Waste Management and Embarked Staff

M. Filomena Teodoro[1,2(✉)] , José B. Rebelo[1], and Suzana Lampreia[1]

[1] CINAV, Center of Naval Research, Naval Academy, Portuguese Navy,
2810-001 Almada, Portugal
`maria.alves.teodoro@marinha.pt`
[2] CEMAT, Center for Computational and Stochastic Mathematics, Instituto Superior Técnico,
Lisbon University, 1048-001 Lisboa, Portugal

Abstract. This case study intends to carry out an analysis of the waste management of the Portuguese Navy ships, limiting the study to the residues referring in Annexes I, IV and V of Marpol 73/78 [4], where the pollution by hydrocarbons, sewage and all types of garbage is approached. Methods and forms are analyzed of how the storage and treatment of ship waste is carried out, checking the existing equipment, its operational status and whether there is an on-board waste management plan. However, it is not enough to assess the materials and procedures. The knowledge and cooperation of the military on board for the environment are also determinants. It was built and implemented a questionnaire to the garrison of some selected NRP ships after permission of the Commander of Portuguese Surface Fleet. We have applied an exploratory factorial analysis (EFA) so we could identify the major questions contributions to the latent variables that explain literacy about waste management in ships. An analysis of variance was applied so we could get significant independent variables that contribute to explain the selected factors.

Keywords: Waste management · Environmental guidelines · NRP ships · Literacy · Questionnaire · Statistical analysis · Factorial analysis · ANOVA

1 Introduction

As is well known, the surface earth is covered mostly by water in the liquid state, representing about 71% [1], becoming a very important medium that helps regulate the balance of the entire climate system of our planet. The sea contains many other important factors for human survival, such as its high biodiversity and natural resources, which contribute to global economic development [2,7,8]. Human activity has been intensifying with the growth of the global economy, and as a direct consequence the pollution of the sea is a problem that has increased over the last centuries with the rapid economic development and consequently the population increase. This high growth has created intense pressure on the environment, in this particular case at sea, where marine litter is a major cause of intense human activity [5]. Approximately 80% of the world trade volume is transported by sea [16], causing heavy traffic of ships to be one of the main sources of pollution, which generates solid wastes, sewage and wastes from hydrocarbons, forgetting that they are also an atmospheric pollutant source [5].

In this article the objectives are to characterize the profile of waste management in NRP ships. This work was started in [12] where was compiled specific regulation about the theme. Also, in the same monography was implemented a questionnaire to evaluate Knowledge, Attitudes and Practice (KAP) about the waste management during the boarded period in the NRP ships. It was performed a preliminary statistical analysis in [14,15] using a non complete sample of boarded population, being used as reference in the present work. In this manuscript, we have continued the statistical approach proposed in [13].

This article is comprised of an introduction and results and final remarks Sects., a Sect. 2 containing the description of methodology. The empirical application, discussion and final remarks can be found in Sect. 3.3.

2   Methodology

2.1   Factorial Analysis

Factor analysis (FA) is a technique often used to reduce data. The purpose is to get a reduced number of variables (frequently denominated latent variables) from an initial big set of variables and get easier interpretations [6]. The FA computes indexes with variables that measures similar things. There are two types of factor analysis: exploratory factorial analysis (EFA) and confirmatory factorial analysis (CFA) [17]. It is called EFA when there is no idea about the structure or the dimension of the set of variables. When we test some specific structure or dimension number of certain data set we name this technique the CFA.

