AN APPROACH TO IDENTIFY CRITICAL RESOURCES: AN INDUSTRIAL CASE STUDY

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ABSTRACT

Resource control is an essential element in improving corporate performance. In order to maximize performance, the company has to identify the critical resources that most influence performance. For this, we propose a new method based on a multi-criterion approach using the attribution of criticality indices. To prioritize company resources, we identified criteria which impact key performance in three categories: manufacturing, technology and management, marketing. This method has the advantage that it refers directly to the profit margin, an essential manufacturing performance parameter. More importantly, it takes into account – by calculating the human-machine availability – the impact of the absence of human skills on material resources. Its application to an SME specialized in subcontracting precision machining is presented as an example.

RESUME

La maîtrise des ressources est un élément essentiel pour l'amélioration de la performance des entreprises. Afin d'optimiser sa performance, l'entreprise doit identifier les ressources les plus critiques, c'est-à-dire celles influençant le plus la performance. Pour ce faire, nous proposons une nouvelle méthode basée sur une approche multicritère. Pour hiérarchiser les ressources d'une entreprise, nous avons identifié les critères impactant les facteurs clefs de la performance répartis en trois catégories: la fabrication, la technologie et la gestion et le marketing. Cette méthode présente l'avantage de prendre en considération la marge de l'entreprise, un paramètre essentiel de performance économique. Plus important encore, elle prend en compte – par le calcul d'une disponibilité homme-machine - l'impact de l'absence de compétences humaines. Un exemple d'application dans une PME de sous-traitance mécanique est présenté.

1. INTRODUCTION

Companies today must improve economic performance. One of the main aspects of this performance is the control of the company's manufacturing system resources. The ability to control these resources constitutes the key to company success. To meet customer requirements, knowledge of critical resources is necessary. For example, the first aim of an airline is to fly its planes. In this case, identifying the critical resource is a simple matter. However, in the case of a small business with several production techniques and many different products and customers, resource prioritization is not so clear. The main reason for identifying critical resources is that it helps managers focus on the resource that provides the greatest opportunity for improvement and it identifies the resources that most penalize overall company performance. In addition, a company must constantly review its production system, remain flexible and be able to make and apply quick and appropriate decisions. Given the time constraints and the increasingly competitive market, the resources that cause the greatest loss of profit when disrupted must be identified. Our definition of the critical resource differs from that of the bottleneck resource, which is also called the critical resource (Goldratt, 2006; Marris, 2005; Grosfeld-Nir and Ronen, 1993). The terms bottleneck resource and critical resource are used to describe a resource which is utilized to its full capacity. According to other authors, to identify critical resources, key company performance must be considered: this performance depends on the industry's key factors to success (Porter, 1980; De Vasconcellos and Hambrick, 1989; Hax and Majluf, 1985; Grant, 1991; Rangone, 1999) and on the core customer benefits that the company wants to address (Prahalad and Hamel, 1994). This study follows the terminology of these authors, and the term "critical resources" includes a wide range of items which have an impact on performance, such as quality, availability, customer importance and profit margin costs.

