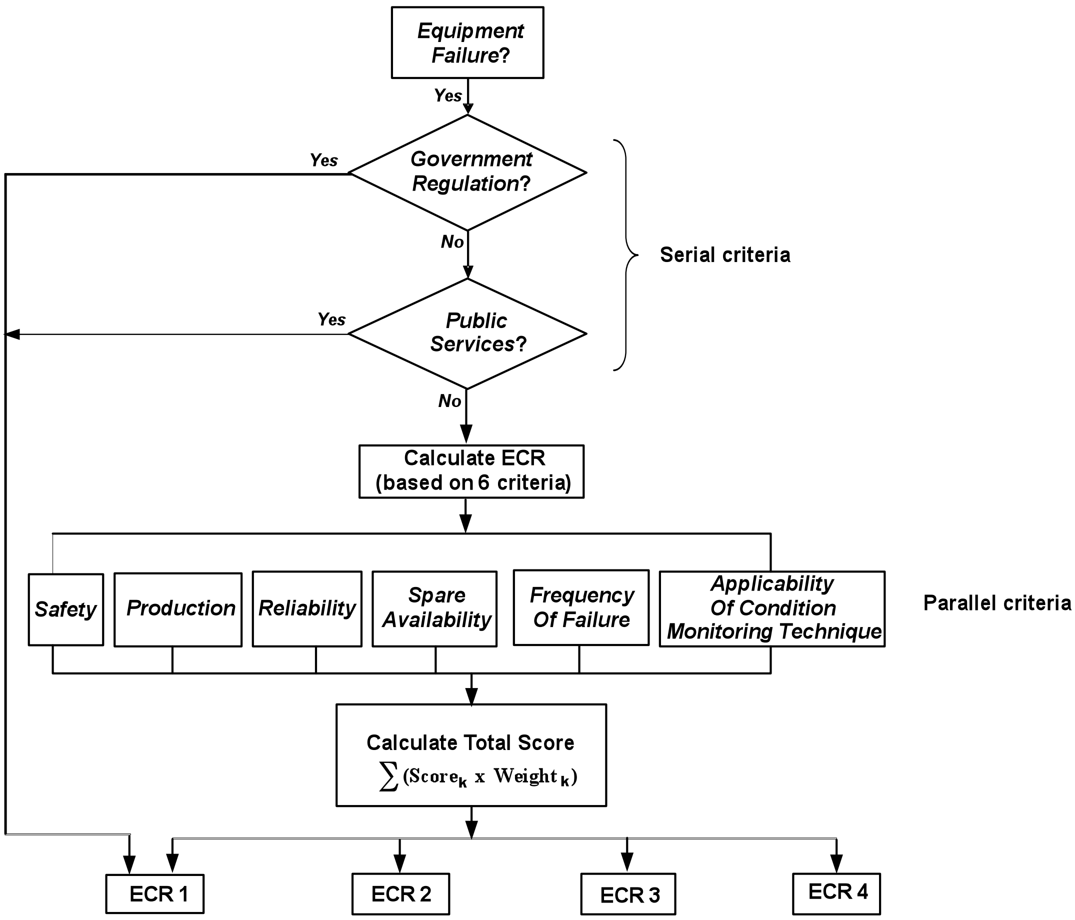

Figure 1. Combination Model of Serial and Parallel

Equipment criticality rating assessment process by using combination model of serial and parallel such as shown at Figure 1 can be explained with the following algorithm:

If (equipment_failure=yes) then
If (government_regulation=yes) then ECR1;
Else If (public_services=yes) then ECR1;
Else calculate_ECR_score_based_on_6_criteria;
If (75<=score<=100) *then* ECR1;
Else If (50<= score <75) *then* ECR2;
Else If (25<=score<50) *then* ECR3;
Else ECR4;

Equipment told to have ECR1 criticality rating, if in direct correlation to government regulation (see at Figure 1). But if first condition is not fulfilled, then equipments will be tested with the secondary criteria that are from public services side. If the equipments correlate to the public services, for example for water supply and waste handling, then that equipment also grouped in ECR1. Then if both criteria are not fulfilled, then equipment will be tested with parallel criteria consists of:

1. *Safety*
   In this case safety mean evaluated from its impact to worker safety if equipment damage happened. If equipment damage happened and affect to safety treatment, then used decision table approach such as shown at Table 1.

Table 1. Score of Safety

Condition Stub		**Condition Entry**				
If	There are not cidera or minor cidera	Yes				
	Temporary disability or is not permanent		Yes			
	A lot of accident causing lose of work time			Yes		
	A lot of cidera with permanent disability				Yes	
	Fatal cidera to some people					Yes
Then	Score = 20 (*Minor*)	X				
	Score = 40 (*Moderate*)		X			
	Score = 60 (*Severe*)			X		
	Score= 80 (*Major*)				X	
	Score = 100 (*Catastrophic*)					X
	Action Stub	**Action Entries**				

2. *Production* (Loss of production capability)
   Production looked from two cases, there are:
   a. When equipment damage has impact to production and measured impact, then used equation following:
      PF = [PL/SC] X 100……………………………...……………… ………………..(1)
      Where:
      - PF: Production Factor
      - PL: Production Loss
      - SC: Sustainable Capacity of equipment

   b. When equipment damage has impact to production and unmeasured impact, and then used decision table approach such as shown at Table 2.

