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Hadamard Matrix to Improve Enterprise's Competitiveness: an Exploratory Research

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ABSTRACT
The main purpose of this study is to evaluate the extent to which there is a relationship between Hadamard matrix utilization and the enterprise success in terms of competitiveness. An exploratory research was conducted to measure the influence of factors identified by Hadamard matrix utilization in enterprises' quality, cost, speed of delivery and flexibility. A broad sample of Malagasy enterprises operating in renewable energy was selected. Data was collected through questionnaire with closed questions. Then it was analyzed using XLSTAT software. The findings suggest that enterprise improvement success is correlated to Hadamard matrix utilization. A case study of a bakery enterprise is given to show that the application is not limited to enterprises operating in renewable energy. The results corroborate that Hadamard matrix is an integrated system to pilot enterprise improvement.

Keywords: *Hadamard Matrix, Improvement, Innovation, Renewable Energy*

1. INTRODUCTION

Nowadays, enterprises research many paths to improve or to innovate their activities. Many processes are tried to solve the corresponding problems. It is important to say that when problem related to cost is solved, it negatively affects quality or speed of delivery or flexibility. Additionally, it is the same when one of those four critical factors is unilaterally solved.

Is there a methodology that could deal with systemic solving process when improvement or innovation is concerned?

Thus, we studied 30 companies operating on renewable energy in Madagascar. It deals with the impact of the use of Hadamard matrix on the improvement of the quality, the flexibility, the speed of delivery, the cost and the output for these enterprises.

A case study led in a bakery allows highlighting the positive correlation between the application of this matrix and the improvement of the quality. More precisely, we will talk about the possible improvement of time of conservation of the bread by the means of the Hadamard matrix. In addition, we will examine the possibility of the main factors identification in the case of bread staling.

2. LITERATURE REVIEW

2.1 Definition

Referring to works of some authors [4] [7] [9] [14] [16] having more or less the same idea, a Hadamard matrix, named after Jacques Hadamard (1865-1963), is a matrix [H] of order n with entries ±1 and whose rows are all orthogonal to each other. It is determined by the following equation:

$$[H]^t.[H]=n.[I_n] \quad (1)$$

The order of a Hadamard matrix is 1, 2 or n≡(0 mod 4). A Hadamard matrix is one type of the method of experiments design.

2.2 Presentation of the experiments design method

The term « experiments design method » indicates a complete method to characterize a system. It is based on the modification and the measure of appropriate variables to the considered system. This mainly includes the examined parameters as well as the origin of their variation. Therefore, this method attempts to build up a link between two types of variable:

- The results: studied physical variables

- The factors: physical variables, adjustable by experimentalist, supposed to have an influence on the variation of the result.

More precisely, that method aims at the well understanding of the relation connecting the result with the factors as well as the factors between themselves. As for this, the proposed solution consists, in any case, in establishing a model, expressing the result according to factors [17]. The following fig.1 presents the experiment system.

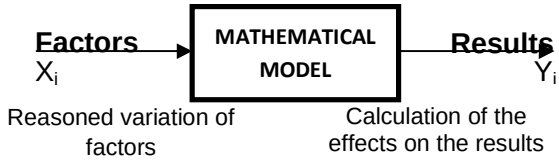

Figure 1: Experiment system

Source: The authors

There are two possible uses of experiments design or experiments matrix:

- the screening technique
- the result surface method

We are here interested in the screening technique, which enables us to classify the factors between themselves according to their particular influence. This technique requires the use of factorial design.

2.3 Construction techniques

- Complete factorial design

A complete factorial design [6] [17] is achieved when at least a trial for each combination of factor is fulfilled.

- Factorial designs at two levels

Those factorial designs are the easiest. They enable to understand the principle of the method, and to have many applications. The number of experience (n) to fulfil is calculated by:

$$n = 2^k \quad (2)$$

The number 2 is due to the two levels; k indicates the number of the factors.

- Notation of Yate [5]

Owing to this modeling, the different variables are transformed into reduced centered variables. That allows comparing variables of completely different measures. Hereafter is the formula to change the current variables into reduced centered variables:

$$a = \frac{A - \bar{A}}{step} \quad (3)$$

a : the reduced centered variable;
A : the current variable;
$\bar{A}$: the average value of current variable;
Step : is the variation between the average position of the variable and the extremity of the domain.