The identification of high priority resources has been an important preventive maintenance issue over the last few decades (Herrou and Elghorba, 2007; Chelbi and Ait-Kadi, 2002; Jamali et al., 2000; Lavina, 1992). Some (Jamali et al., 2000; Lavina, 1992) have proposed prioritizing the physical resources of an agribusiness company according to the PIEU method, developed by Lavina. This approach classifies equipment by assigning values for the following four criticality indexes: the failure index (P), equipment importance (I), equipment condition (E) and the usage rate (U). Another study (Chelbi and Ait-Kadi, 2002) suggests identifying the criteria for prioritizing resources by means of an organization developed by Roy (Roy and Bouyssou, 1993; Bouyssou, 2001). This is a 4-stage method: (1) identifying the equipment to be classified, (2) establishing a coherent list of criteria for determining priority, (3) evaluating the performance of each piece of equipment according to overall performance, and (4) applying an aggregate procedure to classify the equipment according to overall performance. On the basis of this approach, 9 prioritizing criteria have been identified, such as the contribution of the resource to the process flow, the average repair time per resource and the importance of the production line the equipment is part of (Chelbi and Ait-Kadi, 2002). A more recent study, of a plastic product production unit, classified equipment according to a multi-criterion matrix using weighting for each piece of equipment (Herrou and Elghorba, 2007). The criteria used are machine importance, safety and consumption. These studies lead to different ways of prioritizing resources in terms of maintenance. Nevertheless, company resources cannot be perceived as only physical, but should rather be seen as a combination of the physical and the human. Control of a company's human resources is fundamental to obtaining a competitive advantage (Nanda, 1993; Dosi et al., 1992; Hofer and Schendel, 1978).

In a previous study we proposed an alternative approach for identifying critical resources (Lyonnet et al., 2008). A critical resource is one which most influences company performance. Our method was developed on the basis of a multi-criterion approach founded on a criticality matrix. To prioritize resources, a criticality index was calculated according to a scoring method based on the desirability function (desirability was introduced in 1965 by Harrington (Harrington, 1965)), where the decision-maker's preference is assigned a value. This approach allows us to combine qualitative and quantitative data, and maps attribute values onto a common preference scale, such as from 0 to 1 (Xu and Yang, 2001). Overall desirability is calculated from the geometric mean. The originality of our method consists in directly considering the economic aspect: in order to maximize performance, a company must identify the resources that most influence its economic performance. In the previous study we applied this approach to a bar-turning company (Lyonnet et al., 2008). The present article focuses on a case where this was applied to a wide range of resources. In addition, we have continued the development of our previous method by integrating additional criteria. The sections are organized as follows: first, the way resources have been prioritized is presented; an industrial case study is then discussed; finally, we analyze the advantages and limitations of this new approach.

2. METHOD

2.1 A method for prioritizing resources based on a criticality matrix

Our resource prioritization method is based on different hypotheses, as follows:

- To improve performance, a company must control its resources
- The risk of financial loss is greater if a company does not control critical resources
- The identification of critical resources affects a company's key performance
- The identification of critical resources is based on the calculation of the criticality (C) rate which is the complement of the weighted overall desirability (OD').
- The critical resource is the resource which generates the higher financial loss, i.e the resource with the lower desirability

These hypotheses have led to the development of a method for controlling company resources. We propose to identify critical company resources, i.e. those that most penalize overall company performance. To prioritize the resources, Roy proposes (Roy and *Bouyssou, 1993; Bouyssou, 2001*) a 4-stage method:

- Identify the equipment to be classified
- Establish a coherent list of the criteria required to establish priority
- Evaluating equipment performance by comparison with overall performance
- The aggregation procedure to class the equipment

2.1.1 Identify the equipment to be classified

In this study, the company has identified the equipment used to manufacture parts.

2.1.2 Establish a coherent list of the criteria required to establish priority

Resources are compared using grouped criteria. A family of resources is said to be coherent if it satisfies three requirements: exhaustivity (completeness), cohesion and non-redundancy (Roy et al. 93).

- Exhaustivity (completeness): family of criteria dealing with all elements or aspects, omitting none.
- Cohesion: the family of criteria has to be united by act or state.
- Non-redundancy: If a criterion is excluded from a family, then one of the two previous requirements is no longer satisfied.

By following the three conditions, we propose to evaluate the risk of financial loss by identifying the criteria impacting the performance of the company.
Key performances can be divided into three categories (Rangone, 1999):

- manufacturing performances (e.g., quality, dependability, cost, etc.), which in literature on operations management are usually referred to as manufacturing competitive priorities

(e.g., Anderson et al., 1989; Krajewski and Ritzman, 1990; Kim and Arnold, 1992; Vickery et al., 1991; Azzone and Rangone, 1996);
- technological and managerial performance (e.g., development cost, time to market);
- marketing performances, such as brand awareness, brand reputation, customer loyalty, etc.