Table 2. Rating of Production

Condition Stub		Condition Entry				
If	There is no loss production	Yes				
	Loss of 1 day production opportunity		Yes			
	Loss of 1 week production opportunity			Yes		
	Loss of 1 month production opportunity				Yes	
	Loss of more than 1 month production opportunity					Yes
Then	Score = 20 (*Minor*)	X				
	Score = 40 (*Moderate*)		X			
	Score = 60 (*Severe*)			X		
	Score = 80 (*Major*)				X	
	Score = 100 (*Catastrophic*)					X
	Action Stub	**Action Entries**				

3. *Reliability*

Excelsior unreliability score from an equipment, then equipment criticality rating is excelsior. To calculate unreliability score of equipment used equation as following:

$$\mathrm{RF} = \left[1 - \left[\frac{8760 - (\mathit{Unscheduled\ Down\ time} + \mathit{Scheduled\ Down\ time})}{8760 - \mathit{Scheduled\ Down\ time}}\right]\right] \mathrm{x}100 \quad \ldots\ldots\ldots\ldots(2)$$

Where:

- 8760 comes from calculation result 365 equipment working days multiply by 24 hours
- RF: Reliability Factor
- Unscheduled Down time: working equipment is stopped unscheduled
- Scheduled Down time: working equipment is stopped scheduled

4. *Spare Availability*

Spare availability is a comparison between standby equipment units compare to operating equipment. Standby unit is attached equipment that has not been operated yet when system runs normally. The equation that used for calculate spare availability score is as following:

SAF = [1 - (Standby Unit Capacity)/(Running Uni Capacity)] X 100 ....(3)

Where:

- SAF: Spare Availability Factor
- If SAF < 0, then score of SAF assumed 0

5. *Frequency of Failure*

If frequency of failure of equipment is excelsior, then criticality rating is excelsior too. Unit that used for this frequency of failure is sum of failure in the last 4 years. It purpose is to identify that beside its reliability rating, frequency of failure will be effect to production system as a whole too. The equation that used for calculate frequency of failure score is as following:

FoF = (frequency of failure / 4) X 100 ....(4)

Where:

- FoF: Frequency of Failure
- For example, if the last 4 years just 1 failure happend, then criticality score is 1/4.
- If FoF > 100, then score of FoF assumed 100, because maximum criticality value is 100

6. *Applicability of Condition Monitoring Technique*
   This is related to easiness or difficultness to reach equipment when maintenance will be conducted. There are two parameters are availability or unavailability monitoring facility and annoying or not annoying of operation when equipment check is done. Then to calculate score, decision table approach is used (such as shown at Table 3).

Table 3. Applicability of Condition Monitoring Technique

Condition Stub		Condition Entry								
If	There are no monitoring facility	Yes	Yes	Yes						
	Monitoring facility less complete				Yes	Yes	Yes			
	Monitoring facility is complete							Yes	Yes	Yes
	Annoying impact of operation is entire	Yes			Yes			Yes		
	Annoying impact some of operation		Yes			Yes			Yes	
	There are not annoying impact of operation			Yes			Yes			Yes
Then	Score = 0									X
	Score = 10						X		X	
	Score = 25			X		X		X		
	Score = 50		X		X					
	Score = 100	X								
	Action Stub	Action Entries								

2.2 Building of Hierarchy Structure of Combination Model of Serial and Parallel

By using chosen criteria, then a decision hierarchy structure which is consists from four hierarchy levels are arranged. The first level is goal that is equipment classification based on its criticality rating.

The second level is hybrid criteria consists of serial and parallel criteria. Serial criteria consists of government regulation and public services which Boolean characteristic or between yes and no, which meaning is if damage or failure an equipment is happened, while equipment related to government regulation or public services, then equipment will be directly become ECR1 (Figure 1). If not related to both serial criteria, then equipment is assessed based on parallel criteria. Parallel criteria consist of: *safety, production, reliability, spare availability, frequency of failure, and applicability of condition monitoring technique*.

Still in second level there are feedback loop which is used for accomodating decision maker agree or disagree towards criteria and weight that is resulted. So, at second level from this hierarchy there are two layers. The first layer is equipment filter by using serial criteria (government regulation and public services). The second layer by using weighting calculation by parallel criteria.

