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Development of Network DEA Model to Measure Risk in Production Line's Productivity: A Case Study of Automation and Labor Combination

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ABSTRACT--- ***Upgrade production line in the manufacturing industry needs huge investment to come out with good performance. Company can receive Return on Investment (ROI) and save more money from paying labor salary and increase productivity. However, company also may risk from losing the investment done. The main focus of this study is to investigate the risk faced by company after using automation on the production line when dealing with machines breakdown. We use Network DEA model to evaluate risk of the production line since Data Envelopment Analysis (DEA) is one of appropriate tool to evaluate the efficiency of productivity and widely been use in this sector. The automation usage without applying Overall Equipment Effectiveness (OEE) will compare to using human energy related to productivity of the production line. The production lines with a high capacity and long-term demand being selected as a sample of this study. The evaluation of the production line starts before and after the line change to semi-automation.***

Keywords-- Risk, Automation Breakdown, Network DEA

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1. INTRODUCTION

In manufacturing industry, to achieve good productivity depend on how well management and arrangement done the production line. Usually, problem occurs when use human energy as operator to produce a product. To come out with high quality and reach productivity daily is mostly unreachable when dealing with operator. Performance of operator cannot be count put company at risk of losing money day by day. However, quality loss in product from customer complaints and productivity can be measured to know the performance of the operator. This will lead management know one of the causes of any question appear on the production site. W. Kaydos [1] stated that, every responsible related to the operating unit specify as "good performance" in unmistakable terms. From the customer complaints, evaluation toward the needs of automation in the production line can be done. Installation of automation is one of good investment in bringing the productivity reach targeted output. The number of operators can reduced and bring the profit to the company and receive ROI. The high quality and maximum unit of product when use automationscan be reach with effective management of automations maintenance. One of the best methods for keeping the automation with the good performance and reduce the risk by using OEE. However, the installation of automation also can bring losses to the company without proper management. Company risk not achieve targeted output when automation breakdown.

2. DATA ENVELOPMENT ANALYSIS (DEA)

DEA is one of conventional tool that can evaluate performance of multi-sector in industry. This method purpose by Charnes et al. [2]perhaps delegate best technique of performance evaluation among others techniques appraise organization performance. According to Hsieh and Lin [3], decision making units (DMUs) with multiple input and output is homogenous set to measure the relative efficiency by using this linear programming technique. Lazano et al. [4], account the production process of a DMU as a black box in calculating efficiency by using conventional DEA approaches. However, appropriate analysis is done which deal different interconnected processes each one with its own exogenous inputs and final outputs and also with median product that procreate and consumed within the system.The DMU is most efficient if the efficiency obtains a score of one and is inefficient if the score is less than one. Therefore, for every DEA calculation, the objective is to maximize the value of the efficiency.

Assuming that there are n DMUs for the model, each with $m$inputs and s outputs, the relative efficiency score of a target DMU_o, $\theta_o$is obtained by solving the following model proposed by Charnes et al. [2].

$$Max\,\theta_o = \frac{u_1 y_{1o} + u_2 y_{2o} + \ldots + u_s y_{so}}{v_1 x_{1o} + v_2 x_{2o} + \ldots + v_m x_{mo}} = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \quad (1)$$

Subject to:

$$v_i \geq 0\ ,\ i = 1,2,\ldots,m$$

where:

y_{ro} : amount of output r used by DMU_o
x_{io} : amount of input i used by DMU_o
i : number of inputs used by the DMU
r : number of outputs generated by the DMU
u_r : weight assigned by DEA to output r
v_i : weight assigned by DEA to input i

DMU_0 is the target DMU and this calculation will be repeated by changing the target DMU.
The fractional program shown as (1) can be converted to a linear program as shown in (2).

$$max\ \theta = \sum_{r=1}^{s} u_r y_{ro} \quad (2)$$

subject to

$$\sum_{i=1}^{m} v_i x_{io} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0\ ,\ j = 1,2,\ldots,n$$

$$u_r \geq 0\ ,\ r = 1,2,\ldots,s$$

DMU is most efficient if the efficiency $\theta^* = 1$, otherwise DMU is considered inefficient.