There are various extraction algorithms such as principal axis factors, principal components analysis or maximum likelihood (see [3] for example). There are numerous criteria to decide about the number of factors and theirs significance. For example, the Kaiser criterion proposes to keep the factors that correspond to eigenvalues greater or equal to one. In the classical model, the original set contains p variables $(X_1, X_2, \ldots, X_p)$ and m factors $(F_1, F_2, \ldots, F_m)$ are obtained. Each observable variable X_j, $j = 1, \ldots, p$ is a linear combination of these factors:

$$X_j = \alpha_{j1}F_1 + \alpha_{j2}F_2 + \cdots + \alpha_{jm}F_m + e_j, \qquad j = 1, \ldots, p, \tag{1}$$

where e_j is the residual. The factor loading α_{jk} provides an idea of the contribution of the variable X_j, $j = 1, \ldots, p$, contributes to the factor F_k, $k = 1, \ldots, m$. The factor loadings represents the measure of association between the variable and the factor [6,17].

FA uses variances to get the communalities between variables. Mainly, the extraction issue is to remove the largest possible amount of variance in the first factor. The variance in observed variables X_j which contribute to a common factor is defined by communality h_j^2 and is given by

$$h_j^2 = \alpha_{j1}{}^2 + \alpha_{j2}{}^2 + \cdots + \alpha_{jm}{}^2, \qquad j = 1, \ldots, p. \tag{2}$$

According with the author of [9], the observable variables with low communalities are often dropped off once the basic idea of FA is to explain the variance by the common

factors. The theoretical common factor model assumes that observables depend on the common factors and the unique factors being mandatory to determine the correlation patterns. With such objective the factors/components are successively extracted until a large quantity of variance is explained. After the extraction technique be applied, it is needed to proceed with the rotation of factors/components maximizing the number of high loadings on each observable variable and minimizing the number of factors. In this way, there is a bigger probability of an easier interpretation of factors 'meaning'.

2.2   Analysis of Variance

Experimental design is primarily due to *Sir* Fisher in designing a methodology for agricultural experiments. The main purpose of these methods is to

– assess how a set of qualitative explanatory variables, factors, affect the answer variable,
– discern the most important factors,
– select the best combination of factors to optimize the response,
– fit a model that can make predictions and/or adjust controllable factors to maintain the response variable in the proposed objective.

Noise factors (uncontrollable) that condition the response variable will not be considered. The different values of a factor are called levels. A combination of levels of different factors is denominated treatment. If there is only one factor, each level is a treatment. This work considers only two distinct cases: one-factor and two-factor experimental design [10, 11].

Experimental Design One Factor.   The purpose of these techniques boils down to comparing k treatments ($k \geq 2$). Suppose there are k groups of individuals chosen at random. Each group is subject to treatment, i, $i = 1, \ldots, k$. Each group does not necessarily have the same group of individuals. Consider n_i the number of individuals in group i. If in each group the number of individuals is equal, the design is denominated as balanced. When two independent ($k = 2$) random samples are available, t-tests can be established to compare means, when there are $k > 2$ independent samples there is no way to establish this test to proceed with their analysis. It is necessary to resort to a completely different technique known as analysis of variance. The data of k samples are generally presented as y_{ij}, the response of individual j in sample i.

Theoretical Model and Parameter Estimation.   Formal inference to compare means of different treatments implies the definition of probabilistic models. It is assumed that the relative data on the $i - th$ treatment have a normal distribution of mean μ_i and variance σ^2. If Y_{ij} is a random variable (rv) associated to the observed value y_{ij} the theoretical model can be represented by (3)

$$Y_{ij} = \mu_i + \varepsilon_{ij}, \ (\ j = 1, \ldots, n_{i,} \ i = 1, \ldots, k), \tag{3}$$

with ε_{ij} rv's independents and Gaussian

$$\varepsilon_{ij} \cap N(0, \sigma^2) \tag{4}$$

Treatment mean μ_i and error variance σ^2 are unknown parameters (to be estimated). Notice that the model (3) (4) is a generalization of models for two independent random samples with equal variance. It is common to write as (5) and (6)

$$\mu = \mu_i + \alpha_i, \tag{5}$$

where μ is designated the global mean given by

$$\mu = \frac{\sum_{i=1}^{k} n_i \mu_i}{\sum_{i=1}^{k} n_i} = \frac{\sum_{i=1}^{k} n_i \mu_i}{N} \tag{6}$$

with $N = \sum_{i=1}^{k} n_i$, the total number of observations. The deviation α_i, from the global mean of the $i-th$ treatment, denominated the treatment effect, is given by (7)

$$\alpha_i = \mu_i - \mu. \tag{7}$$

It is important to note that α_i are subject to the restriction $\sum_{i=1}^{k} n_i \alpha_i = 0$ with only $k-1$ linearly independent effects. Notice that $\sum_{i=1}^{k} n_i \alpha_i = 0$.