The third level is indicators from chosen criteria, there are: **safety criteria indicators**: *Toxic Reactive* (TR), *Flammable* (F), *Temperature* (T), dan *Pressure* (P); **production criteria indicators**: *Production Loss* (PL) and *Sustainable Capacity* (SC); **reliability criteria indicators:** *Unscheduled Down time* (US) and *Scheduled Down time* (S); **spare availability criteria indicators:** *Standby Unit* Capacity (SC) and *Running Unit Capacity* (RC); **frequency of faillure criteria indicator:** frequency of failure (FF); **applicability of condition monitoring technique criteria indicators:** Monitoring Facility (MF) and Operation Impact (OI). At third level there are feedback loop which is used for accomodating decision maker agree or disagree towards indicators value from chosen criteria. If decision maker disagree with results of criteria assessment and indicators, then reassessment process towards criteria and indicator related can be done. The fourth level is equipment that is assessed by this model. So, the complete hierarchy structure can be seen at Figure 2.

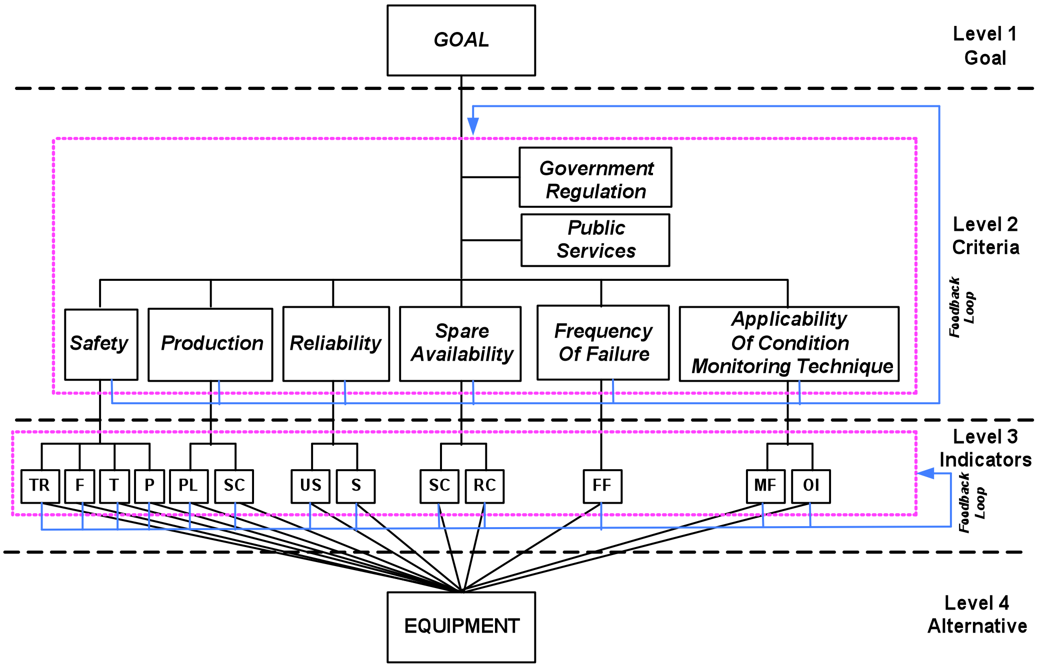

Figure 2. Hierarchy Structure of Combination Model of Serial and Parallel

Weight from each criteria is resulted from analytic hierarchy process or AHP method (Saaty, 1994). The result of criteria weighting by using AHP method are:

1. *Safety* = 35%
2. *Production* = 35%
3. *Reliability* = 10%
4. *Spare Availability* = 6%
5. *Frequency Of Failure* = 8%
6. *Applicability Of Condition Monitoring Technique* = 6%

After equipment is assessed based on parallel criteria (as shown at Figure 1), then to know equipment criticality rating value is used this equation:

$$\sum (\text{Score}_k \text{ x Weight}_k) \quad \ldots\ldots\ldots(5)$$

Where:

- Score_k = Criteria score k
- Weight_k = Criteria weight k

2.3 Equipment Criticality Rating Classification

After each of equipment is assess based on criteria and rule that has been explained before, then classification consists of 4 classes is conducted. To determine score value from each class is calculated by using Suryadi and Salim (2003) and Larose (2005) equation:

$$\text{End Value} = (\text{Model Value - Model Minimum Value}) \times \frac{100}{\text{Model Maximum Value} - \text{Model Minimum Value}} \quad \ldots\ldots\ldots(6)$$

Where:

- End value is score value each class will be founded
- 100 value is maximum scale value

From calculation result using 6th equation above, then limit from each class is resulted such as the following figure:

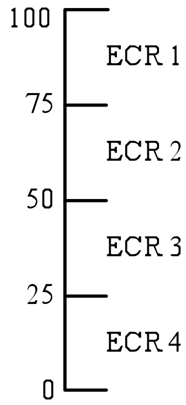

Figure 3. ECR Classification

Based on Figure 3 above, equipment criticality rating is classified become 4 classes which rule as follow:

1. ECR1, if score between 75 until 100.
   ECR1 is all equipment that used at production main process or critical facility where equipment damage can cause production termination or can cause catastrophic danger condition and maintenance with high cost is needed.
2. ECR 2, if score between 50 until <75.
   ECR 2 is all equipment or other facility that used at production process where equipment damage can cause production decline that can causing major to moderate danger and moderate maintenance cost is need.
3. ECR 3, if score between 25 until <50.
   ECR 3 is all supporting equipment that used for production process where equipment damage does not have any impact at production decline or production termination and can cause danger at level moderate and moderate maintenance cost is need.
4. ECR 4, if score <25.
   ECR 4 is all equipment taht used in production process where equipment damage have not impact to production, and only cause danger at level minor and low maintenance cost is needed.