Moreover, the choice of criteria draws on the grid proposed by Nakajima (Nakajima, 1986; Chelbi and Ait-Kadi, 2002). We have added other criteria to those proposed by Nakajima, Chelbi and Ait-Kadi, such as profit margin, risk related to the consequences for customers and the calculation of human-machine availability. The distribution by category of criteria is presented in Table 1.

Table 1. Distribution by category of criteria

Manufacturing performances	Technological and managerial performances	Marketing performances
Human-machine availability	Uniqueness of production means	Consequence on customers
Production restriction of machine	Maintenance costs	
The proportion of manufactured parts	Quality costs	
	Profit margin	
	Safety of employees	

2.1.3. Evaluating equipment performance by comparison with overall performance

Overall performance for each resource is assessed using data collected for each of the criteria listed above.

1) maintenance costs

Maintenance costs can account for as much as 40% of the operational budget (Daft, 1992, Eti et al., 2006) and therefore improved maintenance is a potential source of financial savings. The aim of this criterion is to identify the share of expenditure devoted to machine maintenance. Maintenance costs include the cost of labour and parts for repairs, and information reliability (Seo K and Ahn B. J., 2006).

2) quality costs

Organizations throughout the world have made quality a priority in the form of Total Quality Management, Continuous Improvement, and similar initiatives. Quality costs include ''any cost that would not have been expended if quality was perfect'' (Campanella, 1990). This cost difference reflects the difficulty of calibrating the machine, the complexity of the part and the experience of the employee. The cost of obtaining higher quality depends on the resource used: production disruptions will have a greater impact and therefore financial losses will be greater for resources where the cost of quality is higher.

3) the profit margin

Profit margin is defined as: (sales revenue cost of goods sold)/sales revenue (Min and Wolfinbarger, 2005). Profit margin is the proportion of one dollar of sales revenue that is profit;

thus, lower profit margins are associated with lower profit levels. A company can differentiate resources according to parts manufactured.
Hence, the profit margin (PM) can be calculated in the following way:

$$PM = \sum_{j=1}^{p} Pqi.SPi.pPMi \quad (1)$$

where,

p: number of product types manufactured by the company
Pqi: estimated produced quantity of the product i ($Pqi = TPqi - LPi$)
TPqi: theoretical production of the product i
LPi: estimated loss of production of the product i, linked to the physical and human failures
SPi: Selling price of product i
pPMi: percentage of the profit margin for product i

4) the human and machine availability

A new idea suggested in this study is to calculate the human-machine Mean Time Between Failures (MTBF). This criterion takes into account the risk linked to the absence of human competences. The human resource is considered in the MTBF calculation only if it demonstrates that it is the unique competence for a given machine. In this case if the human resource having the specific skills for a physical resource is absent, the resource to which it is habitually assigned is then stopped. On the other hand, where several human resources have the necessary skills for a given machine, the risk linked to the absence of a competent human resource is then without consequence. The main two parameters needed to evaluate the reliability function are: the repair rate (μ) and the failure rate (λ).

If we consider an exponential distribution, the mathematical expectation E(t) between failures, which represents the MTBF, is:

$$MTBF = E(t) = \frac{1}{\lambda} \quad (2)$$

and the mathematical expectation for downtimes E(tar), representing the Mean Time To Repair (MTTR) is:

$$MTTR = E(tar) = \frac{1}{\mu} \quad (3)$$

The risk of downtimes for the machines having a unique human competence is represented by the human-machine MTBF and MTTR ($MTBF_{HM}$, $MTTR_{HM}$).
Both of the elements – Machine and Human M_{HM} – are represented by a serial system from the viewpoint of reliability, consequently:

$$\lambda_{HM} = \lambda_H + \lambda_M \quad (4)$$

$$\lambda = \frac{\text{Numbers of downtimes}}{\text{Observed time}}$$

with:
Number of human downtimes = number of absences
Number of machine downtimes = number of failures

