International Journal of Science Academic Research
Vol. 06, Issue 01, pp.9113-9126, January, 2025
Available online at http://www.scienceijsar.com

ISSN: 2582-6425

Research Article

AN ANALYSIS OF THE USED LEAD ACID BATTERY (ULAB) COLLECTION NETWORK IN MAURITIUS, USING THE ESMVERE- R-HAMMING-K-MEDIAN CLUSTERING METHOD

***Emmanuel Siyawo Mvere**

Mechanical and Production Engineering Department, University of Mauritius, Moka, Mauritius

Received 15th November 2024; **Accepted** 20th December 2024; **Published online** 31st January 2025

Abstract

This research examines the challenge of hazardous waste management from Used Lead Acid Batteries (ULABs) in Mauritius, a pressing public health and environmental concern due to the risks of lead exposure. To the best of our knowledge for two decades now, there has not been any research about the level of lead poisoning contamination from the ULABs in the Mauritian environment. Thus, research or efforts to cautiously eliminate ULABs, which are one of the main causes of lead poisoning, are missing in the literature. This paper focuses on the analysis of a survey on the ULAB disposal system and probes the need to establish a new ULAB collection system. The research describes the analysis of a questionnaire dataset and contributes a novel clustering method to identify and interpret the clusters of respondents. The new method ascribes a numerical value to the best choice of the number of clusters k, when using the k-median hamming distance metric. To the best of our knowledge this is usually the most complex decision when clustering data using either the k-means or its variant the k-median. There is a need to be sure of the optimum number of clusters that give the best value of the k. The novel method uses the k-median clustering method, which is a popular choice because of its robustness and resistance to outliers. The best choice of the number of clusters is explored through an iteration of different values of k, obtaining a numerical value in each iteration thus enabling a comparison among the iterations. This value determines the measure of the best clustering performance. The data in each iteration is visualized using silhouette plots. The new method uses the Average silhouette width numerical value to simplify the choice of the best number of clusters k. The R Language was used to develop the new method. The results showed that 55% of the respondents strongly agreed that there is a need to develop a new collection system.

Keywords: k-median problem, Clustering, Silhouette value, Hamming distance.

INTRODUCTION

The vehicle population in the Republic of Mauritius is 574,772.00 [2], that is 45% of the population, which is 1,265,711 [4]. These demographics clearly show that the vehicle to person ratio on the island is high at 1:2.2 compared to many developing countries on the African continent, such as Liberia 1:3.9, Nigeria 1:12, South Africa1:5 and Tanzania 1:47 [3]. On one end, this echoes prosperity as members of the community have easy access to services that require vehicles. However, on the other hand, this raises concerns about the environment. Mauritius being an island state, a part of non-continental Africa, a tropical heaven in the Indian ocean, which derives a great measure of its wealth from the tourism industry, would do well to comply to national and international protocols on environment protection. Given that Mauritius is a signatory to numerous conventions on environment protection, it has an obligation to assess the impact of the disposal of Used Lead Acid Batteries (ULABs). The Basel Convention classifies ULABs as hazardous waste [5]. Years of importation of vehicles, resulting in a large population of vehicles, this in turn results in many parts which are disposed of in the environment, among which are vehicle batteries. 17,000–18,000 tons of Hazardous Wastes (HW) are generated annually [6], of these ULABs constitute 1100 tons. The annual 1100 tons of ULABs that are generated each year are a very dangerous health risk to the community and the environment if they are not safely collected and properly disposed. A long distance to collection facilities increases the risk of spillage or leakage to the environment and increases the risks associated with long term storage. If there is no ULAB collection facility nearby, users store the dangerous waste in their garage, or in the back yard for the whole year, where children might play with the harmful ULABs. Section 75(1) of the Environmental Protection (Hazardous Waste Standards) Regulations 2001 of the Environmental Protection Act 1991 of the Republic of Mauritius, provides that no individual shall use, store, transport or otherwise deal with hazardous waste except when that hazardous waste is stored in a container or package - (a) built and constructed to prevent spillage or leakage into the environment (b) materials from which the waste is not susceptible to attack or which are liable to form harmful compounds with the waste; and (c) materials from which the waste is not susceptible to attack; and (d) materials designed to ensure safe, full or partial emptying of the waste [7]. The law has provisions to ensure the safety of the environment and reduces the pollution that results from the handling of all hazardous waste, including ULABs. However, the absence of an appropriate collection system does not help in the enforcement of the regulation.

The atrocious dangers and the adverse health problems associated with ULABs developed the need to study where and how they are being disposed of, in the Republic of Mauritius, to reduce or eliminate the contamination of the environment, and to avoid the harmful health effects associated with lead exposure.

Thus, the following objectives were formulated for this research study:

Corresponding Author:** ***Emmanuel Siyawo Mvere,
Mechanical and Production Engineering Department, University of Mauritius, Moka, Mauritius.

- To investigate the disposal of ULABs in Mauritius
- To investigate the impact of the disposal of ULABs on the Mauritian environment.