The model can be rewritten as (8)

$$Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}, \ (i = 1, \ldots, k, \ j = 1, \ldots, n_i). \tag{8}$$

The estimate of μ is given by the global sample mean (9) considering all values of k samples, being no more than a weighted average of the estimates of the mean μ_i

$$\widehat{\mu} = \bar{y} = \frac{\sum_{i=1}^{k} \sum_{j=1}^{n_i} y_{ij}}{\sum_{i=1}^{k} n_i} = \frac{\sum_{i=1}^{k} n_i \bar{y}_i}{N}. \tag{9}$$

The estimates of μ_i are the treatment sample averages given by (10)

$$\widehat{\mu}_i = \bar{y}_i \ i = 1, \ldots, k. \tag{10}$$

The estimate $\widehat{\sigma}^2$ of σ^2, the pooled sample variance, it is a weighted average of the (corrected) sample variances per treatment, being the weights the respective degrees of freedom $n_i - 1$, and is given by (11)

$$s^2 = \frac{\sum_{i=1}^{k} \sum_{j=1}^{n_i} (y_{ij} - \bar{y}_i)^2}{\sum_{i=1}^{k} n_i - k} = \frac{\sum_{i=1}^{k} (n_i - 1) s_i^2}{N - k}. \tag{11}$$

The estimate of the effect α_i of treatment i is given by the difference between the mean estimates per treatment i with the global average

$$\widehat{\alpha}_i = \bar{y}_i - \bar{y}. \tag{12}$$

We can verify that the restrictions on the effects of the treatment are maintained for the estimates, i.e.

$$\sum_{i=1}^{k} n_i \widehat{\alpha}_i = 0.$$

3   Empirical Application

3.1   The Questionnaire

After authorization by the Portuguese Surface Fleet Commander, the data collection was carried out through questionnaires and some successive visits to the ships, in which the person responsible for waste management was boarded on board each ship and the questionnaires were distributed to the military belonging to each garrison. The questionnaire is divided into two parts, the first part includes socio-demographic variables and personal details, the second part is composed with questions that allow to evaluate KAP. The initial part concerns the socio-demographic information about each participant in general:

- $Q1_1$ - *"Gender."*
- $Q1_2$ - *"Age."*
- $Q1_3$ - *"Grade."*
- $Q1_4$ - *"Have you ever attended an environmental training course?"*
- $Q1_{41}$ *"If you answered "Yes" in the previous question, it was in Navy."*
- $Q1_5$ *"Do you recycle at home?"*

The second part consists in questions of open or closed response, with the possibility of choosing more than one answer in each question, in the form of Likert scale with four levels from 1 to 4 (1 - Totally Disagree, 2 - Partially Disagree, 3 - Partially agree, 4 - Totally Agree; also some questions have a "yes" or "No" answer; one question has an open answer, it is required to identify factors that contribute for a bad waste management, this question will have a qualitative, not a quantitative analysis. The second part of the questionnaire aimed at evaluating participants' knowledge, attitudes and practices regarding waste management, comprising questions about knowledge issues, other about attitudes and some questions that consider practice details. After filling the questionnaire, the participant should give his participation as finished and submit the questionnaire to the researcher. Follows the list of second set of questions:

- $Q2_1$ - *"The environmental concern on board is always present in my daily life."*
- $Q2_2$ - *"I consider good waste management practice on board ships important."*
- $Q2_3$ - *"There are regular lectures on board on waste management ."*
- $Q2_4$ *"Sometimes I dump small waste into the sea."*
- $Q2_5$ - *"I think there is a good waste management policy on board ships."*
- $Q2_6$ - *" There are some types of waste that we can discharge into the sea."*
- $Q2_7$ - *" The glass can be discharged into the sea, as it ends up in the bottom of the sea, having no interaction with the environment."*
- $Q2_8$ - *"Paper and cardboard can be discharged at sea because they easily degrade."*
- $Q2_9$ *"Proper packaging of waste contributes to the welfare, hygiene and safety of the trim."*
- $Q2_{10}$ - *"Waste storage space is adequate."*
- $Q2_{11}$ - *"The conditions of shipboard equipment allow for the treatment of different types of waste."*
- $Q2_{12}$ - *"Even if conditions are not adequate, there is an effort and concern from the trim to minimize the environmental impact of the ship."*

- $Q2_{13}$ - *"The educational offer of the Navy in the environment preservation is sufficient."*
- $Q2_{14}$ - *"The Navy promotes, with its military staff, the preservation of the environment."*
- $Q2_{15}$ - *"There has been an increase in people's awareness of environmental preservation ."*
- $Q2_{16}$ - *" I know the Navy Environmental Policy and I know where I can consult it."*
- $Q2_{17}$ - *"I am aware of national and international regulations for reducing environmental impact."*
- $Q2_{18}$ - *"Sometimes on board, environmentally harmful acts are performed due to lack of waste treatment conditions."*
- $Q2_{19}$ - *"Feels that their role in minimizing waste generation on board is important for good waste management in the organization."*
- $Q2_{20}$ - *"On board are used environmentally friendly consumables."*
- $Q3$ - *"Has the waste generated on board ever compromised your well-being?."*
- $Q4$ - *"elect from 1 to 2 factors that undermine the proper functioning of onboard waste management."*
- $Q5$ - *"As the Navy is a military organization, do you consider your concern about the ecological footprint at sea important?"*

3.2   Sample Characterization

Firstly, was performed a descriptive analysis of the questionnaire output taking into account the quantitative and non-quantitative character of some variables.

In Fig. 1 we can find the summary about individual characterists of the respondents. On left we can observe the histogram of the of age and gender distributions. In sample, about 4/5 are men and 1/5 are women. Almost 45% of participants are aged until 30 years old and 38% are between 30 and 40 years old. The maximum age is 51 years.

Figure 2 evidences that, between the participants, 2/3 do reclycing at home and 1/3 have environmental education training.

Several tests were performed, some non-parametric correlations were computed, namely nonparametric Spearman correlation coefficient, non-parametric test of Friedman for paired samples, etc.

3.3   Results and Final Remarks

The first step is to verify the questionnaire inter consistence and homogeneity. to evaluate the internal consistence. The most common measure of questionnaire internal reliability, the alpha-Cronbach coefficient, has given a good internal consistency; also, this index indicates that when some of questions are let out of study, the internal consistence can be improved. This detail is confirmed when we perform some questions distribution comparison tests (for the set of questions asociated to knownledgement). The paired T-test, McNemar's test for frequencies comparison, Crochan's Q test comparison (where the aggregation of the distinct levels per answer as Yes/No took place). Also the Friedman test ($p-value < 0.001$) and the concordance test using the kendals coefficient ($p-value < 0.001$) were applied. The results were consensual and significant:
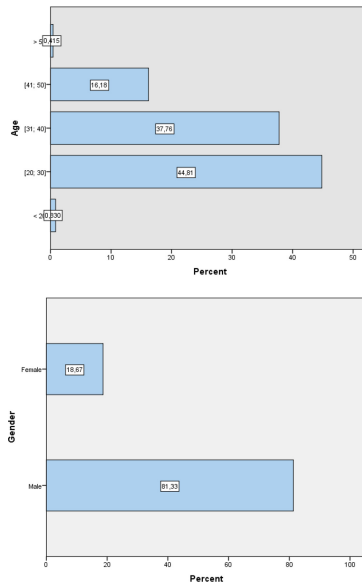
Fig. 1. On left: Sample age distribution. Considered classes: $< 20, [20, 30], [30, 40], [41, 50]$ and > 50. On right: Sample distribution per gender (male/female).

