COMPLETELY RANDOMIZED DESIGN OF A MARKETING EXPERIMENT

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ABSTRACT: *The marketing experiment is a deliberate, "challenged", simulated small-scale, and relatively artificial, marketing phenomenon to highlight how its evolution is influenced by one or more causal factors. The design of the marketing experiment represents the process of anticipated structuring, by means of a statistical model or a schematic representation, of the various combinations of the analyzed variables, combinations constituting the experimental treatments envisaged to be applied to groups of experimental units. The paper presents the way of organizing a marketing experiment based on the completely random method, followed by the example of the procedure for analysis and interpretation of the data obtained using the ANOVA method. The variation table summarizing the results of the dispersal analysis allows to highlight the marketing stimuli that have had a significant influence on the evolution of the dependent variable.*

KEY WORDS: *marketing experiment, completely randomized design of an experiment, analysis of variance (ANOVA), sum of squares, mean squares, observed F.*

JEL CLASSIFICATION: *C10, C90, M31.*

1. INTRODUCTION

The theory and practice of marketing research has led to the possibility of extracting relevant information about consumer and market behavior as a whole through the marketing experiment. Unlike the factual observation of marketing phenomena, an approach where marketing specialists usually play a passive role, the design of marketing experiments calls for the actual manipulation of independent variables by the experimenters in order to quantify the influence they exert on other marketing variables considered to be dependent.

The definition of the experiment is not easy to achieve, given that the term is not yet accepted unanimously. However, from the practical point of view that this work would like to offer on the statistical methods of research on economic processes, we

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can say that the marketing experiment is a deliberate, "provoked" simulation, carried out on a small scale and under relatively artificial conditions of a phenomenon of marketing to highlight how its evolution is imprinted by one or more causal factors.

Generally, conducting a marketing experiment pursues two major goals:

1) *Identifying the causal link between different marketing variables*. Depending on the chosen design scheme of the experiment, it is possible not only to estimate the isolated influence of each explanatory variable (independent) on the variance of the explained (dependent) variables but also the possibility to know *the influence of the interaction between the factorial variables on the analyzed marketing phenomenon*;

2) *Quantification of the effect (exclusive) that a change in the sphere of explanatory variables exerts on the variables explained*. As a rule, the variation of one or more explanatory variables is manipulated by the researcher in order to measure the effects it exerts on *observation units* (which may be represented by consumers, users, business units, etc.), interpreting the results obtained and identifying foreseeable evolution laws.

2. THE COMPONENTS OF THE MARKETING EXPERIMENT

The basics of any marketing experiment are:

1. Marketing variables. An experiment operates with two major categories of variables:

a) ***Independent variables*** are the factors of influence whose evolution is analyzed in the experiment. They are further grouped into two distinct categories:

- *Explanatory variables*, also called *experimental factors* or *marketing stimuli*, the value of which is deliberately modified by the organizers of the experiment to analyze the effects of these changes on the dependent variables - demand volume, sales, competition intensity, distributors' efficiency etc. Explanatory variables or experimental factors can be represented by products, their features, packaging, ancillary services, distribution channels, price levels, advertising messages etc.;
- *The random variables (from outside)* are variables that are not subject to experimental treatment, and their action can’t be manipulated by the person performing the experiment. If in the field of exact sciences, the organizer of the experiment has the possibility to ensure a constant level of these random variables, this is more difficult to achieve in marketing experiments. Therefore, a more sophisticated, statistical control of these variables is practiced in this area. In practice, this control involves two complementary approaches: *the random selection of the observation units* (which wishes to remove the influence of any differences between them in terms of location, size, structure or behavior) and the *calculation of the effect due to the experimental error* as an element apart from the effects generated by the dynamics of the explanatory variables.

b) ***Dependent variables*** (also called ***explained variables***) are effect variables that could be expressed by sales volumes, demand levels, time needed to make purchasing decisions, consumer attitudes, competition strategies, intermediary efficiency etc. During the experiment, it is vital that these categories of variables are not exposed to the effects of the disturbing factors.