LITERATURE REVIEW

The impacts of lead exposure from ULABS in the Republic of Mauritius

A survey conducted [8] evaluated the lead burden of the Mauritian population. A sample of 312 people were chosen as selected occupational and residential subgroups. Blood samples from these individuals showed a high blood lead in certain population groups in Mauritius, such as traffic policemen, paint sprayers and petrol station attendants, with levels averaging 12-15 mcg dl ^(-1) [8]. High blood lead results were detected in the vicinity of a lead battery factory on the outskirts of the capital city Port Louis in which 4 children living adjacent to the battery factory were found to have blood lead in the range 30-66 mcg dl ^(-1) [8]. This research was conducted in the early nineties; however, the survey proved the dangers that some members of the population were facing due to the ULAB contamination then. 30-66 mcg dl ^(-1) is very high and at a level harmful to the developing brain of young children. Since [8] there is a wide gap in research and not much data on the subject. Journal articles and reports on this danger are scarce.

Hamming Distance

A name is an important symbol of any person or any object's individual distinctive identity. The upsurge of the modern ubiquitous computing environments, interactive Artificial Intelligence, quantum computing and many global trends in communication technology, have resulted in extremely large volumes of data from which meaningful information must be obtained. There is now more than ever a need to be innovative in terms of how we derive meaning from all this data. There is an impending need to develop new methods of analyzing the new types and large volumes of data that have become available across multiple social media platforms in response to surveys. At times, there is a need to know who is saying what? about a topic or specifically from which group or cluster or class of respondents do they belong to, so that we can verify their credibility towards the subject matter. This is where the clustering of data with names or string labels becomes more significant.

The emergence and popularity of e-governance and various online social media platforms like X, LinkedIn, WhatsApp and Facebook offer unique opportunities for people to interact and share their opinions, voice their concerns regarding public policy decisions, shaping social and economic policies in their society and in the global community. In cases such as the voters' role for online elections, names and string data can be found to be of crucial importance. Clinical documents data such as medication labels or symptom names all these platforms demand the need of analyzing strings or named or labeled data. The hamming distance is the number of points between two strings of equal length where the corresponding letters of the strings are different [1]. This is the distance between the strings datatype or simply the difference between the characters of two string words of equal length. For example, when names are grouped into clusters, the distance between two names is the difference in the number of letters within the names that are identical or similar in the same corresponding position. When four names Mvere, Mwire, Ponsly and Consly are clustered into two clusters for k = 2. The names Mvere and Mwire form a cluster because they have the letters M, r and e that are identical and in the same corresponding position, grouping them into a cluster. The hamming distance between the name Mvere and Mwire is closer than the distance between Mvere and Consly or Mvere and Ponsly. However, the hamming distance between Ponsly and Consly is closer than the distance between Mvere and Mwire because, Ponsly and Consly have only one word character which is different in the same corresponding position, the P or the C. The two names Ponsly and Consly have the letters o, n, s, l and y that are identical and in the same corresponding position, so they have a closer hamming distance and form a second separate cluster. All the names in the data-set are divided into groups or clusters, then the median names become the center of each cluster. That is how the k-median algorithm minimizes the hamming distance between two strings of equal length.

k-median problem

The k-median algorithm is a variant of the k-means clustering technique. The aim of the K-means algorithm is to minimize the sum of squared distances between the data points and their respective cluster centroid. The data collected in many real-world applications may be contaminated with outliers, which can make traditional clustering methods such as K-means sensitive to their presence. Thus, robust clustering algorithms such as k-medians are used to produce more reliable outcomes [9]. Clustering is a popular form of unsupervised learning [10]. Unsupervised learning deals with unlabeled data, neither an example is given to the model, nor an output is given; only input data is given and based on that the model makes predictions.[12]. k-Median is perhaps the most well-studied clustering objective in finite general metrics.[13]. In metric k-median clustering, we are given as input a set of *n* points in a general metric space, and we have to pick k centers (median points) and cluster the input points around these chosen centers, so as to minimize the median objective function [12]. This paper describes the analysis of a survey questionnaire dataset to identify clusters of named respondents and understand what these clusters are. The need of a new system of ULAB collection in the Republic of Mauritius is investigated. The main objectives are to investigate the disposal of ULABs in Mauritius, and to investigate the impact of the disposal of ULABs on the Mauritian environment. A novel data analysis method, the ESMvere-R-hamming-k- median clustering method, is developed to analyze the data. The novel method is based on the hamming distance variant of the k-median clustering technique. The R Language was used to develop the new method. Survey research was conducted which involved raw data collection and statistical analysis

METHODOLOGY

Research Approach

The quantitative research approach was adopted for this study. Numbered data was analyzed using statistical procedures and techniques. However, there were also some qualitative findings from the face-to-face interviews, which were compared and analyzed. Survey research was conducted which involved raw data collection and statistical analysis on published health data from the Mauritius Institute of Health and Metrics Evaluation.

Research Questions

To achieve the objectives, the following research questions were devised:

- Is there a system in place to carefully collect and dispose of ULABs?
- What is the existing structure and network for the life cycle of a vehicle battery in the Republic of Mauritius?
- To what extend is lead exposure from ULABs a health concern in Mauritius?
- How has the environment and the community been affected by exposure to lead poisoning or Sulphuric acid poisoning from the ULABs?
- Is there any related health research that has been conducted to analyze the risk of lead poisoning and its effects?
- Are there any health records that are related to the exposure of lead poisoning from ULABs?
- Have samples been collected prior to the research, from the community, from the soil, from animal life, from the plants that could assist in capturing the extent of the pollution?
- Could the results from the samples be related to inadequate ULAB disposal?