globally the questions conduced to different distribution of answers. The Spearmann correlation coefficient reveals significant relations between some questions, Friedman's test supports such association ($p - value < 0.001$). These preliminary analysys can be found in [14] Table 1 summarizes 1st, 2nd and 3rd quartiles associated to each question. In last three columns of Table 1, are displayed the median tests $p - value$ (runs test and wilcoxon test) and decision. Using such information we can say that there is enidence that m ore than 50% of participants declare that there exists the daily environmental care, consider it an important procedure, also consider that some waste can be left in sea, the waste storage contributes to welfare, security and hygiene of staff. Also embarked staff considers that the existent equipment to process waste is not enough.

The staff declares to know the internal and external rules but claims that there is not a good offer of formation in environmental education. Besides this the environmental awareness is increasing.

With the idea of simplify a high dimensional system, was applied a technique from multivariate Statistics, the EFA, reducing a large number of correlated variables to factors, establishing the correlation of observable variables and organizes them into factors, which in themselves are unobservable variables. The factors communality was computed, the R-matrix gave a significant test, the multi-collinearity or singularity was evaluated. The Bartlett's sphericity test provided a strongly significant level $p < 0.001$, confirming that there exists important patterned relations between the variables. Also, the Kaiser-Meyer-Olkin measure of sampling adequacy evidences confirmed that is appropriate to apply an EFA.
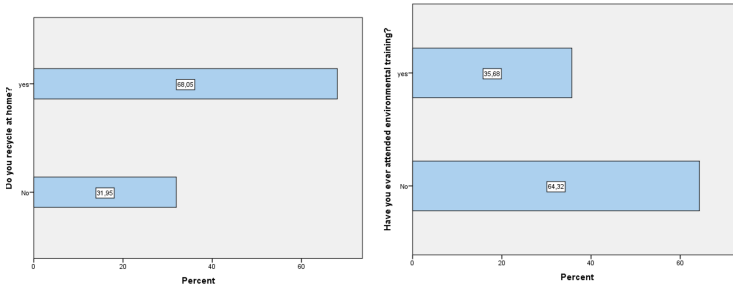
Fig. 2. On left: Sample distribution of training on environmental issues (no/yes). On right: Sample distribution of recycling activity at home (no/yes).

Table 1. Questionnaires answers. Percentiles: 25th, 50th, 75th, Wilcoxon test $p-value$, sign test $p-value$, tests decision.

Question	$1st$ quartile	$2nd$ quartile	$3rd$ quartile	Wilcoxon	Sign	Decision
$Q2_1$	2.2500	3.0000	3.7500	0.000	0.000	$med > 2.5$
$Q2_2$	3.2500	4.0000	4.0000	0.001	0.001	$med > 2.5$
$Q2_3$	1.0000	2.0000	2.0000	0.000	0.000	$med < 2.5$
$Q2_4$	1.0000	1.0000	2.7500	0.000	0.000	$med < 2.5$
$Q2_5$	1.2500	20000	3.0000	0.000	0.000	$med < 2.5$
$Q2_6$	2.0000	3.0000	4.0000	0.000	0.000	$med > 2.5$
$Q2_7$	1.0000	1.0000	1.0000	0.000	0.000	$med < 2.5$
$Q2_8$	1.0000	1.0000	3.0000	0.000	0.000	$med < 2.5$
$Q2_9$	4.0000	4.0000	4.0000	0.000	0.000	$med > 2.5$
$Q2_{10}$	2.0000	2.0000	3.0000	0.000	0.005	$med < 2.5$
$Q2_{11}$	1.0000	2.0000	3.0000	0.000	0.000	$med < 2.5$
$Q2_{12}$	3.0000	3.0000	3.7500	0.000	0.000	$med > 2.5$
$Q2_{13}$	1.0000	2.0000	2.0000	0.000	0.000	$med > 2.5$
$Q2_{14}$	1.0000	2.0000	3.0000	0.000	0.000	$med < 2.5$
$Q2_{15}$	3.0000	3.0000	3.0000	0.000	0.000	$med > 2.5$
$Q2_{16}$	2.0000	3.0000	3.0000	0.000	0.000	$med > 2.5$
$Q2_{17}$	2.0000	3.0000	3.0000	0.317	0.165	$med = 2.5$
$Q2_{18}$	2.2500	3.0000	3.0000	0.000	0.000	$med > 2.5$
$Q2_{19}$	3.0000	3.0000	4.0000	0.000	0.000	$med > 2.5$
$Q2_{20}$	2.0000	3.0000	3.0000	0.000	0.001	$med > 2.5$
$Q3$	0.0000	0.0000	0.7500	0.000	0.000	$med < 0.5$