3. Example of Numeric and Prototype Software

After model combination of serial and parallel is developed (such as Figure 1), then data collecting from equipment sample that used as testing towards model. That data is real data from a company. Testing for data equipment sample is conducted by serial and parallel.

3.1. Testing by using Serial Criteria

This testing is done by using serial criteria that are *government regulation* and *public services.*
Example:

- Equipment: Safety Valve
  This equipment based on government regulation must be done resertification each 3 years. It means that safety valve related on government regulation, so that equipment classified to vital equipment or ECR1.
- Equipment: Boiler
  The worst impact if this equipment has damage is explosion can be happen. And cause fire, so that environment arround campany or public services can be disturb. It means boiler related to public services criteria, so that equipment is classified to vital equipment or ECR1.

3.2. Testing by using Parallel criteria

This testing is conducted by using parallel criteria that are: *safety, production, reliability, spare availability, frequency of failure, and applicability of condition monitoring technique.* Then for calculate equipment criticality rating score is used equation and rules that has been explained at explanation part of base model. Calculation process equipment criticality rating is conducted by involving all managers and supervisors that known characteristic of each of equipment.

Example:

- *Safety* criteria

Table 4. Example of Calculation Based on *Safety* Criteria

Number	Equipment Name	*SAFETY*		
		Score	Weight	Score*Weight
1	Gas Operated Valve	100	35%	35
2	Pump	40	35%	14
3	Power Heater	40	35%	14
4	Switch	40	35%	14

From Table 4 could be seen that gas operated valve equipment has 100 score. This number is resulted according to Table 1; where this equipment has broken or failure to operate can cause fatal cidera towards some people (score=100). Meanwhile, equipments of pump, power heater, and switch have 40 score (see Table 4). This number according to Table 1; where if this equipment has broken or failure to operate can cause temporary disability or not permanent (score = 40). After that, 35% weight of production criteria is resulted from calculation by using AHP method. This following are calculation process equipment criticality score for *safety* criteria:

- Gas Operated Valve
  Where:
  - Score = 100
  - Weight = 35%

  So, equipment criticality score of gas operated valve for *safety* criteria is:
  Score x Weight = 100 x 35% = 35

- Pump
  Where:
  - Score = 40
  - Weight = 35%

  So, equipment criticality score of pump for *safety* criteria is:
  Score x Weight = 40 x 35% = 14

- Power Heater
  Where:
  - Score = 40
  - Weight = 35%

  So, equipment criticality score of power heater for *safety* criteria is:
  Score x Weight = 40 x 35% = 14

- Switch
  Where:
  - Score = 40
  - Weight = 35%

  So, equipment criticality score of switch for *safety* criteria is:
  Score x Weight = 40 x 35% = 14

- *Production* criteria

Table 5. Example of Calculation Based on *Production* Criteria

Number	Equipment Name	***PRODUCTION***				
		Production Loss	**Sustainable Capacity**	**Score**	**Weight**	**Score*Weight**
1	Gas Operated Valve	714	714	100	35%	35
2	Pump	714	714	100	35%	35
3	Power Heater	362.5	725	50	35%	17.5
4	Switch	0	714	0	35%	0

Data of production loss and sustainable capacity from gas operated valve, pump, power heater, and switch equipments are taken from history data in a company (such as shown at Table 5). Meanwhile, 35% weight of production criteria is resulted from calculation by using AHP method. This following are calculation process equipment criticality score for *production* criteria (see equation 1):

- Gas Operated Valve
  Where:
  - Production Loss (PL) = 714
  - Sustainable Capacity (SC) = 714

  And:
  PF = [PL/SC] x 100
  = [714/714] x 100
  = 100
  So, equipment criticality score of gas operated valve for *production* criteria is:
  Score x Weight = 100 x 35% = 35

- Pump
  Where:
  - Production Loss (PL) = 714
  - Sustainable Capacity (SC) = 714

  And:
  PF = [PL/SC] x 100
  = [714/714] x 100
  = 100
  So, equipment criticality score of pump for *production* criteria is:
  Score x Weight = 100 x 35% = 35

- Power Heater
  Where:
  - Production Loss (PL) = 362.5
  - Sustainable Capacity (SC) = 725

  And:
  PF = [PL/SC] x 100
  = [362.5/725] x 100
  = 50
  So, equipment criticality score of power heater for *production* criteria is:
  Score x Weight = 50 x 35% = 17.5