Research Design and Data Sources

Descriptive research which sought to describe the existing structure and network of the ULAB life cycle, from importation to the disposal, including a study of the effects of the inadequate disposal of ULABs was chosen. Primary data sources included information collected and processed directly from observations, face-to-face interviews, paper, and email questionnaires.

Population Size

Data was collected from a population of 91 authorized dealers in the importation and sale of motor vehicles [15], 31 authorized dealers in the importation and sale of vehicle batteries [2] and from a population of 10 registered exporters of ULABs. Five other members of various industries were selected, including the Ministry of Health and Wellness. This made a total population of 137 companies or their chosen representatives. This was an adequate size population considering that Mauritius is a very small island with a total population of less than 1.2 million people.

Sample size

A sample size of 40 was chosen to represent the population. Stratified sampling was used to divide the members of the population into subgroups. The subgroups comprised of 26 authorized dealers in the importation and sale of motor vehicles, 9 authorized dealers in the importation and sale of vehicle batteries, 3 registered exporters of ULABs and 2 members from the Ministry of Health and Wellness. Primary data sources included data from the Solid Waste Management Division of the Ministry of Environment, Solid Waste Management and Climate Change of Mauritius, the Ministry of Health and Wellness and the Mauritius Institute of Health and Metrics Evaluation. Primary data was collected from the Interim Storage Hazardous Waste Facility at La Chaumière, Bambous were face-to-face interviews were conducted, and paper questionnaires were filled. Data collection also involved a trip to the Mare Chicose Landfill area were face-to-face interviews were conducted, and paper questionnaires were filled. Data collection also involved a trip to the company Edasich Metals Ltd in Triolet, which is a registered ULAB exporter, were face-to-face interviews were conducted, and paper questionnaires were filled in.

Data was also collected from the company Eclair Batteries Ltd in the Plaine-Lauzun industrial zone Port Louis, which is an industry leader in the vehicle battery business in Mauritius, with over 60 years' experience, Eclair Batteries Ltd imports, resells, repairs, and exports the ULABs. Data collection also involved a trip to the company Companies Mauricienne de Commerce CMC were face-to-face interviews were used to collect data from the personnel of this company which is an automotive industry leader in vehicle tire retreading. Secondary data on prior research related to the objectives of this study was collected. Secondary data sources included data from the website of the Trade Division of the Ministry of Industry, Commerce and Consumer Protection. Sources of the data included the Internet and library searches. Secondary data was also collected via emails from the Central Statistics Office (CSO) and the National Transport Authority.

Data was also collected from the author of [1], who was consulted via email to verify the use, discovery, innovation, and invention of the novel method of data analysis. His work on applying the k-median algorithm to perform marketing data, customer segmentation in the R Language was modified and reconstructed through innovations on the dataset data questions realignment, to develop a new method which segments the specific ULAB dataset, both the results and the modifications of this method are novel and unique to this study. However, the model developed is replicable in other contexts for other type questionnaires as it simply involves rewriting the questionnaire questions on the data csv excel data sheet.

Questionnaire Design

A questionnaire was developed for the purpose of data collection (Appendix B). The questions were structured in relation to the objectives of the study. It was designed to measure if ULABs were being adequately, safely disposed of in the Republic of Mauritius. Both closed and open-ended questions were used to test the accuracy of the ULAB disposal methods**.** Respondents gave their knowledge, observations, views and opinions regarding the disposal, the impact of the disposal, and whether developing a new system of ULAB disposal was the key solution. The same questionnaire was used to target the distinct categories of the population. A Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used to rank the responses of five key questions (See Appendix B). The questionnaire was designed in such way that it would give an overview of the history of ULAB collection in the Republic of Mauritius. The current situation around the collection of ULABs was also investigated so that it would give room to the proposed suggestions of a new collection system if the need for it was determined. The main purpose of the questionnaire was to investigate if the current collection systems were adequate for the safety and health of the people, and the environment in general. Thus, questions of whether there were direct health impacts from the current collection systems in place?

The target population consists of all those who were involved in the vehicle battery industry including importers, the users, the collectors and the senior health officials**.** The information was going to be used to investigate if the current collection network of disposal was sufficiently safe and healthy for the people and the environment or if a new collection, new collection network was needed? The questionnaire was to find out if there was a need to develop a reverse collection network for ULABs. The questionnaire was adequate because it had a few very clear questions that were specific to the investigation of the old, current and suggestions for the future if there was a need to develop the network.