Then,

$$MTBF\ HM = \frac{1}{\lambda M + \lambda H} \tag{5}$$

For the evaluation of the $MTTR_{HM}$ the average of the weighted downtimes is given by:

$$MTTR_{HM} = \frac{\lambda_H \times MTTR_H}{\lambda_H + \lambda_M} + \frac{\lambda_M \times MTTR_M}{\lambda_H + \lambda_M} \tag{6}$$

For the evaluation of the availability *(A)*, the calculation is given by:

$$A = \frac{MTBF}{MTBF + MTTR} \tag{7}$$

5) the machine's production restriction

A machine's production restriction is the ratio of the machine running time to the theoretically available production time for (Chelbi and Ait-Kadi, 2002). The estimated production restriction of machine (EPr) is calculated in the following way:

$$\mathrm{EPr} = \frac{TPqi\,.Pt}{Ot} \tag{8}$$

where:

TPqi: theoretical production of product i
Pt: operating time (the processing time for product i)
Ot: Opening Time of the machine

6) the proportion of parts manufactured (pM)

This criterion is the ratio of the number of different parts manufactured per resource to the total number of parts (Chelbi and Ait-Kadi, 2002).
This criterion is calculated in the following way:

$$pMj = \frac{TPqj}{\sum_{i=1}^{n} TPqi} \tag{9}$$

where:

n: number of machine
pMj: proportion of parts for machine j.
TPq: theoretical production of machine

7) the uniqueness of the means of production

This criterion aims to identify those resources that have a rare or unique manufacturing technique. To this end, the company must answer the following questions: Are there any other devices capable of replacing the machine in the event of failure? If yes, the resource is not a priority. If no, what alternative means can be used?

8) employee safety

Some resources present a risk to employee safety. The aim of this criterion is to identify those resources which could generate such a risk. The company must answer the following question: what is the impact of resource failure on employee safety (discomfort, worrying damage, reversible pathology, irreversible pathology)?

9) the consequences for the customer

This criterion aims to answer the following question: Is the resource used to manufacture a product strategic or essential for the survival of the company?

Scale of measurement

The company has to identify values for each criterion. For qualitative criteria, or if the company does not have the actual values for each criterion, employees can use the Likert scale (Likert, 1931) . The choice of ranking from 1 to 5 or 1 to 10 will depend on the ability of the company to develop a corresponding semantic scale. The company can assess the risk as shown in Table 2.

Table 2. Scale of measurement

Cotation	Risk
1	Very low
2	Low
3	Medium
4	High
5	Very high

2.1.4. Mathematical formulation of the problem: a multi-criterion approach

A new method for prioritizing resources is presented based on a multi-criterion approach, developed from a criticality matrix. The mathematical formulation of the problem defined as the multi-criterion approach has been created by calculating the criticality (C) rate as the complement of the weighted overall desirability (OD'). Our prioritization is developed with a criticality matrix and criticality rates. Two steps were taken to calculate these criticality rates: attributing a value to each criterion (cf. table 3) and then converting each value into desirability (given as *di* for *Vi*). There are many different multi-criterion approaches in the literature (Baykasoglu et al., 2009): some are very easy to implement, while others are relatively complex and require a variety of information. We have chosen the desirability approach since it has the advantage of needing relatively less information and can be used by several people. The desirability approach converts an estimated response into a scale-free value called desirability. This is a value between 0 and 1, with 1 being the most desirable. In our approach the items are quantitative or qualitative, and the desirability approach easily handles this data structure. The overall desirability, also from 0 to 1, results from combining the individual desirability values. The overall desirability (OD) is determined using the geometric mean.