Because of this representation of levels, the field of study is intrinsically unobtrusive. That simultaneously allows the use of quantitative variables as well as the qualitative variables or differential variables. The notation of Yate, in fig. 2, authorizes a simple presentation of combinations of levels and allows an easy calculation of effects and interactions [6]. The levels are showed with + and – symbolizing respectively the high and low values of the factor.

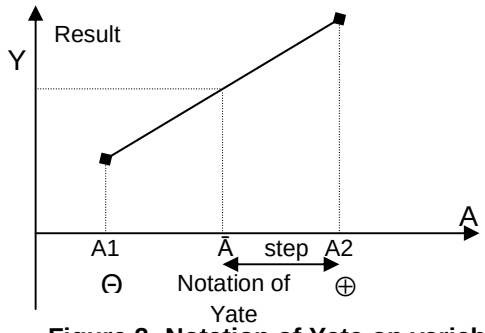

Figure 2: Notation of Yate on variable A

- Plackett – Burman matrix [6] [17]

The Plackett – Burman matrix is built from Hadamard matrix [6]. The associated Plackett – Burman matrix constitutes a general and simple mean to perform the Hadamard matrix [17]. Thus, for a k factors, let us choose the matrix such as n ≥ k+1, n ≡ (0 mod 4). For the found value n, we should use the series of +1 and -1 indicated by the table of reference below:

Table 1: Table of reference for the construction of the Hadamard matrix [17]

n	Series of levels
4	++-
8	+++ - + - -
12	++ - +++ - - - + -
16	++++ - + - ++ - - + - - -
20	++ - - ++++ - + - + - - - - ++ -
24	++++ - + - ++ - - ++ - - + - + - - - -
32	- - - - + - + - +++ - ++ - - - +++++ - - ++ - + - - +

Source: Vivier [17]

Then, the rows of the experiments matrix are deduced from all the cyclic permutation of the sequence of +1 and –1. Thus, for example, with k=2, we must choose n=4. By permutation on the right, we have the matrix:

$$\begin{bmatrix} + & + & - \\ - & + & + \\ + & - & + \end{bmatrix}$$

For the select value of n, we add an additional row of -1:

$$\begin{bmatrix} + & + & - \\ - & + & + \\ + & - & + \\ - & - & - \end{bmatrix}$$

To obtain a matrix of order n, it is necessary to add a column of +1 on the left (average column). Finally, when the average column is added, we obtain the Plakett – Burman matrix that can serve for the creation of experiments design:

$$\begin{bmatrix} + & + & + & - \\ + & - & + & + \\ + & + & - & + \\ + & - & - & - \end{bmatrix}$$

Let's note [H] this matrix, we have the formula below:

$$[H]^t.[H] = n.[I_n] \quad (4)$$

$[H]^t$ is the transposed matrix of [H],
$[I_n]$ is the identity matrix and n the number of experiences.

The calculation of the model coefficients comes from the relation below:

$$[H].\{E\} = \{Y\} \quad (5)$$

{Y}: vector of results
{E}: vector of effects

Thereby, for a complete factorial design, {E} is given by:

$$\{E\} = [H]^{-1}.\{Y\} \quad (6)$$

Alternatively, because of the property of the matrix [H]:

$$\{E\} = \frac{1}{n}[H]^t.\{Y\} \quad (7)$$

2.4 Hadamard matrix and improvement

Generally, literature shows that improvement and innovation are possible with Hadamard matrix. The following paragraphs will show this positive sight.

On the first hand, Beaufort A. and al. [3] have determined the factors on the level of *Listeria monocytogenes* reached during storage of smoked salmon at positive temperature. The results confirmed that the degradation of the quality of this food product could be controlled by using Hadamard matrix as experiments method. On the second hand, Matthew H. and al. [13] have reported that beside the success of Hadamard matrix in the theory of signal processing; many kinds of cyclic permutations of genetic elements unexpectedly lead to reconstruction of initial Hadamard matrices into new Hadamard matrices. Thus, they proved the existence of connection of Hadamard matrices with a structural phenomenology of the genetic code that is a path of improvement and innovation.