Data Analysis Software Methodology

The R language code that follows is a detailed series of steps that were used to analyze a data-set of questionnaire responses, gathered for the survey of this study. The k-median method was to cluster the data using the hamming distance metric. The series of steps that processed the data-set were already existing before they were used for this study [1]. However, the purpose for which they were used was changed from marketing segmentation to the Data analysis of questionnaire responses. The series of steps that were being used to analyze marketing data for market segmentation, were reconstructed to perform Data analysis. A deep study was made on the series of steps before they were refocused, and the marketing dataset was also thoroughly analyzed. A deep study of the data-set led to the discovery that the method could be modified and reconstructed to process questionnaire type questions. A careful study of the excel csv spread sheet revealed that the layout of the variables could be reconstructed to develop a binary Matrix from a data-set of questionnaire responses. This discovery led to a series of tests on the new data analysis method. The results of the tests proved successful. The success came from how the questionnaire questions were laid out on the excel csv spread sheet. Expert opinion was used to verify the method and to also analyze the results on the innovation. The author of [1], confirmed the innovation and further explained the results and offered key advice. The method can be used in many other cases where there is a data-set of questionnaire responses. It simplifies the process of obtaining the silhouette value that reflects the best choice of the number of clusters in a hamming distance metric, string type dataset of questionnaire responses. It is a method which groups the names of the respondents and clusters their responses. The responses of the method could be extended by further work to artificial intelligence because it affords the median sentence like responses to questions from each cluster. While the largest cluster is the most meaningful representation of the data. It gives groups of clusters as silhouette plots.

The R Language

R's $skmeans$ package was used to perform k-medians clustering [1] used the k-medians clustering technique to perform customer segmentation with R and visualize the data as clusters, using silhouette plots. The method of data analysis used by [1] was modified and the k-medians clustering technique was used to perform segmentation of the responses to the questionnaire. Using the Esmvere hamming k-median clustering method, respondents with similar answers were grouped together to form a cluster, their names were used to distinguish and identify to which cluster they belong, The largest cluster would give the best representation of the dataset. The k-median algorithm was used to partition the data into clusters, and to analyze the characteristics of each cluster. The median of the k-median clustering technique is a statistic that is highly resistant to outliers, as opposed to the mean of the k-means clustering technique, which is a measurement that is highly vulnerable to outliers. Even just one drastic outlier can pull the value of the mean away from the majority of the data set, which can be a high concern when operating on very large data sets [14]. Silhouette plots, were used in describing the data and presenting the characteristics of each cluster. The respondents were grouped into clusters from k2- meaning 2 clusters to k5 meaning 5 clusters. The silhouette can help identify the value of k which produces the best clustering performance from the data. The average silhouette value acts as a measure of the overall clustering performance, the higher the value, the closer it is to 1, the better. Thus the data was clustered repeatedly from k2 to k5, to achieve the highest value from the average silhouette widths, this needed to be done because it was a comparison of them that would give the best value of **k**. The value of the average silhouette widths which was closest to 1, gave the best value of k and the best description of the characteristic qualities of the data. Responses from the questionnaires were analyzed using R version 4.0.0 (2020- 04-24) – "Arbor Day".

The list that follows, is a list of R commands used to partition the data into clusters : Responses from the questionnaires were used to develop a comma separated values dataset Figure 1.

- ulab <- $read.csv(".ulabdata.csv")$ was used to read the csv file from the documents library [1]. The data was read as a data frame and brought to the R application for processing.

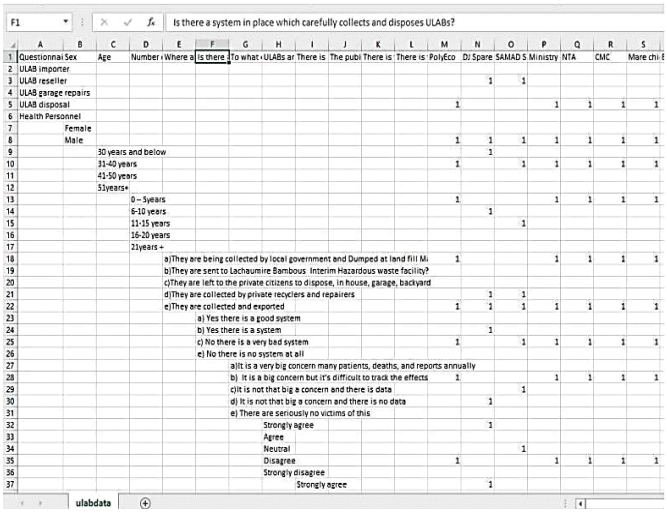


Figure 1. Dataset

The R libraries $skmeans$, $cluster$, and $dplyr$ were called. The $skmeans$ library is required for the k-medians algorithm. The $cluster$ library is required for calling the silhouette function. The library $dplyr$ is required for summarizing, ordering and filtering data features

Metadata columns were removed. The metadata columns are the innovative idea behind the invention of the new data analysis method. The questions are arranged in the metadata column in such a way that the answers can be converted to binary form. This method is usable on all questionnaires , however, to use it there has to be a thorough, careful study of the metadata arrangement of the questionnaire questions.

Figure 2 shows the metadata columns that were removed to create a matrix from the data set.