$$OD = (d1.d2.d3....dk)^{1/k} = \left(\prod_{i=1}^{k} di\right)^{1/k} \quad (10)$$

The relative importance of a particular criterion can be weighted. Simos's review of the literature (Simos, 1990) presents several ways of determining these weights, such as:

- categorization, where the decision-maker must rank criteria in categories such as "very important," "moderately important" and "unimportant"
- ratio questioning, where the decision-maker must answer questions such as "what is the importance of criteria C1 relative to C2?"
- ranking, which means prioritizing criteria from most to least important
- the indifference trade-off. This method requires only a minimum amount of information on the nature of the decision-maker's utility function. Specifically, he must be able to specify the trade-offs among objectives for any feasible solution.
- multiple regressions, where criteria weighting is obtained by multiple regression. The decision-maker must rank the alternatives.
- rating. For this study, we used the rating which requires weighting ranked according to the importance assigned to each criterion. This is the most commonly used method, and also the simplest.

In order to balance the criteria, we introduced a weight (w) in this calculation:

$$OD' = \left(\prod_{i=1}^{k} d_i^{w_i}\right)^{1/\sum_{i=1}^{k} w_i} \quad (11)$$

The figure 1 illustrates the impact of the weight on the desirability function when the maximal value represents the most desirable value.

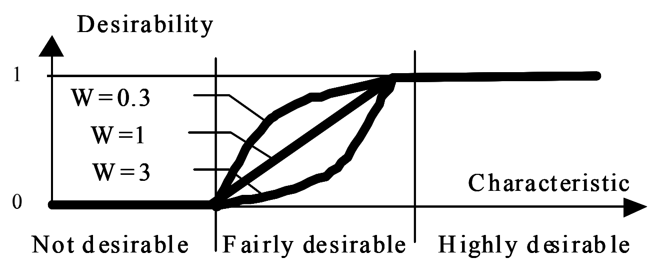

Figure 1. Illustration of the approach of the desirability

In this case the calculation of the desirability *di* is the following (Derringer and Suich, 1980):

$$di = \frac{V_i - MinV}{\text{Max V - Min V}} \quad (12)$$

where,

Vi: the value of criterion i
Max V: the desirable value for V
Min V: the not desirable value for V

This calculation is adapted in the case in which the maximum value is more desirable. We can define two others cases for the desirability:

- the case when the minimal value represents the most desirable value. The figure 2 illustrates this case:

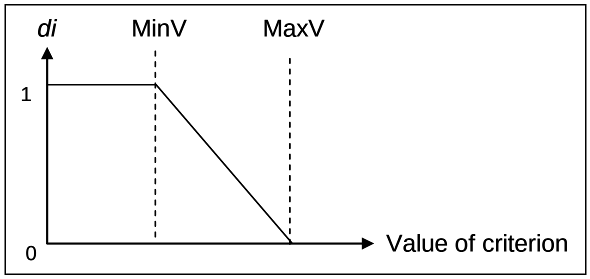

Figure 2. Case of the minimal value

In this case the calculation of the desirability *di* is the following:

$$di=\frac{V_i - Max(V)}{Min(V) - Max(V)} \tag{13}$$

- the case when the most desirable value is between the maximum and minimum values. The figure 3 illustrates this case:
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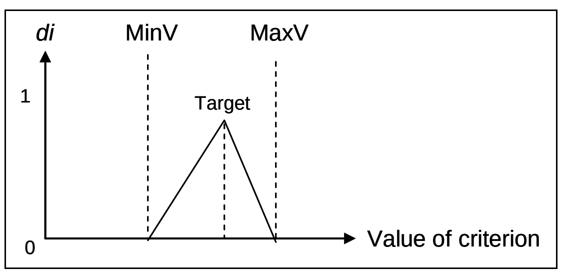