As previously, the work of Horadam K. J. [8] relates the different applications of Hadamard matrices. He said that Hadamard matrices are marvelously useful when improvement and innovation are concerned. He mentions three principal applications of Hadamard matrices: Hadamard transform spectroscopy, object recognition, and coding of digital signals. Applications of experiments are not included in his work but this current survey will deal with it.

Finally, Kazuki H. and al. [9] have confirmed that the ratio of the signal in the electropherogram can be improved by a factor of 5 using Hadamard matrix in comparison with that obtained by a conventional single-injection method. Other authors stipulate a new speech-scrambling concept based on Hadamard matrices [15]. They were also employed by Asaff A. and al. [1] in order to increase submerged conidia yields and brown pigmentation of fungal propagules.

The list is likely to be long concerning the improvement of the output and cost reduction carried out by certain industries due to the application of Hadamard matrix parameters [6] [17]. Hadamard matrix and parameters are considered equivalent to customization of a product happens before its production [11].

3. METHODOLOGY

3.1 Enterprises operating in renewable energy

This research was conducted in 30 enterprises operating in renewable energy in Madagascar. These enterprises had utilized Hadamard matrix to improve their activities. In each enterprise, we have studied the hypothesis: "there is a relationship between Hadamard matrix and the improvement of quality, flexibility, speed of delivery, cost and output. Pearson, Kendall, and Spearman correlation are used to analyze the collected data.

3.2 Case study: a bakery enterprise

A case of a bakery, which plans to improve its activities, has been studied. The use of the logical framework allowed to detect that this closure is due, in particular, to the bread staling. The Ishikawa diagram applied in this case shows six main factors causing the bread staling: moulding, fermentation, heating, yeast, water and salt. The levels of the three less important factors, molding, yeast and salt were fixed. In order to improve the quality of the bread to improve the activity of the bakery, the influences of the other three factors were studied using Hadamard matrix.

It is obvious that other experimental fields, because of the existence of these 6 initial factors, are also important to explore. Therefore, because of the cost of experimentation for a complete factorial design 2^6, our study is focused on these 3 factors to show the advantage got by the use of Hadamard matrix in the resolution of our problem.

3.3 Fixation of the levels of the 3 factors:

We have fixed a lower and a higher levels of the 3 factors in order to know the effect of those factors in bread staling. These levels are reported in table 2.

Table 2: Level of factors

FACTORS	Notation	Lower level	Higher level
Hydratation rate	A	60% (bastard dough)	64% (soft dough)
Mode of fermentation	B	Polish	Direct
Heating (Time-Temperature)	C	25 min - 250°C	15 min - 300°C

Source : The authors

3.4 Experiments recipes

The table 3 shows a matrix of experiences for 3 factors at 2 levels or matrix of complete experiences. It allows determining the trials to carry out

Table 3: Experiments matrix of a factor planning at 3 factors

	Factor 1	Factor 2	Factor 3	
n°	A	B	C	Result
1	-	-	-	Y_1
2	+	-	-	Y_2
3	-	+	-	Y_3
4	+	+	-	Y_4
5	-	-	+	Y_5
6	+	-	+	Y_6
7	-	+	+	Y_7
8	+	+	+	Y_8

Source: Gillon [6]

The detailed recipes of the 8 experiences arise from the previous experiments design 2^3. The calculation base of hydration rate has been done with regard to the farina. The weight of the farina used for each experience is of 400g. The method of direct fermentation corresponds to 0g of polish

and 11g of baking powder. 4g of baking powder have been used for the polish. The levels of the 3 factors are shown in the following table:

Table 4: Recipes of experiments

	Kneaded dough			Polish			Salt (g)	Time-Temperature
n°	Farina (g)	Water (g)	Yeast (g)	Farina (g)	Water (g)	Yeast (g)		
1	280	120	4	120	120	4	9	25'-250°C
2	272	128	4	128	128	4	9	25'-250°C
3	400	240	11	0	0	0	9	25'-250°C
4	400	256	11	0	0	0	9	25'-250°C
5	280	120	4	120	120	4	9	15'-300°C
6	272	128	4	128	128	4	9	15'-300°C
7	400	240	11	0	0	0	9	15'-300°C
8	400	256	11	0	0	0	9	15'-300°C

Source: The authors

After each experiment, we have measured the duration of conservation and the development of the bread.