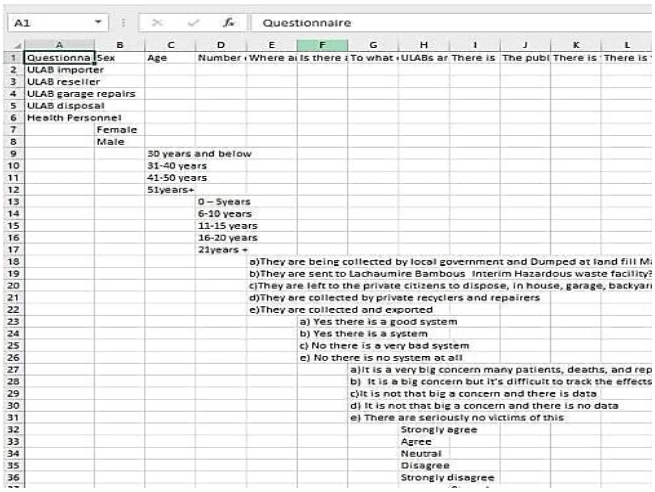


Figure 2. Metadata

- ulabUB <- $t(ulab[, -c(1,2,3,4,5,6,7,8,9,10,11,12)])$ declares a new variable $ulabUB$, metadata columns are removed, and the data frame is transposed.

Blank entries were removed to create a 0 and 1 matrix.

- ulabUB[$is.na(ulabUB)$] <- 0 replaces blank entries with zeros
- ulabMatrix<-$as.matr(ulabUB)$ converts the data frame to type matrix The variable $partition$ was used repeatedly to partition the dataset into clusters from k2 for 2 clusters to k5 for 5 clusters. This needed to be done because it was a comparison of them that would give the best value of k.
- partition <- $skmeans(ulabMatrix, 2)$ Segments the respondents into clusters looping from 2 clusters to 5 clusters $skmeans(ulabMatrix, 5)$. Figure 3, 4, 5 show the outcome of the segmentation. $partition$ returns a summary statement of the segmentation [1]

```
> partition <- skmeans(ulabMatrix, 2)
> partition
A hard spherical k-means partition of 40 objects into 2 classes.
Class sizes: 22, 18
Call: skmeans(x = ulabMatrix, k = 2)
```

Figure 3: Partition of k2.

```
> partition <- skmeans(ulabMatrix, 3)
> partition
A hard spherical k-means partition of 40 objects into 3 classes.
Class sizes: 10, 8, 22
Call: skmeans(x = ulabMatrix, k = 3)
```

Figure 4. Partition of k3

- Create a vector of respondent names for each cluster. The vector, partitioncluster contains the information on which cluster each respondent has been assigned to Figure 5
- Print the respondent names for each respondent in their cluster, Figure 5.

```
> cluster_1 <- names(partition$cluster[partition$cluster == 1])
> cluster_2 <- names(partition$cluster[partition$cluster == 2])
> cluster_3 <- names(partition$cluster[partition$cluster == 3])
> cluster_1
[1] "PolyEco"                 "Ministry.of.Environment"
[3] "NTA"                     "CMC"
[5] "Mare.chicosse.Landfill"  "Bennett"
[7] "Brooks"                  "Brown"
[9] "Butler"
> cluster_2
 [1] "DJ.Spare.parts" "Campbell"       "Carter"         "Clark"
 [5] "Collins"        "Cook"           "Cooper"         "Cox"
 [9] "Cruz"           "Davis"
> cluster_3
 [1] "SAMAD.Silencers" "Diaz"            "Edwards"         "Evans"
 [5] "Fisher"          "Flores"          "Foster"          "Garcia"
```

Figure 5. Vector of names

Examine the characteristics of each cluster using the aggregation function, the range [,2: 56]) informs R that it is reading from row 2 to row 56, which is the last row of the csv dataset excel spread sheet.

- clusterCounts <- $t(aggregate(ulabUB, by = list(partitioncluster), sum)[,2: 56])$

The range $ul[, c(1: 12)]$ informs R that it is adding back the meta data columns from column 1 to column 12 of the csv dataset excel spread sheet.

- clusterCounts <- $cbind(ulab[, c(1: 12)], clusterCounts)$ add back the meta data columns
- $he(arrange(clusterCounts, -clusterCounts"1"),12)$ The arrange function in the dplyr package is used to view the characteristics of the different clusters [1]. Results are arranged by cluster

Figure 6 shows that the cluster center is from the ULAB disposal, male respondents in their 31-40 years who have spent about 0-5 years in the automotive industry. These cluster responses were displayed per each cluster, for k2 they were 2 clusters and for k5 they were 5 clusters. The median responses for each question in the questionnaire for the cluster were displayed. The most relevant responses were from the value of k which had the highest average silhouette widths.

The highest average silhouette widths was from the k3 clusters of 0.35 for 3 clusters, Figure 10. Therefore the responses for each questionnaire question, for each of the 3 clusters were studied, these defined the characteristics of the data. The differences between the responses per each question of the questionnaire for each of the 3 clusters, as well as the size of each cluster gave an accurate representation of the data.

```
> head(arrange(clusterCounts, -clusterCounts$"1"), 12)
    Questionnaire  Sex         Age Number.of.years.in.the.Automotive.industry
V4  ULAB disposal
V7                Male
V9                     31-40 years
V12                                                          0 - 5years
V17
V21
V24
V27
V34
V38
V45
V46
                                        Where.are.ULABs.being.disposed.of.in.Mauritius.
V4
V7
V9
V12
V17 a)They are being collected by local government and Dumped at land fill Mare Chicose
V21                                                    e)They are collected and exported
V24
V27
V34
V38
V45
V46
    Is.there.a.system.in.place.which.carefully.collects.and.disposes.ULABs.
V4
V7
V9
V12
V17
V21
V24                                    c) No there is a very bad system
V27
V34
V38
V45
V46
                To.what.extend.is.exposure.to.ULABs.a.health.concern.in.Mauritius.
```

Figure 6. Characteristics of Cluster1

The variables silhoutte_k2, silhoutte_k3, silhoutte_k4, silhoutte_k5 were created to perform the silhouette function on the $partition$ variable. The variables silhoutte_k2, silhoutte_k3, silhoutte_k4, silhoutte_k5 were then used to display a summary of the clustering at each k.