In Table 2 are displayed the eigenvalues associated to each factor and correspondent explained variance before extraction and after extraction considereding raw data and scaled data. Is also displayed the cumulative variance percentage explained by the first i factors, we have. When we consider raw data, the first 4 factorsexplain almost 50% of variance. By opposite, when we use scaled data, we need to consider 6 factors to explain the same percentage of variance (almost %50).

Table 2. Total variance explained per factor. Top:raw data; bottom: rescaled data.

Total Variance Explained

	Component	Initial Eigenvalues[a]			Extraction Sums of Squared Loadings		
		Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
Raw	1	2,912	19,351	19,351	2,912	19,351	19,351
	2	1,545	10,265	29,616	1,545	10,265	29,616
	3	1,482	9,851	39,467	1,482	9,851	39,467
	4	1,104	7,337	46,805	1,104	7,337	46,805
	5	,860	5,716	52,520	,860	5,716	52,520
	6	,823	5,468	57,989	,823	5,468	57,989
	7	,730	4,849	62,838	,730	4,849	62,838
Rescaled	1	2,912	19,351	19,351	4,230	18,392	18,392
	2	1,545	10,265	29,616	1,466	6,374	24,766
	3	1,482	9,851	39,467	1,628	7,079	31,845
	4	1,104	7,337	46,805	1,510	6,566	38,411
	5	,860	5,716	52,520	1,040	4,524	42,935
	6	,823	5,468	57,989	1,228	5,340	48,275
	7	,730	4,849	62,838	,940	4,087	52,362

Extraction Method: Principal Component Analysis.

a. When analyzing a covariance matrix, the initial eigenvalues are the same across the raw and rescaled solution.

Table 3. Analysis of variance. Dependent variable:factor 2 (*Hygiene and Safety*). Explanatory variable: Kind of ship.

ANOVA

REGR factor score   2 for analysis 1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16,176	6	2,696	2,819	,011
Within Groups	223,824	234	,957		
Total	240,000	240			

When we use the Kaiser criterion, we select the factors whose eigenvalues are great or equal to one. We have kept the first 4 factors. We can use distinct techniques to select the "best" factors, e.g. the scree plot or the average of extracted communalities can determine the eigenvalue cutt-off (see Fig. 3).
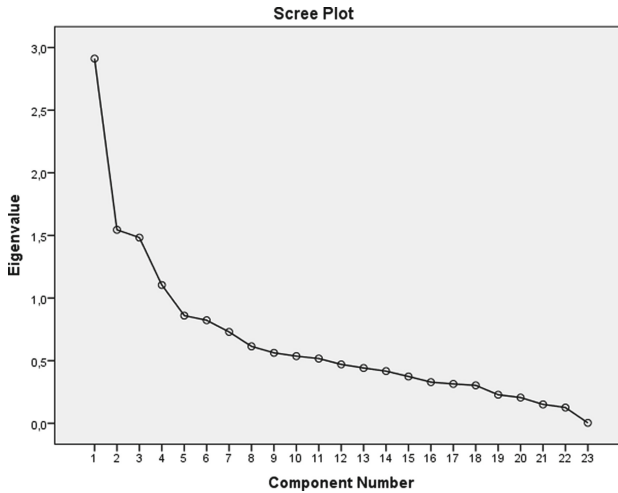
Fig. 3. Scree plot.