4. RESULTS

The table below resumes Pearson, Kendall, and Spearman correlation analysis. It shows the relationship between Hadamard matrix and the improvement of quality, flexibility, speed of delivery, cost and output carried out in the 30 enterprises.

30 enterprises operating in renewable energy

Table 5: Relationship between Hadamard matrix and the improvement of some domains in 30 enterprises

HADAMARD MATRIX	ENTREPRISE	PEARSON		KENDALL		SPEARMAN		RELATIONSHIP
		r	p	τ	p	ρ	p	
Quality	30	0.694	0.000	0.510	0.001	0.692	0.000	Yes (p<0.0005)
Flexibility	30	0.585	0.001	0.433	0.001	0.589	0.001	Yes (p<0.0005)
Speed of delivery	30	0.396	0.0017	0.164	0.197	0.144	0.123	Yes (p<0.02)
Cost	30	0.557	0.001	0.415	0.001	0.584	0.001	Yes (p<0.0015)
Output	30	0.585	0.00	0.433	0.00	0.589	0.00	Yes (p<0.0005)

Source: The authors

Case study: a bakery enterprise

The results of the experiments are shown in the table 6 below. "A" is the hydration rate, "B" the fermentation, "C" the parameter of cooking. The

unit of results is “day” for the duration of conservation and “cm^3” for the development.

After sweating, the breads are left under an ambient temperature under shelter of the sun in order to evaluate the duration of their conservation. Its appreciation has been done through the visual scrutinizing of the change of the texture of the crumb. The results are shown in table 6.

Table 6: Effects of factors on the duration of conservation

n°	Average	A	B	C	AB	AC	BC	ABC	Result
1	+	-	-	-	+	+	+	-	$Y_1 = 3$
2	+	+	-	-	-	-	+	+	$Y_2 = 3$
3	+	-	+	-	-	+	-	+	$Y_3 = 2$
4	+	+	+	-	+	-	-	-	$Y_4 = 2$
5	+	-	-	+	+	-	-	+	$Y_5 = 4$
6	+	+	-	+	-	+	-	-	$Y_6 = 4$
7	+	-	+	+	-	-	+	-	$Y_7 = 2$
8	+	+	+	+	+	+	+	+	$Y_8 = 2$

Effect	I = 2,75	$E_A = 0$	$E_B = -0,75$	$E_C = 0,25$	$I_{AB} = 0$	$I_{AC} = 0$	$I_{BC} = -0,25$	$I_{ABC} = 0$

The effects of the factors on the development are shown in table 7.

Table 7: Effects of the factors on the development

n°	Average	A	B	C	AB	AC	BC	ABC	Result
1	+	-	-	-	+	+	+	-	$Y_1 = 2,51$
2	+	+	-	-	-	-	+	+	$Y_2 = 2,60$
3	+	-	+	-	-	+	-	+	$Y_3 = 2,08$
4	+	+	+	-	+	-	-	-	$Y_4 = 2,49$
5	+	-	-	+	+	-	-	+	$Y_5 = 2,39$
6	+	+	-	+	-	+	-	-	$Y_6 = 2,66$
7	+	-	+	+	-	-	+	-	$Y_7 = 2,26$
8	+	+	+	+	+	+	+	+	$Y_8 = 2,49$

Effect	I = 2,43	$E_A=0,125$	$E_B=-0,10$	$E_C=0,01$	$I_{AB}=0,03$	$I_{AC}= 0$	$I_{BC} =0,03$	$I_{ABC}=-0,04$

5. DISCUSSION

Using Hadamard matrix permits to improve enterprise’s activities. Two cases have been studied.