- Switch
  Where:
  - Production Loss (PL) = 0
  - Sustainable Capacity (SC) = 714

  And:
  PF = [PL/SC] x 100
  = [0/714] x 100

= 0

So, equipment criticality score of swich for *production* criteria is:

Score x Weight = 0 x 35% = 0

- *Reliability* criteria

Table 6. Example of Calculation Based on *Reliability* Criteria

Number	Equipment Name	RELIABILITY				
		Unscheduled Down Time	Scheduled Down Time	Score	Weight	Score*Weight
1	Gas Operated Valve	0	4	0	10%	0
2	Pump	6	16	0.07	10%	0.01
3	Power Heater	0	8	0	10%	0
4	Switch	0	2	0	10%	0

Data of unscheduled down time and scheduled down time from gas operated valve, pump, power heater, and switch equipments are taken from history data in a company (such as shown at Table 6). Meanwhile, 10% weight of *reliability* criteria is resulted from calculation by using AHP method. This following are calculation process equipment criticality score for *reliability* criteria (see equation 2):

- Gas Operated Valve

  Where:
  - Unscheduled Down Time = 0
  - Scheduled Down Time = 4

  And:

$$RF = \left[1 - \left[\frac{8760 - (Unscheduled\ Down\ time + Scheduled\ Down\ time)}{8760 - Scheduled\ Down\ time}\right]\right] x100$$

$$RF = \left[1 - \left[\frac{8760 - (0 + 4)}{8760 - 4}\right]\right] x\,100$$

RF = [1-1] x 100

= 0

So, equipment criticality score of gas operated valve for *reliability* criteria is:

Score x Weight = 0 x 10% = 0

- Pump

  Where:
  - Unscheduled Down Time = 6
  - Scheduled Down Time = 16

  And:

$$RF = \left[1 - \left[\frac{8760 - (Unscheduled\ Down\ time + Scheduled\ Down\ time)}{8760 - Scheduled\ Down\ time}\right]\right] x100$$

$$RF = \left[1 - \left[\frac{8760 - (6 + 16)}{8760 - 16}\right]\right] x\,100$$

RF = [1-0.9993] x 100

= 0.07

So, equipment criticality score of pump for *reliability* criteria is:

Score x Weight = 0.07 x 10% = 0.01

- Power Heater

  Where:
  - Unscheduled Down Time = 0
  - Scheduled Down Time = 8

And:

$$RF = \left[1 - \left[\frac{8760 - (Unscheduled\ Down\ time + Scheduled\ Down\ time)}{8760 - Scheduled\ Down\ time}\right]\right] x100$$

$$RF = \left[1 - \left[\frac{8760 - (0 + 8)}{8760 - 8}\right]\right] x\,100$$

RF = [1-1] x 100
= 0

So, equipment criticality score of power heater for *reliability* criteria is:
Score x Weight = 0 x 10% = 0

- Switch
  Where:
  - Unscheduled Down Time = 0
  - Scheduled Down Time = 2

  And:

$$RF = \left[1 - \left[\frac{8760 - (Unscheduled\ Down\ time + Scheduled\ Down\ time)}{8760 - Scheduled\ Down\ time}\right]\right] x100$$

$$RF = \left[1 - \left[\frac{8760 - (0 + 2)}{8760 - 2}\right]\right] x\,100$$

RF = [1-1] x 100
= 0

So, equipment criticality score of switch for *reliability* criteria is:
Score x Weight = 0 x 10% = 0

- *Spare Availability* criteria

Table 7. Example of Calculation Based on *Spare Availability* criteria

Number	Equipment Name	***SPARE AVAILABILITY***				
		Standby Unit Capacity	**Running Unit Capacity**	**Score**	**Weight**	**Score*Weight**
1	Gas Operated Valve	0	1	100	6%	6
2	Pump	1	1	0	6%	0
3	Power Heater	0	1	100	6%	6
4	Switch	0	1	100	6%	6

Data of standby unit capacity and running unit capacity from gas operated valve, pump, power heater, and switch equipments are taken from history data in a company (such as shown at Table 7). Meanwhile, 6% weight of *spare availability* criteria is resulted from calculation by using AHP method. This following are calculation process equipment criticality score for *spare availability* criteria (see equation 3):

- Gas Operated Valve
  Where:
  - Standby Unit Capacity = 0
  - Running Unit Capacity = 1

  And:

SAF = [1 - (Standby Unit Capacity)/(Running Unit Capacity)] x 100
= [1 - (0/1)] x 100
= 1 x 100
= 100

So, equipment criticality score of gas operated valve for *spare availability* criteria is:
Score x Weight = 100 x 6% = 6

- Pump

  Where:

  - Standby Unit Capacity = 1
  - Running Unit Capacity = 1

  And:

  SAF = [1 - (Standby Unit Capacity)/(Running Unit Capacity)] x 100
  = [1 - (1/1)] x 100
  = 0 x 100
  = 0