2. Units of observation may be represented by stores selling certain goods, batches of products being tested, economic units involved in the experiment, buyer groups etc. whose responses to the different levels of experimental factors are monitored, quantified and analyzed. The units of observation are also divided into two categories:

- ***the experimental units*** to which experimental treatment is applied and on which the necessary measurements are carried out;
- ***control units (witness)*** that are also subject to observation but are not subject to experimental factors (statistical treatments), their role being to serve as reference for underlying changes in experimental units as a result of stimulus marketing analyze.

3. Experimental treatments are a set of actions and procedures by which the marketing specialist manipulates the explanatory variables (which in turn determines the level and dynamics of the experimental units) to record and then analyze the variance of the dependent variable values. In other words, *treatments are the very essence of the marketing experiment.* For example, they can track the change in price levels (to measure variance in demand in response to this change), functional product features (to track turnover variation), advertising (to observe changes caused by the speed of adopting purchasing decisions), etc.

4. Experimental errors. They inevitably accompany any experiment and are mainly due to the following causes:

- violation of the principle of random selection in the establishment of observation units (experimental and witness), a factor that leads to the occurrence of *selection errors*;

- inadequate precision of data measurement methods and tools that are applied during the experiment and which lead to the manifestation of *instrumental errors*;

- anomalies occurring in the behaviors of subjects who are aware of being subject to observation, thereby generating *stress errors*;

- the influence of time that causes the attention of the subjects to be distracted, the change in their mood and the commitment to take responsibility with the activities involved in the experiment, the changing of the market situation, the disappearance of subjects etc., which causes the *temporal errors*;

- random events "from outside" that cannot be controlled by researchers: changing legislation in a certain area, unpredictable strategies put in place by competing firms, natural disasters, etc.;

- intuition by the investigated subjects of the "desired results" of the research, which causes them to provide cosmeticized information, often inconsistent with reality, but which, in their view, accords with the expectations of the organizers of the experiment.

Regardless of the causes that lead to the occurrence of experimental errors, they must be quantified and kept within reasonable limits, so that their existence does not significantly affect the validity of the whole experimental approach.

The design of the marketing experiment represents the *process of anticipated structuring*, by means of a statistical model or a schematic representation, of the various combinations of the variables analyzed, *combinations consisting precisely of* *the experimental treatments* envisaged to be applied to groups of experimental units. The efficiency of organizing a marketing experiment is decisively conditioned by the choice of the *specific design scheme*.

Thus, a first category of experimental design schemes assumes the existence of a single experimental factor that acts on the explained variable and takes into account the hypothesis of a constant influence from other factors, *caeteris paribus* (such as the Solomon test or the test signs). However, the marketing practice requires the use of more elaborate experimental design methods, capable of reflecting with high fidelity the complexity of marketing phenomena. Thus, there are bi- or multi-factorial experiments that study the influence of two or more experimental factors on the variance of the dependent variable, and possibly the impact of the interaction between them on the effects of the experiment. Among the design methods of the experiments considered to be of high efficiency are mentioned: completely randomized design (uni or multi-factorial), design using random blocks (uni or multi-factorial), Latin squares, Greek-Latin squares and so on.

3. THE COMPLETELY RANDOMIZED DESIGN OF MARKETING EXPERIMENTS

This experimental design scheme is considered to be one of the most accessible organizational schemes that make it possible to observe the behavior of several experimental groups as a result of the action of different levels of an experimental factor. It has been named in agreement with the random distribution of experimental units to one of the experimental groups. To organize a marketing experiment according to this design scheme, the information extracted from the field research is systematized in the form of table 1.