Figure 3. Case of the target value

The desirability *di* is a combination of both previous definitions. According to the geometric mean definition, if a desirability *di* calculated on one criterion is equal to zero, the overall desirability would be equal to zero, and other criteria which have an impact of the risk of financial loss would not be taken into consideration. In order to prevent this possibility of desirability *di* at zero, we uses an adapted definition for the desirability allows that the desirability (*di*) is necessarily comprises to 0.1 and 1. The calculation of the desirability when the maximal value is the most desirable is the following:

$$di=0.1+0.9 \text{ x } \frac{V_i - Min(V_j)}{max(V_j) - min(V_j)} \tag{14}$$

where,

Vj: the value of criterion for resource J.

We define the critical resource as the resource which generates the higher financial loss, i.e as the resource with the lower desirability. Then, in order to provide results more understandable, from the desirability rates, the calculation of the criticality (C) rate is the complement of the weighted overall desirability (OD').

$$C = 1 - OD' \tag{15}$$

The interpretation of our criticality matrix is realized from these criticality rates. The resource with the higher criticality rate is the critical resource of the company.

3. APPLICATION AND RESULTS

3.1 Application of the proposed criticality method to the data of a screw cutting company

3.1.1 Identifying the set of equipments to be classified

The company that was studied is located in the Arve valley (Haute-Savoie region, France) which is considered to be one of the main local production systems in France. The companies in the valley generate more than 60% of French turnover in the screw-cutting sector. The company in question uses both digital and traditional (analogue) machines. This 30-employee company is an interesting case study for the application of this method because it has many similar resources, such as bar-turning. In such a context, it is difficult to identify the high-priority resource, and a method for prioritizing resources is thus necessary. The flow mapping of almost products manufactured by the company is presented in the figure 4.

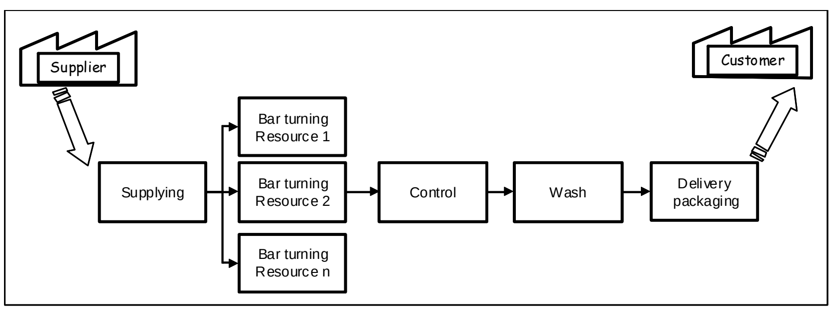

Figure 4. Flow mapping for almost products

3.1.2. Evaluating equipment performance

The data presented below were gathered during the observations carried out in this company and using software from the company GesProDec in collaboration with the Chief Executive Director. This package monitors all production operations (ordering, procurement, scheduling, manufacturing, shipping, and billing). At first, the company identified the contribution to the grid of the process-flow and the production restrictions for each resource. It is important to note that almost all of the products require washing, supply, inspection and packaging operations. These operations are carried out by resources R6, R15, R16 and R17. The production restrictions on resources are between 0.7 and 1. For all other criteria, a weighted scale is used; the highest value is 5. Two resource profiles can be seen: resources with higher maintenance costs and lower quality costs, and resources with lower maintenance costs and higher quality costs. This is attributable to the type of resource in question. Resources with higher maintenance costs are digital machines, whereas the others are traditional machines. Quality costs for traditional machines increase due to the additional calibration that they require. Customer-connected risk is high for only one resource (R6). Traditional machines are more available than digital machines. Digital machine maintenance is less thoroughly monitored. Human availability is similar for each resource. As the personnel are versatile, they are able to operate the various processes.