  So, equipment criticality score of pump for *spare availability* criteria is:

  Score x Weight = 0 x 6% = 0

- Power Heater

  Where:

  - Standby Unit Capacity = 0
  - Running Unit Capacity = 1

  And:

  SAF = [1 - (Standby Unit Capacity)/(Running Unit Capacity)] x 100
  = [1 - (0/1)] x 100
  = 1 x 100
  = 100

  So, equipment criticality score of power heater for *spare availability* criteria is:

  Score x Weight = 100 x 6% = 6

- Switch

  Where:

  - Standby Unit Capacity = 0
  - Running Unit Capacity = 1

  And:

  SAF = [1 - (Standby Unit Capacity)/(Running Unit Capacity)] x 100
  = [1 - (0/1)] x 100
  = 1 x 100
  = 100

  So, equipment criticality score of switch for *spare availability* criteria is:

  Score x Weight = 100 x 6% = 6

- *Frequency of Failure* criteria

Table 8. Example of Calculation Based on *Frequency of Failure* criteria

Number	**Equipment Name**	***FREQUENCY OF FAILURE***				
		Frequency	**Year**	**Score**	**Weight**	**Score*Weight**
1	Gas Operated Valve	0	4	0	8%	0
2	Pump	5	4	100	8%	8
3	Power Heater	4	4	100	8%	8
4	Switch	0	4	0	8%	0

Data of frequency of failure from gas operated valve, pump, power heater, and switch equipments are taken from history data in a company in the last 4 years (such as shown at Table 8). Meanwhile, 8% weight of *frequency of failure* criteria is resulted from calculation by using AHP method. This following are calculation process equipment criticality score for *frequency of failure* criteria (see equation 4):

- Gas Operated Valve
  Where:
    - Frequency of failure in the last 4 years = 0

  And:
  FoF = (Frequency of failure / 4) x 100
  = (0/4) x 100
  = 0
  So, equipment criticality score of gas operated valve for *frequency of failure* criteria is:
  Score x Weight = 0 x 8% = 0

- Pump
  Where:
    - Frequency of failure in the last 4 years = 5

  And:
  FoF = (Frequency of failure / 4) x 100
  = (5/4) x 100
  = 125
  Because FoF > 100, then FoF is assumed 100, because maximum criticality value is 100. So, equipment criticality score of pump for *frequency of failure* criteria is:
  Score x Weight = 100 x 8% = 8

- Power Heater
  Where:
    - Frequency of failure in the last 4 years = 4

  And:
  FoF = (Frequency of failure / 4) x 100
  = (4/4) x 100
  = 100
  So, equipment criticality score of power heater for *frequency of failure* criteria is:
  Score x Weight = 100 x 8% = 8

- Switch
  Where:
    - Frequency of failure in the last 4 years = 0

  And:
  FoF = (Frequency of failure / 4) x 100
  = (0/4) x 100
  = 0
  So, equipment criticality score of switch for *frequency of failure* criteria is:
  Score x Weight = 0 x 8% = 0

- *Applicability of Condition Monitoring Technique* criteria

Tabel 9. Example of Calculation Based on
Applicability of Condition Monitoring Technique Criteria

Number	Equipment Name	***APPLICABILITY OF CONDITION MONITORING TECHNIQUE***		
		Score	**Weight**	**Score*Weight**
1	Gas Operated Valve	25	6%	1.5
2	Pump	25	6%	1.5
3	Power Heater	25	6%	1.5
4	Switch	25	6%	1.5

From Table 9 could be seen that gas operated valve, pump, power heater, and switch equipment has 25 score. This number is resulted according to Table 3; where this equipment has broken or failure to operate can cause annoying of entire operation and that equipment has complete monitoring facility (score=25). After that, 6% weight of *applicability of condition monitoring technique* criteria is resulted from calculation by using AHP method. This following are calculation process equipment criticality score for *applicability of condition monitoring technique* criteria:

- Gas Operated Valve
  Where:
  - Score = 25
  - Weight = 6%

  So, equipment criticality score of gas operated valve for *applicability of condition monitoring technique* criteria is:
  Score x Weight = 25 X 6% = 1.5

- Pump
  Where:
  - Score = 25
  - Weight = 6%

  So, equipment criticality score of pump for *applicability of condition monitoring technique* criteria is:
  Score x Weight = 25 X 6% = 1.5

- Power Heater
  Where:
  - Score = 25
  - Weight = 6%

  So, equipment criticality score of power heater for *applicability of condition monitoring technique* criteria is:
  Score x Weight = 25 X 6% = 1.5

- Switch
  Where:
  - Score = 25
  - Weight = 6%

  So, equipment criticality score of switch for *applicability of condition monitoring technique* criteria is:
  Score x Weight = 25 X 6% = 1.5

Then calculation result of score multiply by weight based on six criteria above are summed to know equipment criticality rating. For example, total score of equipment criticality rating of gas operated valve = $\Sigma(\text{Skor}_k \text{ x } \text{Bobot}_k)$ = 35+35+0+6+0+1.5 = 77.5. Criticality value of fourth of equipments are shown at Table 10.