The case of 30 enterprises operating in renewable energy has revealed positive and significant relationship between Hadamard matrix and the 5 metrics of performance. First we have obtained relationship between Hadamard matrix and quality ($r = 0.694$, $\tau = 0.510$, $\rho = 0.692$ ($p < 0.0005$)). Second, relationship between Hadamard matrix and flexibility is ($r = 0.585$, $\tau = 0.433$, $\rho = 0.589$ ($p < 0.0005$)). Thirty, Hadamard matrix and speed of delivery ($r = 0.396$, $\tau = 0.164$, $\rho = 0.144$ ($p < 0.02$)). Fourth, Hadamard matrix and cost ($r =$

0.557, τ = 0.415, ρ = 0.584 (p < 0.0005)). Fifth Hadamard matrix and output (r = 0.585, τ = 0.433, ρ = 0.589 (p < 0.0005)).

Statistically, the results above showed that Hadamard matrix has permitted to improve and to innovate the performance of these enterprises operating in renewable energy. Such innovation generates financial results as verified by Fatur and al. [5]. That is because organizational innovations are conducive of cost reduction [11]. Therefore, our idea is to benchmark Hadamard process in baking industry. According to the table 6, we can deduce that the change of the hydration rate from 60% to 64% does not practically have any effect on the conservation ($\mathbf{E_A}$ = **0**). Change in the method of direct fermentation into polish (high level to low level, hence the sign minus for $\mathbf{E_B}$ = **-0,75**) brings an effect of 75% for the improvement of conservation duration. In the same way, the level of high temperature (300°C) followed up with the short time of cooking (15') contributes at 25% of the conservation of the bread ($\mathbf{E_C}$ = **0,25**). Moreover, we have noticed an effect of interactions of 25% ($\mathbf{I_{BC}}$ = **-0,25**) between the cooking method and the fermentation method. The other interactions are null. The best results (4 days) agree to experience 5 and 6; that is to say, a fermentation method on polish and a couple time-temperature of 15'-300°C. The result concerning polish confirms the previous researches while the one in relation to the cooking method is inconsistent with the affirmation saying that the lowering of temperature improves the conservation [12].

In fact, the prolonged cooking (25'-250°C) removes a great quantity of water from the dough, and more than that, the crust of the bread becomes thicker. Experimentally, the bread staling is explained as a migration of water from the crumb to the crust [2]. The bread cooked at 250° is getting stale quickly because of this loss of water and because the importance of the thickness of the crust which amplifies the trapping of the water in this external part of the bread.

To sum up, we can deduce that the most influential factor for a better conservation of the bread is the pre fermentation, in our case the polish. However, we have also to use a higher temperature and a shorter time of cooking.

As for the development, the calculation of effects of factors cited in the table 6 proves that the change of the hydration rate from 60 to 64% contributes to 12.5% ($\mathbf{E_A}$ = **0,125**). The fermentation method on polish improves also the development with a weight of 10.5% ($\mathbf{E_B}$=**-0,105**). The effects of the method of cooking and the other interactions are insignificant.

To reach the aim of our researches, we have to keep an eye on the good conservation of the bread as well as its development at the same time. Among the six levels of factors studied in the experiments matrix, we have to retain a high rate of hydration, pre fermentation instead of direct fermentation, a higher temperature followed by a shorter time of cooking. This corresponds to the experiment n°6. In other respects, let us note that we can reduce the quantity of yeast until 50% by using the fermentation on polish. Hadamard matrix has not only brought an improvement to the bread quality but it also allows a low operating cost. Fatur and al. demonstrated the last when they say that there is a correlation between the revenues arising from innovation and the financial results of a company [5].

6. CONCLUSION

An investigation was carried out in 30 enterprises operating in renewable energy in Madagascar to evaluate the relationship between Hadamard matrix and the success of the enterprises and projects, in term of improvement. The results of Pearson and Kendall and Spearman correlation analysis were positive and significant. Hadamard matrix has permitted to improve the performance of these enterprises operating in renewable energy. Moreover, a case study in bakery highlights the effectiveness of the improvement of bread conservation and its development at the same time. The previous results open another field of experiences in the optimization of the duration of bread conservation. Other matrices as composite matrices, Tagutsi design and simplex can be used in order to find the optimum of this duration. This will contribute generally to the development of the field of researches and particularly the baking and biscuits industry.

Practical implications:

- The research output permits to guide enterprise managers when improvement and innovation are concerned.
- The research process allows benchmarking to other areas.