- silhoutte_k2<-$silhouette(partition)$
- $summary(silhoutte\_k2)$

The silhouette function $silhou()$ was used to produce a summary of the silhouette clusters. The closer the value is to 1 the better [1]. The mean value of 1 means that the responses within the cluster are so close together towards the cluster center that they are almost identical.

```
> silhouette_k2 <- silhouette(partition)
> summary(silhouette_k2)
Silhouette of 40 units in 2 clusters from silhouette.skmeans(x = partition) :
 Cluster sizes and average silhouette widths:
      18       22
0.2192964 0.3859765
Individual silhouette widths:
    Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
0.06478 0.24579 0.29441 0.31097 0.39813 0.49411
```

Figure 7. Summary of k2

```
> silhouette_k3 <- silhouette(partition)
> summary(silhouette_k3)
Silhouette of 40 units in 3 clusters from silhouette.skmeans(x = partition) :
 Cluster sizes and average silhouette widths:
      22       10        8
0.3582610 0.2540336 0.4410298
Individual silhouette widths:
    Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
0.03267 0.28848 0.36139 0.34876 0.44020 0.50512
```

Figure 8. Summary of k3

The silhouette clusters were displayed as plots using the plot function $p()$.The average silhouette width is displayed as part of the plot. A summary of 2 clusters Figure 7 produces the silhouette plot Figure 9. A summary of 3 clusters Figure 8 produces the silhouette plot Figure 10. A summary of 4 clusters produces the silhouette plot Figure 11.

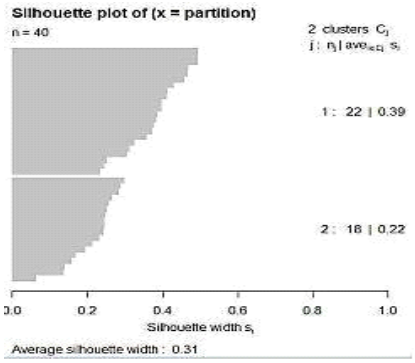


Figure 9. Silhoutte plot of k2

The average silhouette widths for 2 clusters is 0.31 on Figure 9, for 3 clusters is 0.35 on Figure 10, for 4 clusters is 0.30 and for five clusters is 0.31. The values report that the best value of k was 3 for 3 clusters. 3 clusters were then used to describe the data, because the highest average silhouette width of 0.35 was from the k3 cluster.

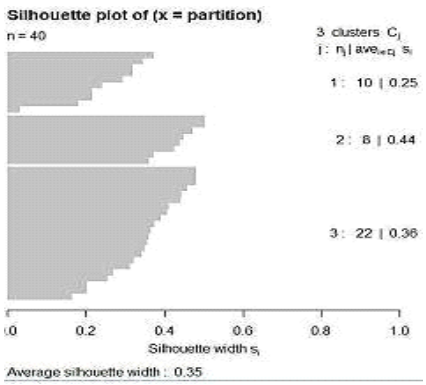


Figure 10. Silhouette plot of k3

Sensitivity testing and validation

To test the validity and reliability of this novel method of data analysis, a dummy CSV dataset was used. The 30 respondents of the dummy data set were grouped into 6 groups of 5 responses. Each of the 6 groups had five identical responses from 6 questionnaires. This was done to test if:

- The method would identify the 6 clusters of size 5 each
- The method would expose that the responses within the 6 different clusters are all identical with a silhouette width of only 1
- The method would be able to produce the six different responses and distinguish which cluster they belong

The method was able to cluster the dummy data set of 30 respondents into 6 well separated clusters, Figure 11. The silhouette width of each cluster was 1, Figure 12.

```
> summary(silhouette_k6)
Silhouette of 30 units in 6 clusters from silhouette.skmeans(x = partition) :
 Cluster sizes and average silhouette widths:
5 5 5 5 5 5
1 1 1 1 1 1
Individual silhouette widths:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
      1       1       1       1       1       1
```

Figure 11. Test of k6.