After the extraction process, was applied the Varimax approach,allowing to get orthogonal factors. This usefuul algorithm is often applied to identidy variables that can contribute to build indexes or new non correlated variables. We consider the case using raw data, taking the first 4 factors. In this study, we could associate a 'meaning' for the first 3 factors. The interpretation of such meaning is done analyzing the rotated factors scores. We can identify a meaning for each: F_1 combines variables that usually are associated to *Awareness*, F_2 considers variables from *Hygiene and Safety*, F_3 combines variables from *Practice*.

The selected factors (factors that have a higher variance explanation) can be considered as explanatory variables in a predictive model.

With such purpose, we have used the ANOVA technique to investigate if the *new* variables identified as important (the selected factors in the EFA) to describe the problem are related with kind of ship, the attendance of training courses, the military hierarchical posts (*praças, sargentos, oficiais*).

The kind of ship revealed significant differences in the second factor F_2 (see Table 3) when we consider different king of ships. The F test conduced to a $p-value = 0.001$ We can find such differences in the Fig. 4 where is displayed the difference of the global mean of the factor F_2 relatively to the mean per kind of ship. This difference is usually denominated an effect. Notice that from Fig. 4 we can evidence that the *hidrográfico* and *lancha* are the ships with greater positive effects on $F2$, by opposite, the *corveta* is the kind of ship that has the effect with bigger effect with negative sign. The *lancha hidrográfica*,*veleiro*, *fragata* e *patrulha oceânica* have smaller effects on factor $F2$. The military hierarchical posts (category) have no significant effects in factors $F1$, $F2$ and $F3$.
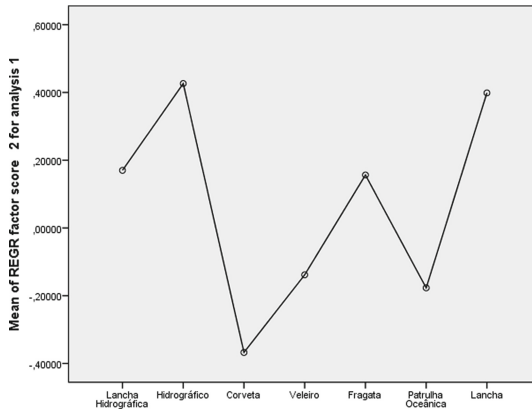
Fig. 4. Effects of the kind of ship in factor 2: difference between the mean estimates per treatment *i* with the global average (12).

The statistical evidence for different means of distinct kind of ships using Scheffé simultaneous intervals for their difference was determined, the difference of distinct means of *F*2 for the several kind of ships was considered, where the $p - value$ associated to *F* test performed to evaluate the hypothesis was obtained. We can conclude that there is significant statistical difference between the *lancha hidrográfica* and *fragata, hidrográfico, patrulha oceânica*; between *hidrográfico* and *corveta, veleiro*; between *patrulha oceânica* and *corveta, veleiro*; and between *lancha* and *corveta, veleiro*. In general, *corveta, veleiro* have a distinct padron of *Hygiene and Safety* relatively to the most of other ships.

Also were studied another kind of relations withe the 3 factors obtained by EFA, but the study is too detailed and will appear in a continuation of the present article. Some related some questions (attendance of an environmental training course, or the space to store waste) with the different qualitative variables were considered. Also was built and indicator of good practices combining the information of some questions. The results appear to be adequate and in accordance with what is expected.

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