Table 10. Example of Equipment Criticality Classification Results

Number	Equipment Name	Total Score	Equipment Classification
1	Gas Operated Valve	77.5	ECR 1
2	Pump	58.51	ECR 2
3	Power Heater	47	ECR 3
4	Switch	21.5	ECR 4

3.3. Software Prototype

Data processing is done by previously develop this model in form of software prototype by using language of PHP program and Mysql which used to test at real data of 125 equipments. Example of data processing result based on serial criteria is shown at Figure 4, meanwhile the example of data processing result based on parallel criteria is shown at Figure 5. And then, data processing results as a whole are shown at pareto diagram (see Figure 6).

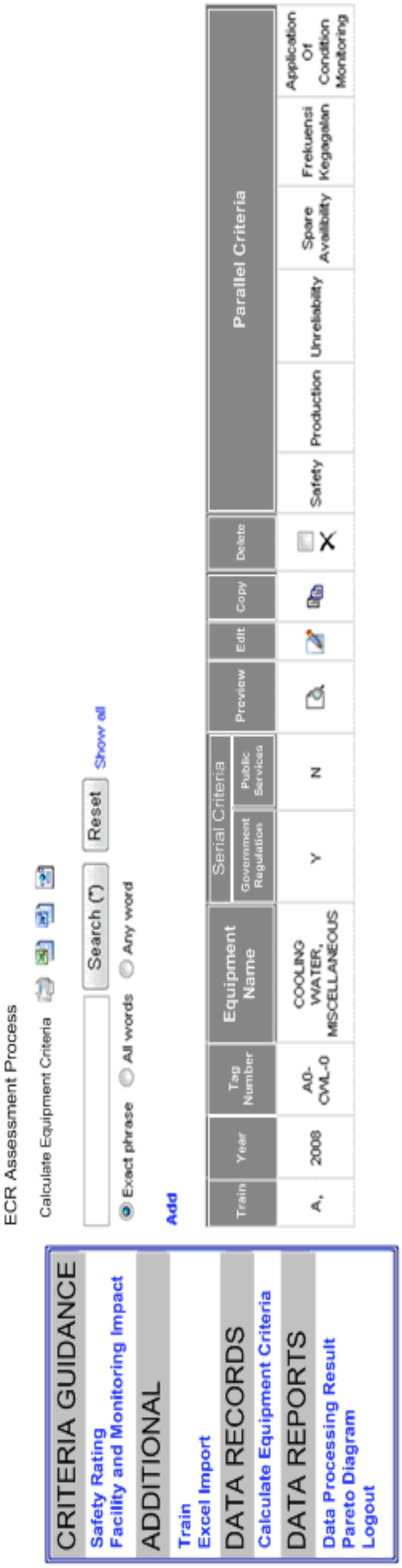

Figure 4. Example of ECR Assessment Process Form Based on Serial Criteria

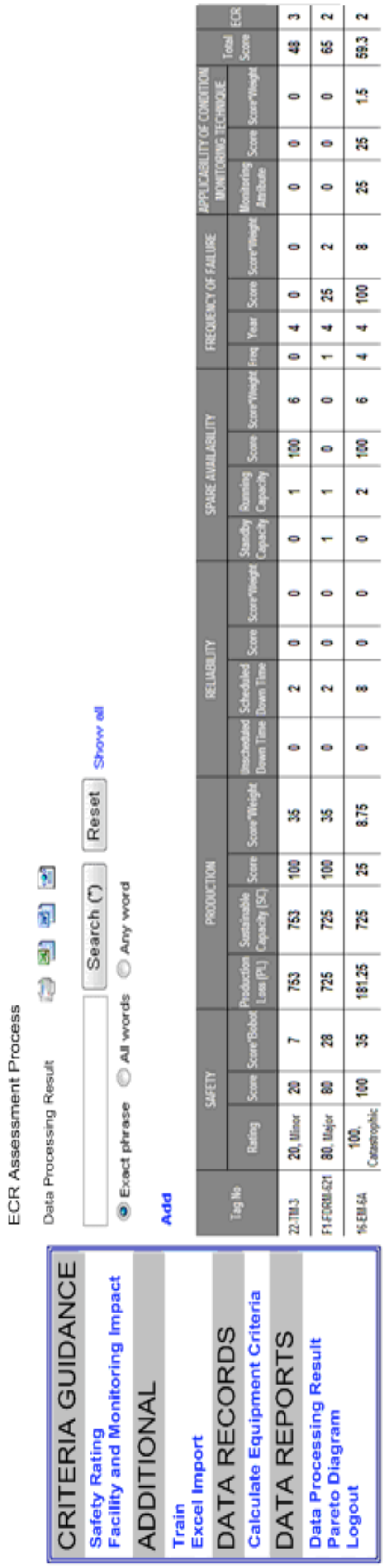

Figure 5. Example of ECR Assessment Process Form Based on Parallel Criteria

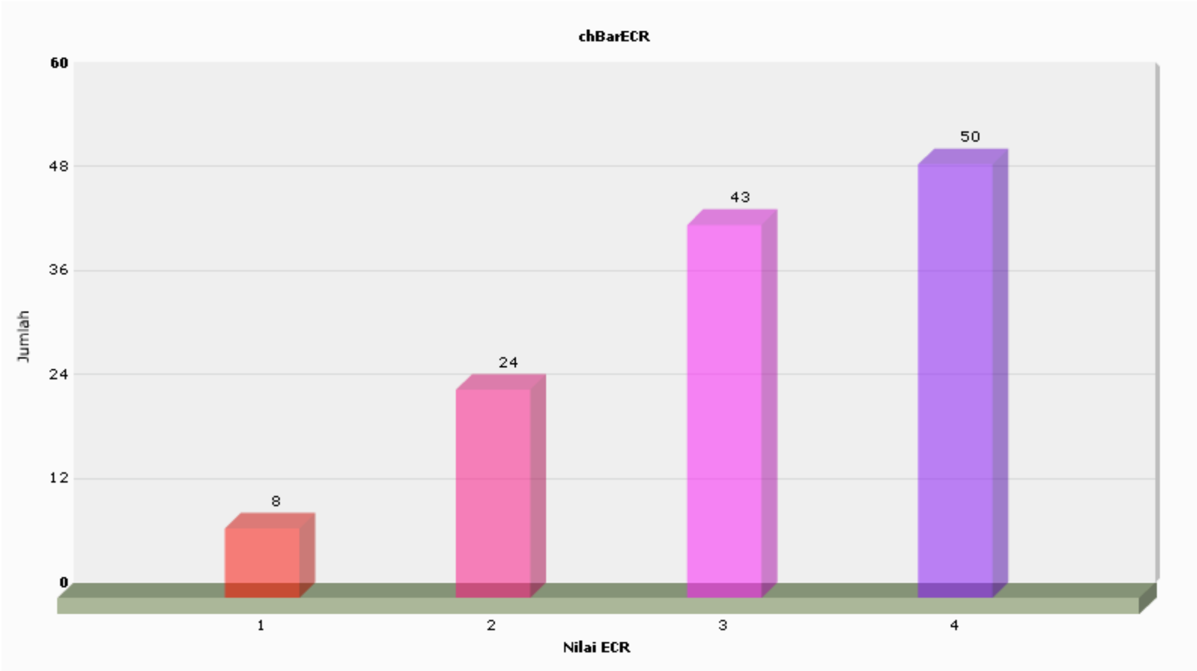

Figure 6. Pareto Diagram of Equipment Criticality Rating

4. Analysis

4.1 Criteria Weight Analysis

From weighting result by using AHP method is known that criteria of safety and production have the highest importance rating, with the weight value is equal to 35%. Then the next importance ratings are reliability (10%), frequency of failure (8%), and the lowest importance ratings are spare availability and applicability of condition monitoring technique with the weight are 6%.

4.2 Equipment Sample Analysis

In taking equipment sample, respondens that ask to doing assessment has understand how to assess equipment based on criteria and indicator that used in this model. Assessors or responden that asked are people that expert and understand to equipment will be assessed. So that, assessement hopefully has already reflect the true condition. Beside that, assessment process of equipment criticality rating is based on fact, not based on perception, so that equipment criticality rating reflect the true condition.