Table 1. Organization of the marketing experiment by completely random design

	Levels of experimental factor					
The dependent variable	1	2	j	..	r	**Total**
The level of the dependent variable on experimental unit nj	x_{11} x_{21} . x_{1j} . x_{n1}	x_{12} x_{22} . x_{2j} . x_{n2}	x_{1j} x_{2j} . x_{ij} . x_{nj}	.. .. ..	x_{1r} x_{2r} . . . x_{nr}	***T1.*** ***T2.*** ... ***Ti.*** ... ***Tn.***
Total	***T.1***	***T.2***	***T.j***	**...**	***T.r***	***T..***
Averages	$\overline{x}_1$	$\overline{x}_2$	$\overline{x}_j$	**...**	$\overline{x}_r$	$\overline{x}$
Sum of squares	$\sum x_1^2$	$\sum x_2^2$	$\sum x_j^2$	**...**	$\sum x_r^2$	$\sum(\sum x_j^2)$

In the first column of the table below are presented experimental units to which the first level of the experimental factor was applied; the second column comprises n units to which the second level of the experimental factor has been attached; similarly, in the column j n units are presented, having sustained the level j of the experimental factor.

The meaning of the symbols that have been shown in the table below is further explained:

x_{ij} - represents the level of the variable dependent on the experimental unit *i* $(i = 1,2,\ldots,n)$ to which the experimental factor *j* applies $(j = 1,2,\ldots,r)$;

$T_{.j}$ – total column *j*;

$T_{i.}$ – total column *j*;

$T_{...}$ – the overall total of the dependent variable for all experimental units;

$\overline{x}_j$ - average values on the column *j*;

$\overline{x}$ - overall average of the dependent variable for all experimental units;

$\sum x_j^2$ - sum of the squares of the variable dependent on the experimental units in column *j;*

$\sum(\sum x_j^2)$ - sum of the squares of the dependent variable for all experimental units.

In order to successfully apply this marketing experiment scheme, the following compulsions are required:

- ✓ *A single value of the dependent variable must be associated with each experimental unit;*
- ✓ *The number of experimental units in each group (column in the table) must be the same (typically, these groups include 10-15 experimental units);*
- ✓ *Although the number of experimental factor levels is considered to be arbitrary, it is recommended that it does not exceed 5.*

Using the variance analysis (ANOVA method), we will determine whether the considered experimental factor has a significant influence on the dependent variable. For this purpose, the following steps are gone through:

1) Determining *the amount of square deviations per total (SS_T)*:

$$SS_T = \sum_{j=1}^{r}\sum_{i=1}^{n} x_{ij}^2 - \frac{T_{..}^2}{N} = \sum(\sum x_j^2) - \frac{T_{..}^2}{r \cdot n} \quad (1)$$

N – total number of experimental units observed ($N = r \cdot n$).

2) In the case of completely randomized design, the sum of the total square deviations is composed of two elements: ***the sum of square deviations between groups*** (SSFr) - which shows the influence of the experimental factor and ***the sum of square deviations within the groups*** (SSE), also called experimental error. The computational relationships for determining the two components are shown further:

Calculus of the *amount of square deviations between groups SS_{Fr}*:

$$SS_{Fr} = \sum_{j=1}^{r} \frac{T_{.j}^2}{n} - \frac{T_{..}^2}{r \cdot n} \quad (2)$$

Determining *the sum of deviations of squares within the groups SS_E*:

$$SS_E = SS_T - SS_{Fr} = \sum(\sum x_j^2) - \frac{\sum T_{.j}^2}{n} \quad (3)$$

3) *Verifying the statistical significance of the results obtained using the Fisher test*. The calculated value of F for r-1 degrees of freedom in the numerator and (or N-r) degrees of freedom at denominator is determined by the relationship:

$$F_{r-1,N-r} = \frac{SS_{Fr}}{r-1} : \frac{SS_E}{N-r} = \frac{MS_{Fr}}{MS_E} \quad (4)$$

in which: MS_{Fr} - the average of the amounts of square deviations between groups ($MS_{Fr} = \frac{SS_{Fr}}{r-1}$);

MS_E – the average of the sums of square deviations in the groups ($MS_E = \frac{SS_E}{N-r}$).