Originality/value:

- Hadamard Matrix may be included in the list of classical strategic auditing models.

Future research:

- A research about the comparison between Hadamard Matrix and other strategic auditing models to find precision of each method can be conducted. It permits to appreciate the Hadamard Matrix strengths.

7. REFERENCES

[1]. Asaff A., Escobar F., Mayra de la Torre (2009), "*Culture Medium Improvement for Isaria Fumosorosea Submerged Conidia Production*", Biochemical Engineering Journal, Vol. 47, pp. 87-92.

[2]. Baik M., Chinachoti P. (2000),"*Moisture Redistribution and Phase Transitions During Bread Staling*", *Cereal Chem*., Vol. 77, pp. 484-488.

[3]. Beaufort A., Bourdin G., Lebail A., Cardinal M. (2007), "*Effects of a Storage at -2°C/-3°C Before Retail Displaying on the Qualities of Smoked Salmon*", 22nd International Congress of Refrigeration, Beijing, China.

[4]. Cameron P. J. (2006), "*Hadamard Matrices*", The Encyclopaedia of Design Theory*,* pp. 1-7.

[5]. Fatur P., Likar B., Ropret M. (2010), "*Going More Open in Innovation: Does It Pay?*", International Journal of Industrial Engineering and Management, Vol. 1, N°3, pp. 77-83.

[6]. Gillon F. (2004), "*Modeling and Optimization by Experimental Design of an Engine with Electronic Commutations*", Sciences and Technologies University, Lille, France, pp. 40-60.

[7]. Holzmann W. H., Kharaghani H., Orrick W. (2010), "*On the Real Unbiased Hadamard Matrices*", University of Lethbridge, Lethbridge, Alberta, T1K 3M4, Canada, Department of Mathematics, Indiana University, Bloomington, Indiana 47405, USA.

[8]. Horadam K. J. (2006), "*Hadamard Matrices and Their Applications*", Princeton University Press.

[9]. Jennifer S., Beata J., Wysocki and Tadeusz A. (2003), "*Williamson–Hadamard Spreading Sequences for DS-CDMA Applications*", Wireless Communication Mobile Computer, University of Wollongong, NSW2522, Australia, pp. 597-607.

[10]. Kazuki H., Yasuhiko K., Takashi K., Totaro I. (2003), "*Hadamard Transform Microchip Electrophoresis Combined with Diode Laser Fluorometry*", Anal. Chem., Vol. 75, N° 7, Kyushu University, Hakozaki, Fukuoka, Japan, pp. 1765-1768.

[11]. Kohl H., Depner H. (2010), "*The Implementation of an Organizational Innovation: Examples of Mass Customizing Firms of the Capital Goods Industry*", International Journal of Industrial Engineering and Management, Vol. 1, N°3, pp.85-95.

[12]. Le-Bail A., K. Boumali, Jury V., Ben-Aissa F. (2009), "*Impact of the Kinetic of Baking on Staling Rate and on the Mechanical Properties of Crumb and degassed Crumb*", Journal of Cereal Sciences, Vol. 50, pp.235-240.

[13]. Matthew. H., Petoukhov S. (2010), "*The Genetic Code, Hadamard Matrices and Algebraic Biology*", Journal of Biological Systems, Vol. 18, Special Issue, pp. 159-175.

[14]. Onoghojobi B. (2010), "*Subsample Goal Model for Multivalve on Outliers*", Journal of Mathematics and Statistics*,* Vol. 6, pp. 347-349.

[15]. Senk V., Delic V.D., Milosevic V.S. (1997), "*A New Speech Scrambling Concept Based on Hadamard Matrices*", Signal Processing Letters-IEEE*,* Vol. 4, pp. 161-163.

[16]. Singh S., Singh M. K., Singh D. K., Sindri B. (2010), "*Generalized Hadamard Matrices from Generalized Orthogonal Matrix*", Global Journal of Computer Science and Technology, Vol. 10, pp. 22-30.

[17]. Vivier S. (2002), "*Optimization Strategies Using the Experimental Design Method and Application to Electrotechnical Devices Modeled by Finite Elements*", Sciences and Technologies University, Lille, France, pp. 290-296.