4.3 Data Processing Analysis

From data processing result towards 125 equipments (as seen in Figure 4 and 5), then could be known the percentage from each ECR, there are: ECR 1 (6.4%), ECR 2 (19.2%), ECR 3 (34.4%), and ECR 4 (40%). ECR 1 is categories emergency (first priority), it means the work must be done immedietly and continously. It means the equipment that be priorities to be done to maintenance less in a number, because ECR1 total less then ECR2, ECR3, or ECR 4. It is matched with pareto principle that equipment has high criticality rating have a less number then equipment that has low criticality rating.

5. Conclusion

The result of this research is an equipment classification model based on hybrid criteria by using feedback loop mechanism and criterion assessment based on fact by using support of decision table. This Feedback Loop is used to place the opinion of all decision makers when done assessment process of equipment criticality rating. It is as adjustment when there are different ideas among all decision makers. The results of data processing are showing that the decision table could be used as support for criteria assessment which has indicators in a lot of number.

This equipment classification model based on hybrid criteria will be able to assist all decision makers for prioritizing equipments to be done maintenance based on value of criticality rating.

Meanwhile, this research is needed furthermore development, there is software prototype is need to be realized in form of more complete software and accommodate online system which is connected to each company unit so that facilitate all party in conducting totality equipment criticality assessment. Beside that, equipment criticality determination model could be developed by using data mining principle and considering serial criteria and also parallel criteria.

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