4) *Determining the results of the experiment*. The null hypothesis H_{0Fr} postulates, for a certain level of significance (α), that the experimental factor did not exert any influence on the dependent variable. If the calculated value $F_{r-1,N-r}$ exceeds the theoretical value F taken from the statistical tables, the null hypothesis is rejected by concluding the conclusion of a significant influence of the experimental factor on the dependent variable. Therefore, H_{OFr} is rejected, if $F_{Fr\ calculat} > F_{teoretic\ (r-1);N-r;\alpha}$.

4. CASE STUDY: UNIFACTORIAL MARKETING EXPERIMENT BY COMPLETE RANDOM METHOD

Managers of a company producing natural goat cheese according to a traditional recipe would like to know if the packaging of the new product is of significant importance to potential buyers. For this purpose, a marketing research is conducted on the markets of ten localities and on four different types of packaging, consisting of a sample of 12,000 consumers sent to each sample of a product presented in one type distinct packaging.

The number of orders arriving at the address of the company following the dispatch of samples of products packaged in the four different ways is systematized in the form of the data in table 2.

Taking into account the steps outlined above, we will seek to find out whether or not the packaging design has a significant influence on the number of orders received by the producing company.

For the example we consider, we will have the following notations:

i – indicative for the town;

n – number of towns considered;

j – indicative of the type of packaging;

r – the number of types of tested packaging;

x_{ij} – the number of orders received from the town *i* for the *j* type packaging;

$T_{i.}$ - the number of orders received from consumers in the *i* town;

$T_{.j}$ – the number of orders received for each type of packaging;

$T_{..}$ – total number of orders received (sum of all values of the dependent variable);

N – the number of different combinations of towns and types of packaging (total number of observation units).

Table 2. Number of orders recorded

Town	Packaging type A_1	Packaging type A_2	Packaging type A_3	Packaging type A_4
L_1	103	105	118	159
L_2	120	116	124	139
L_3	88	77	92	102
L4	141	109	150	187
L_5	90	88	100	120
L_6	98	121	128	122
L_7	85	133	148	174
L_8	110	112	131	181
L_9	143	139	106	138
L_{10}	122	130	83	168
Total	**1100**	**1130**	**1180**	**1490**

Applying the variance analysis for the marketing experiment organized according to the rules of the completely random method involves performing the following determinations:

a) In the first step, *the sum of the square deviations for the orders made in the marketing experiment* is calculated.

The number of localities considered is 10 (so n = 10) and the number of types of packaging is 4 (so r = 4); therefore the total number of constituted observation units (of combinations of localities - types of packaging) is:

$$N = 10 \text{ x } 4 = 40$$

The total number of orders is:

$$T = 1110 + 1130 + 1180 + 1490 = 4900$$

For the 10 towns, in order to determine the sum of the squares of the requested orders $\left(\sum_{j=1}^{10} x_{ij}^2\right)$ a table calculation will be made, the results of which are presented below, in table 3.

It results that:

$$\sum_{i=1}^{4}\sum_{j=1}^{6}x_{ij}^2 = 103^2+120^2+88^2+\ldots+105^2+116^2+77^2\ldots+118^2+124^2+92^2+159^2+139^2+102^2+\ldots+$$
$$+138^2+168^2=629.528$$

Therefore, the sum of the square deviations - the total variation associated with the marketing experiment will be:

$$SS_T=\sum_{i=1}^{n}\sum_{j=1}^{m}x_{ij}^2-\frac{T^2}{N}=629.528-\frac{4.900^2}{40}=629.528-\frac{24.010.000}{40}=29.278$$

Table 3.