3. NETWORK DEA

There is many weight needed to evaluate in manufacturing industry. Each of weight connected to each other to come out with high performance and high quality of product. Using Network DEA, the relationship of those weight can be estimate more detail and structured. According to Rolf and Shawna [5], Network DEA model can be apply into a variety of situations such as intermediate products, allocations of budgets or fixed factors and certain (time separable) dynamic systems. Almost all basic DEA model treat their Decision Making Unit (DMU) as black boxes. Difference with networks model introduces by Rolf and Shawna [5], the model allow user to look into these boxes and to evaluate organizational performance and its component performance. Azhar et al. [6] stated that, appropriate analysis is done which deal different interconnected processes each one with its own exogenous inputs and final outputs and also with median product that procreate and consumed within the system. Using this method, risk will put as input in this Network DEA model to evaluate the performance of production line.

4. NETWORK DEA MODEL TO MEASURE PRODUCTION LINE'S PERFORMANCE

To measure the risk of using automation without OEE, the inputs and outputs data for the evaluation must be identified and relevant. Figure 2 shows the network DEA model to measuring performance of production lineoriginally proposed by Reza and Roza [7]. Using this model we generalized the model to evaluate risk using this model. At stage 1, we evaluated the productivity of each production line with high demand. The idea behind this model is $x_1^{s_1}$ of total working hour of $x_1^{s_2}$ labor and $x_1^{s_3}$ number of automation usage to produce $x_1^{s_4}$ product at it standard time. These activities then give the result of $y_1^{s_1}$ of total unit produce and $y_1^{s_2}$of total quality product. Both results from stage 1 then become input in stage 2. At this stage we evaluate the risk face by production line using automation without applying OEE. Results in stage 1 give new result in stage 2 which are $y_2^{s_1}$ of time waste, $y_2^{s_2}$of cost waste and $y_2^{s_3}$ of productivity.

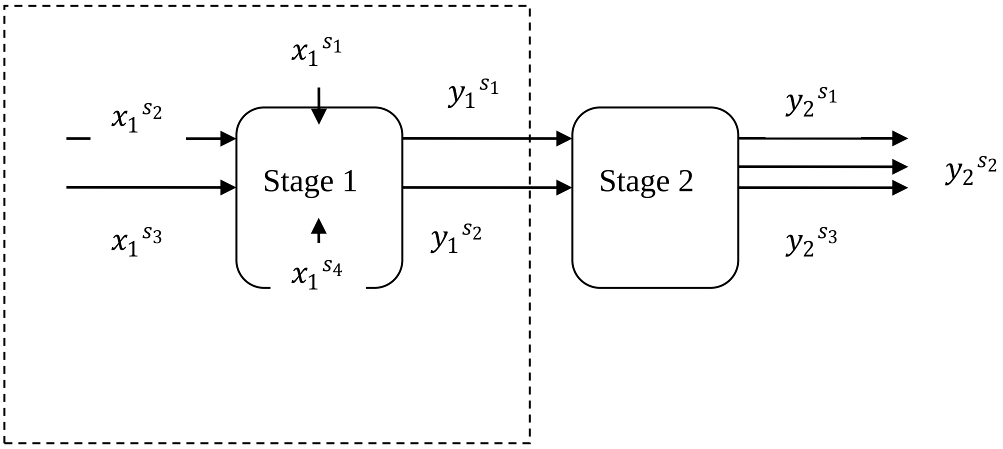

Figure 2. Network DEA Model for Production Line Performance

5. RESULT AND DISCUSSION

The data are taken from one of manufacturing company in Pahang. There are 5 models being selected to study the performance of production time and productivity that assumed as A, B, C, D and E.

5.1 Stage 1: Evaluation of Production Line's Productivity before and after considers Risk

There will be two set of data in this stage. First data evaluate the normal production line's productivity. The second data will evaluate the production line's productivity when deal with breakdown for two days(normal). Here the value$x_1^{s_1}$, $y_1^{s_1}$, and$y_1^{s_2}$each data were change accordingly.