3.1.3 An aggregation procedure to class the equipment: criticality matrix

The criticality matrix is presented in the table 4. For each resource a desirability value (di) comprises between 0.1 and 1 and the final index of the criticality were calculated. This calculation required knowing the direction of criticality (negative or positive). The five identified resources with higher critical index are the resource R16 (90%), R17 (82.3%), R15 (82%) and R6 (71.5%). Resources R6, R15, R16 and R17 are uniqueness of production means and are essential to the manufacturing of the majority of products. In this example we chose as full scale the minimum and maximum value of the data. Then for all criteria de desirability is between 0.1 and 1. With this choice all criteria with the same weight have the same importance. It is possible to make the choice to fix the minimum and maximum value. In these conditions, desirability will be in a shorter scale than [0.1 – 1]

Table 3. Data gathered in the studied company

	Availability	Flow process grid contribution	Production restriction	Profit margin	Uniqueness of mean	Consequence on customer	Maintenance costs	Quality costs	Safety of employees
Weights	1	1	1	2	1	1	1	1	1
Direction	1	2	2	2	2	2	2	2	2
Maximal value	3	100	1	5	5	5	5	4	2
Minimal value	1	32	0.7	1.19	1	1	1	1	1
R1	1	32	0.7	1.48	3	1	1	3	2
R2	1	32	0.7	1.79	1	1	1	3	2
R3	1	32	0.7	1.95	3	1	1	3	2
R4	1	32	0.8	1.29	3	1	1	3	2
R5	1	32	0,8	1.19	3	1	1	3	2
R6	1	99	0,7	1.43	5	5	1	1	2
R7	3	68	1	5.00	1	1	5	1	1
R8	3	68	0.7	4.05	1	1	5	1	1
R9	3	68	0.7	3.52	1	1	5	1	1
R10	3	68	0.7	4.24	1	1	5	1	1
R11	3	68	0.8	4.05	2	1	5	1	1
R12	3	68	0.7	3.90	1	1	5	1	1
R13	3	68	0.7	3.57	1	1	5	4	1
R14	3	68	0.7	1.71	1	1	5	1	1
R15	1	100			5				
R16	1	100			5	3		3	
R17	1	100			5	2		3	

Table 4. Criticality matrix according to desirability approach

	Availability	Flow process grid contribution	Reliability rate	Profit margin	Uniqueness of mean	Consequence on customer	Maintenance costs	Quality costs	Safety of employees	Criticality
Weights	1	1	1	2	1	1	1	1	1	
Direction	1	2	2	2	2	2	2	2	2	
The most desirable value	0.10	1	1	1	1	1	1	1	1	
R1	0.10	1.00	1.00	0.93	0.55	1.00	1.00	0.40	0.10	46.4%
R2	0.10	1.00	1.00	0.86	1.00	1.00	1.00	0.40	0.10	41.1%
R3	0.10	1.00	1.00	0.82	0.55	1.00	1.00	0.40	0.10	47.6%
R4	0.10	1.00	0.70	0.98	0.55	1.00	1.00	0.40	0.10	47.6%
R5	0.10	1.00	0.70	1.00	0.55	1.00	1.00	0.40	0.10	47.4%
R6	0.10	0.11	1.00	0.94	0.10	0.10	1.00	1.00	0.10	71.5%
R7	1.00	0.52	0.10	0.10	1.00	1.00	0.10	1.00	1.00	59.2%
R8	1.00	0.52	1.00	0.33	1.00	1.00	0.10	1.00	1.00	37.7%
R9	1.00	0.52	1.00	0.45	1.00	1.00	0.10	1.00	1.00	33.9%
R10	1.00	0.52	1.00	0.28	1.00	1.00	0.10	1.00	1.00	39.3%
R11	1.00	0.52	0.70	0.33	0.78	1.00	0.10	1.00	1.00	42.4%
R12	1.00	0.52	1.00	0.36	1.00	1.00	0.10	1.00	1.00	36.5%
R13	1.00	0.52	1.00	0.44	1.00	1.00	0.10	0.10	1.00	46.6%
R14	1.00	0.52	1.00	0.88	1.00	1.00	0.10	1.00	1.00	25.3%
R15	0.10	0.10			0.10					82.0%
R16	0.10	0.10			0.10	0.55		0.40		90.0%
R17	0.10	0.10			0.10	0.78		0.40		82.3%