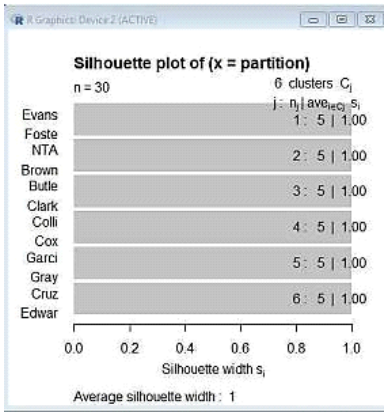


Figure 12. Silhouette plot of k6

The same data set of 30 respondents was grouped into 2 groups from the 6 questionnaires. This was done to test if:

- The method would create the 2 clusters
- The method would expose that the responses within the different clusters are different as opposed to the previous example.
- The method would be able to classify the 6 different questionnaires of 5 each to create a test dummy data set of 30, into 2 clusters

```
> silhouette_k2 <- silhouette(partition)
> summary(silhouette_k2)
Silhouette of 30 units in 2 clusters from silhouette.skmeans(x = partition) :
 Cluster sizes and average silhouette widths:
      15       15
0.4892829 0.4193574
Individual silhouette widths:
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
 0.3695  0.4129  0.4741  0.4543  0.4975  0.4978
```

Figure 13. Test of k2

The tests ULAB-k6test Figure 11 and ULAB-k2test Figure 13 from the 6 different questionnaires of 5 each, which was used to create a test dummy data set of 30, brought out the differences between the identical responses with a silhouette width of 1 for each cluster, which means the responses are

exactly the same. The same data set was partitioned into two clusters. The results clearly showed that the responses from the two clusters have silhouette widths of 0.49 and 0.42 for clusters 1 and cluster 2 respectively, Figure 14.

The data from the k6 was well separated with an average silhouette width of 1 which means the groups are identically the same. The data from the k2 was not well separated, the clusters are not quite clear with an average silhoutte width of 0.45. Thus the groups are not exactly the same, the two groups don't have the same values, there is a difference between the groups.

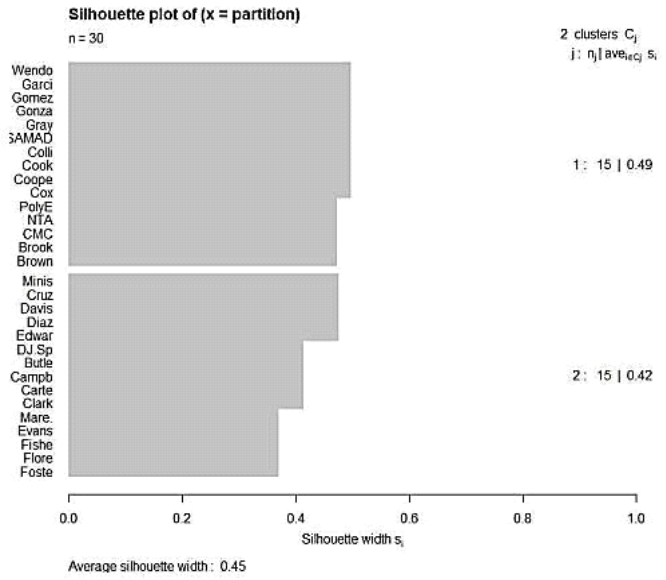


Figure 14. Silhouette plot of k2

The differences from the two tests from the dummy dataset, clearly spell out how reliable the k-median can be in analyzing and grouping the similarities of the datasets.

To verify this method [1] was consulted via email, the response revealed:

- In using k-medians, one has the freedom to specify the number of clusters (k).
- The silhouette can help identify the value of k which produces the best clustering performance from the data.

This is the strength of the new method; this statement also coincides with [10] who propose the choice of the optimal number as the minimization of a risk function via penalization.

- The average silhouette value acts as a measure of the overall clustering performance, the higher the value the better.

The new method is an improvement to the conventional

The new method of data analysis gives direct sentences like responses that are clearer in their meaning. Figure 6, Figure 15, to Figure 23 demonstrate the interactive sentence like responses from each cluster. This makes interpretation of the responses extremely easy. The use of Silhouette plots is another advantage of this method. The Silhouette plots make it easy to identify were the larger percentage of responses from the data are grouped together. Figure 9, Figure 10 demonstrates how k=3 produces the best clustering performance of the data with an average Silhouette value of 0.35. Cluster 3 of Figure 10 groups 22 out of 40 respondents together then the characteristics of this large cluster are analyzed in Figure 15 to Figure 23.

RESULTS AND DISCUSSION

Data Analysis of the questionnaire responses

The most relevant responses were from the value of k which had the highest average silhouette width. The highest average silhouette width was from the k3 clusters of 0.35 for 3 clusters, Figure 10. Therefore the responses for each questionnaire question, for each of the 3 clusters were studied; these defined the characteristics of the data. The differences between the responses per each question of the questionnaire for each of the 3 clusters, as well as the size of each cluster gave an accurate representation of the data. The largest of the 3 clusters grouped 22 respondents together with a silhouette width of 0.36 . The second and third largest clusters grouped 10 and 8 respondents with silhouette widths of 0.25 and 0.44 respectively. This shows that the largest cluster, cluster 3, Figure 10 grouped more respondents, 22, than the two other clusters combined, cluster 1 and cluster 2 which grouped 18 respondents together. Figure 15 shows the outcome of the questionnaire responses for the largest of the 3 clusters. The first section displays the demographic characteristics of the respondents and from which area of the ULAB industry they are from. In this case the cluster consists of respondents from the ULAB garage repairs. It is composed of both male and female respondents. The age of the respondents is 31-40 years.

```
> head(arrange(clusterCounts, -clusterCounts$"2"), 12)
       Questionnaire    Sex         Age
1
2
3
4
5  ULAB garage repairs
6
7
8
9                      Male
10                          31-40 years
11                   Female
12
   Number.of.years.in.the.Automotive.industry
1
2
3
4
5
6
7
8
9
10
11
12
   Where.are.ULABs.being.disposed.of.in.Mauritius.
1
2
3
4
5
6              e)They are collected and exported
7
```

Figure 15. Characteristics of cluster 2 for k3

The second section shows that there was an error in the response to the question of the number of years in the automotive industry, the results did not display the median response of the cluster. The software results showed that only this response from the largest cluster was not properly filled.