Month	DMU	A	B	C	D	E
1	$x_1^{s_2}$	617	629	261	600	197
	$x_1^{s_1}$	6752	6575	2396	5962	2077
	$x_1^{s_4}$	197426	87784	94704	249456	54658
	$x_1^{s_3}$	60	80	100	100	100
	$y_1^{s_1}$	307501	103699	86326	244817	47024
	$y_1^{s_2}$	290574	103478	82676	242704	45916
2	$x_1^{s_2}$	670	518	228	577	394
	$x_1^{s_1}$	7417	5293	2028	5409	3476
	$x_1^{s_4}$	216872	70668	80158	226318	91474
	$x_1^{s_3}$	60	80	100	100	100
	$y_1^{s_1}$	304201	78365	73500	212752	74445
	$y_1^{s_2}$	297206	78182	70810	211565	73455
3	$x_1^{s_2}$	591	834	406	744	344
	$x_1^{s_1}$	6598	8611	2702	7404	3033
	$x_1^{s_4}$	192924	114967	106798	309790	79812
	$x_1^{s_3}$	60	80	100	100	100
	$y_1^{s_1}$	310701	128897	101500	308246	67302
	$y_1^{s_2}$	305476	128615	99067	306850	64389
4	$x_1^{s_2}$	485	584	270	314	210
	$x_1^{s_1}$	5410	5682	2412	3168	1886
	$x_1^{s_4}$	158188	75862	95336	132553	48484
	$x_1^{s_3}$	60	80	100	100	100
	$y_1^{s_1}$	256454	81851	95822	130751	47940
	$y_1^{s_2}$	250513	81681	92500	288	47195
5	$x_1^{s_2}$	400	594	181	2651	62
	$x_1^{s_1}$	4461	4952	1605	130505	610
	$x_1^{s_4}$	130439	66115	63439	1109201	15682
	$x_1^{s_3}$	60	80	100	100	100
	$y_1^{s_1}$	219230	80996	66905	95714	13221
	$y_1^{s_2}$	214120	80857	65000	93087	13056

Table 1. Inputs and outputs data of production line productivity for five difference model in 5 months

Table 1 shows the inputs and outputs data to evaluate the productivity produce by five different production lines in 5 months. From table 1 we can see that the data tendency of value is mixed and different from each other. For no. of automation $x_1^{s_3}$, the ideal situation is not using no of automation. Therefore we gave 100 marks for lines not using automation. Since the high number of automation usage is 4, we divided 100 by 5, which give 1 automation usage equal to 20 marks. The marks then being deduct from full mark (100 marks) depend on automation usage. Then, the data being evaluate using DEA-solver. Using DEA-Solver software, we calculated the data in Table 1 using window analysis where the length of window is 1.

Those data being evaluate to know the risk face by company when dealing with breakdown. Figure 3 showed the result of the evaluation for normal production line's productivity. We can see that model A was excellent compare to others model. The installation of automation in help the process making this model influence these production lines achieve excellent. However model D with nonautomation usage can score higher that model B. These show that not all the automation usage in production line gives advantages in productivity. Figure 4 shows the result when the production line face breakdown. The efficiency of production line productivity of model C, D and E increase after consider the risk face by model A and B.

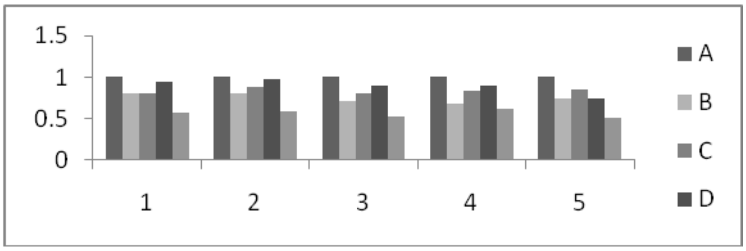

Figure 3. Normal Production Line's Productivity

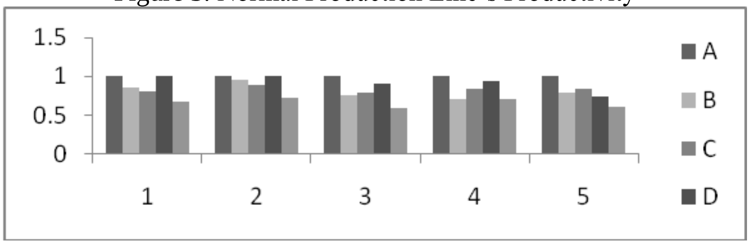

Figure 4. Production Line's Productivity (automation breakdown/hour)