4. DISCUSSION

4.1 Criticality matrix

Our approach for establishing priority is based on the attribution of the criticality index for criteria that influence company performance. In the present case, the resources generating the biggest risk for the company are resources R15 and R16. In order to combine quantitative and qualitative criteria, we used the desirability approach. This approach combines different kinds of data, converts estimated data to the same scale, from 0 to 1, and makes comparing the desirability of each resource easier. The qualitative criteria used in our method targets the risk of unsatisfied customers, the uniqueness of the production techniques, maintenance costs and risks linked to employee safety. These criteria would seem to be essential, as they generate a risk of financial loss for the company. Indeed, in some cases customer dissatisfaction can lead to financial loss through the termination of a contract. The criterion linked to the uniqueness of production techniques is required to prioritize a resource (Herrou B and Elghorba M, 2007). In the present case, the absence of resource R16, with a unique production technique, could lead to the dissatisfaction of all customers; this resource must therefore remain available. The criterion relating to the risk to employee safety is also essential for establishing priorities: this criterion could, in an extreme situation, generate financial loss. Moreover, taking employee safety into consideration directly contributes to the improvement of working conditions, thus constituting a competitive advantage.

4.2 Analysis of human resources-related risks

One of the criteria used in our method for prioritising resources is unavailability due to failure. The notion of "human failure" has already been widely discussed through the issue of absenteeism, which is common to every company. It would seem advantageous to consider a company's human resources by calculating the human-machine MTBF on the basis of employee absenteeism. However, other human factors may influence production stoppages as well, such as human error. This factor could not be taken into account in the company analyzed in the present paper. It would, however, be interesting to model this aspect in the future.

4.3. Criticality matrix: actions for improvement

Several preventive actions can be identified to ensure the availability necessary for continued production. In order to improve the availability of resources, the company can implement preventive maintenance actions, Maintenance Based on Reliability (MBR) or Reliability Centred Maintenance (RCM) (Richet et al., 1995) in adition to taking a long-term approach, Total Productive Maintenance (TPM) (Nakajima, 1986). Corrective or preventive maintenance planning must take the importance of equipment into account (Chelbi and Ait-Kadi, 2002). This is especially true if multiple resources break down at the same time and only one can be repaired at a time. The risk to employee safety can be decreased by implementing preventive action, such as ensuring the rapid supply of spare parts, and setting up a safety plan for resources identified as critical (Hessa et al., 2007; Cai, 1996). Identifying critical resources, the company may identify critical flow. Therefore, the company must focus on all the critical flow.

5. CONCLUSION AND PERSPECTIVES

This method draws upon a multi-criterion approach based on the use of a criticality matrix comprised of criteria directly related to financial loss. This matrix has the advantage of referring to the profit margin, which is an essential parameter of economic performance. The desirability function approach combines both qualitative and quantitative data. This method for establishing priorities is rapid and simple to apply, and is aimed at companies wishing to know at any given time which resource generates the greatest financial loss, as much for the sake of everyday management as for the development of new strategies. With rapid insight into resource priority, a company can implement actions aimed at improving a given situation, centred on the critical resource itself, in order to increase economic performance. On the basis of this prioritization of resources, a company can ensure the availability necessary for production, economic performance and customer satisfaction. Based on the prioritization of resources in this company, we developed an action plan to minimize disruption of resources, a plan which included ensuring the availability of spare parts, maintenance scheduling and plans for continuous improvement. In our future work we will develop an approach to improve preventive and corrective actions to ensure the availability of critical resources.

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