Town	Packaging type A_1	Packaging type A_2	Packaging type A_3	Packaging type A_4
L_1	103^2 =10.609	105^2 = 11.025	118^2 = 13.924	159^2 = 25.281
L_2	120^2 =14.400	116^2 =13.456	124^2 =15.376	139^2 =19.321
L_3	88^2 =7.744	77^2 =5.929	92^2 =8.464	102^2 =10.404
L4	141^2 =19.881	109^2 =11.881	150^2 =22.500	187^2 =34.969
L_5	90^2 =8.100	88^2 =7.744	100^2 =10.000	120^2 =14.400
L_6	98^2 =9.604	121^2 =14.641	128^2 =16.384	122^2 =14.884
L_7	85^2 =7.225	133^2 =17.698	148^2 =21.904	174^2 =30.276
L_8	110^2 = 12.100	112^2 =12.544	131^2 =17.161	181^2 =32.761
L_9	143^2 =20.449	139^2 =19.321	106^2 =11.236	138^2 =19.044
L_{10}	122^2 =14.884	130^2 =16.900	83^2 =6.889	168^2 =28.224
Total	**124.996**	**131.130**	**143.838**	**229.564**

2) In the second step, the sum of square deviations per total (SS_T)decomposes into:

● *variation of orders due to experimental factor (packaging type) or sum of square deviations between groups* - *SS_{FR}*, is determined based on the relationship:

$$SS_{Fr}=\sum_{j=1}^{r}\frac{T_{.j}^2}{n}-\frac{T_{..}^2}{r\cdot n}=\frac{1110^2}{10}+\frac{1130^2}{10}+\frac{1180^2}{10}+\frac{1490^2}{10}-\frac{4900^2}{40}=609.940-600.250=9.690$$

● *the sum of the square deviations in the groups*, the deviations due to the experimental error (and arising from the influence of factors other than the type of packaging), shall be calculated using the formula:

$$SS_E=SS_T-SS_{Fr}=29.278-9690=19.588$$

3) In the last step, we will use the Fisher statistical test to *test the influence of the packaging type* (variation of the independent or experimental variable) *on the number of orders* (on the variance of the dependent variable).

The calculated value of F for a number of (r-1), i.e. of (4-1) = 3 degrees of freedom in the numerator and (N-r), i.e. (40-4) = 36 degrees of freedom in the denominator, as well as for a significance level of 95% (a margin of error of 5%), is determined by the relationship:

$$F_{4-1,40-4,1\%} = F_{3,36,1\%} = \frac{SS_{Fr}}{3} : \frac{SS_E}{36} = \frac{9690}{3} \div \frac{19588}{36} = \frac{3230}{544{,}11} = 5{,}936$$

5) *Determining the result of the experiment* - For 3 degrees of freedom in numerator and 20 degrees of freedom in the denominator, as well as for a significance level of 1% (corresponding to 99% probability of guaranteeing the results), *the theoretical value of F*, taken over from tables specifically drawn up for this purpose, will be 4.51.

5. CONCLUSIONS

Since the calculated value of F (equal to 5,936) is higher than the theoretical one (4,51), it follows that the null hypothesis H_{0Fr} should be rejected **and we will keep the conclusion that the influence of the packaging on the number of orders is significant.**

The final panel of the variance analysis is highlighted in Table 4.

Table 4.

Source of variation	**Sum of square deviations - SS**	**Number of degrees of freedom**	**The averages of square deviation sums -MS**	**Test F**	**p**
TOTAL	SS_T = 29.278	$r \cdot n - 1 = 39$	-	-	-
Between groups	SS_{Fr} = 9.690	*(r-1)*= 3	MS_{Fr} = 3230	F_{Fr}=5,936	$< 0{,}01$
Within the groups	SS_E = 19.588	*(N-r)*=36	MS_E =544,11	-	-
Final decision	H_{0Fr} is rejected because $F_{calculated}$ (5,936) > $F_{theoretical\ 3;36;1\%}$(4,51)				

The most popular type of packaging is the one with *the highest number of orders*. As, in columns, the highest total in Table 3 (equal to 1490 orders) corresponds to the A_4, package, it appears that this is the preferred option for the potential consumers in the sample.