5.1 Stage 1: Evaluation of Production Line's Quality product before and after considers Risk

Table 2 show the data being use to evaluate quality product produce when deal with automation breakdown. The outputs data from stage 1 have been use as inputs data in this stage. We ignore the value $y_2^{s_3}$ of productivity to evaluate those data since the does not involve in this evaluation.Here the value$y_2^{s_1}$ and$y_2^{s_2}$each data were change accordingly. We give total full mark for both output value equal to 600 and 270. The idea behind this the more reject unit less mark given. Figure 5 show the result from window analysis with the length of window equal to one while Figure 6 show the result after taking the risk face when breakdown happen. From evaluation using DEA-solver, the result show the model A score was lowest than others even this production line have automation.

Month	DMU	A	B	C	D	E
1	$y_1^{s_1}$	307501	103699	86326	244817	47024
	$y_1^{s_2}$	290574	103478	82676	242704	45916
	$y_2^{s_1}$	21	583	508	549	558
	$y_2^{s_2}$	9	254	242	257	257
2	$y_1^{s_1}$	304201	78365	73500	212752	74445
	$y_1^{s_2}$	297206	78182	70810	211565	73455
	$y_2^{s_1}$	361	586	532	572	562
	$y_2^{s_2}$	162	257	249	263	258
3	$y_1^{s_1}$	310701	128897	101500	308246	67302
	$y_1^{s_2}$	305476	128615	99067	306850	64389
	$y_2^{s_1}$	421	579	538	567	489
	$y_2^{s_2}$	190	250	251	262	236
4	$y_1^{s_1}$	256454	81851	95822	130751	47940
	$y_1^{s_2}$	250513	81681	92500	130505	47195

	$y_2^{s_1}$	397	587	516	594	572
	$y_2^{s_2}$	179	258	244	269	261
5	$y_1^{s_1}$	219230	80996	66905	95714	13221
	$y_1^{s_2}$	214120	80857	65000	93087	13056
	$y_2^{s_1}$	425	590	552	537	594
	$y_2^{s_2}$	191	260	255	254	268

Table 2. Inputs and outputs data of production line productivity for five difference model in 5 months

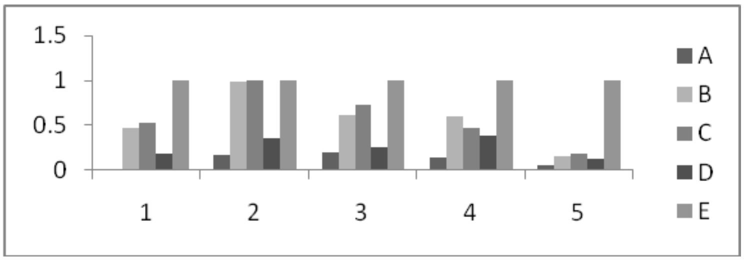

Figure 5. Normal Production Line's Produce Quality Product

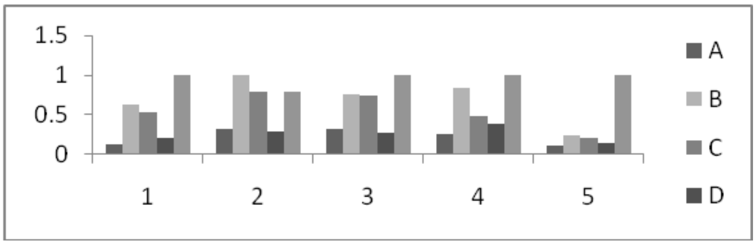

Figure 6. Production Line's Produce Quality Product (automation breakdown/hour)

6. CONCLUSION

This paper use network DEA to evaluate the risk faced by industry when deal with automation break down without OEE. The efficiency of the production line productivity without automation increase from 50% to 70% shows that the efficiency of model A and B with an addition of automation was drop after breakdown for two days. The total losses of productivity and quality product after considering the risk of breakdown from 30% -40%. From the result production department need to manage the usage of automation to ensure, every installation of automation does not give losses to the company. OEE is one of best measurement method to manage automation. From this person responsible for the production line can plan strategies to ensure the production line with automation not decrease in performance of productivity and quality.

6. ACKNOWLEDGMENT

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