REFERENCES:

[1]. Balaure, V. (coord.) (2003) *Marketing*, Uranus Publishing House, Bucharest

[2]. Bucea-Manea-Ţoniş, R.; Bucea-Manea-Ţoniş, R.; Epure, M. (2010) *SPSS şi Excel în analiza datelor statistice în domeniile economic, social, tehnic (SPSS and Excel in the Process of Analyzing Statistical Data within Economic, Social and Technical Fields)*, Editura AGIR, Bucharest

[3]. Alexa, E.; Stoica, C.M. (2010) *Cercetări de marketing. Teorie și aplicații (Marketing Research. Theory and Practice)*, CH Beck Publishing House, Bucharest

[4]. Cătoiu, I. (coord.) (2009) *Cercetări de marketing. Tratat (Marketing Research. Treaty)*, Uranus Publishing House, Bucharest

[5]. Constantin, C. (2012) *Analiza datelor de marketing. Aplicații în SPSS (Marketing Data Analysis. Applications in SPSS)*, CH Beck Publishing House, Bucharest

[6]. Drăguț, B.M. (2013) *Cercetări de marketing (Marketing Research)*, Pro Universitaria Publishing House, Bucharest

[7]. Foltean, F.; Lădar, L. (coord.) (2004) *Marketing. Sinteze şi aplicaţii (Marketing. Summary and Applications)*, Mirton Publishing House, Timişoara

[8]. Gherasim, T.; Gherasim, A. (2003) *Cercetări de marketing (Marketing Research*), Economica Publishing House, Bucharest

[9]. Gherghina, L. (2014) *Cercetări de marketing. Sinteze și studiu de caz (Marketing Research. Synthesis and case Studies)*, Eftimie Murgu Publishing House, Reșița

[10]. Isaic-Maniu, A.; Vodă, V.G. (2006) *Prelucrarea statistică a experimentelor (Analysis of Statistic Experiments*), Economica Publishing House, Bucharest

[11]. Jaba, E.; Grama, A. (2004) *Analiza statistică SPSS sub Windows (Statistical Analysis SPSS for Windows)*, Polirom Publishing House, Iași

[12]. Jaba, E.; Pintilescu, C. (2007) *Statistică. Teste grilă și probleme (Statistics. Tests and Applications)*, Second Revised Edition, Sedcom Libris Publishing House, Iași

[13]. Jaba, E. (2002) *Statistică (Statistics)*, Economica Publishing House, Bucharest

[14]. Lădaru, G.R.; Sima, V. (2017) *Introducere în cercetări de marketing (Introduction in Marketing Research)*, ASE Publishing House, Bucharest

[15]. Meghișan, G.; Stancu, I.; Meghișan, G.M. (2008) *Cercetări de marketing (Marketing Research)*, Sitech Publishing House, Craiova

[16]. Meghișan, G.M. (2008) *Marketing – definiții, studii de caz, aplicații (Marketing – Definitions, Case Studies, Applications)*, Sitech Publishing House, Craiova

[17]. Nedelea, M.A. (2017) *Cercetarea de marketing (Marketing Research)*, Economica Publishing House, Bucharest

[18]. Papuc, M.; Kacso, S.; Zbuchea, A. (2004) *Cercetări de marketing. Aplicaţii (Marketing Research. Applications)*, Lumina Lex Publishing House, Bucharest

[19]. Prutianu, Ş.; Anastatsiei, B.; Jijie, T. (2005) *Cercetarea de marketing. Studiul pieței pur și simplu (Marketing Research)*, Polirom Publishing House, Second Edition, Iași

[20]. Stioca, C.M. (2007) *Cercetări de marketing (Marketing Research)*, Tehnopress Publishing House, Iași

[21]. Țimiraş, L.C. (2012) *Cercetări de marketing* - *curs universitar (Marketing Research - University Course)*, Alma Mater, Publishing House, Bacău