This question displayed a blank response. Further analysis and testing on the use of this method and the software is to be done, so as to answer why some responses were not displayed.
For the third section of the largest cluster, the dominating response for those in this cluster, for the questionnaire question: Where are ULABs being disposed of in Mauritius? is : e) they are collected and exported. From this response it is clear that the cluster answered that ULABs are being collected and they are being exported. The outcome of the questionnaire responses for the fourth section Figure 16, from the largest cluster, in response to the question: Is there a system in place which carefully collects and disposes of ULABs is: c) No there is a very bad system.

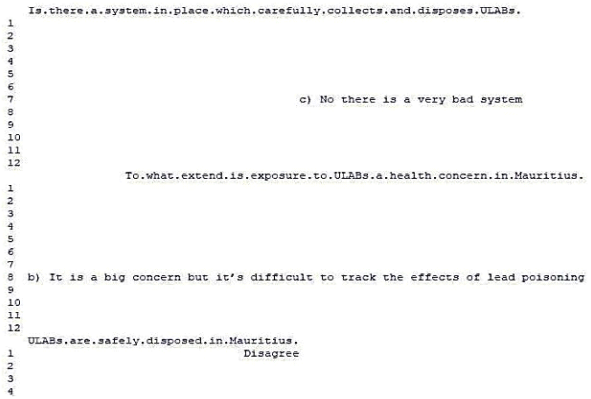


Figure 16. Characteristics of cluster2 for k3b

This response is coming from the largest of the three clusters which groups 22 responses Figure 10. The outcome of the questionnaire responses for the fifth section, Figure 16, from the largest cluster, in response to the question: To what extent is exposure to ULABs a health concern in Mauritius is: b) It is a big concern but it's difficult to track the effects of lead poisoning. This means the hazard of exposure to lead from ULABs is a concern to members of this industry but it is difficult to track those who have been affected. The outcome of the questionnaire responses for the sixth section, Figure 16, from the largest cluster, in response to the question: ULABs are safely disposed in Mauritius? is: Disagree. This means the largest cluster of those in this industry is saying ULABs are not safely disposed of in Mauritius.

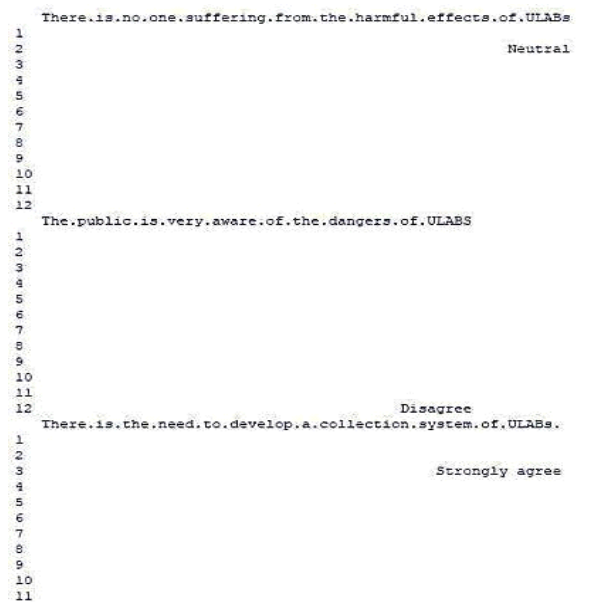


Figure 17. Characteristics of cluster2 for k3c

The outcome of the questionnaire responses for the seventh section Figure 17, from the largest cluster, in response to the question: There is no one suffering from the harmful effects of ULABs is: Neutral. This question is from a Likert- type scale ranging from 1 (strongly disagree) to 5 (strongly agree), neutral is the medium answer. This could mean it is not clear how to define a victim of the effects of ULABs so the median response is neutral. Some qualitative responses to the question, from the interviews, were it is a medium to long term problem it can take years before some members of the community even know that they have been poisoned. The results of the questionnaire responses for the eighth section Figure 17, from the largest cluster, in response to the question: The public is very aware of the dangers of ULABs? is: Disagree. This means the largest cluster of those in this industry is saying there is no public awareness on lead exposure from ULABs. The outcome of the questionnaire responses for the ninth section, Figure 17, from the largest cluster, in response to the question: There is the need to develop a collection system of ULABs? is: Strongly agree. The response for this cluster to the question: There is a need to develop a collection system of ULABs?, Figure 17 showed they strongly agreed from the Likert-type scale. Figure 18 shows that the question was rephrased and asked whether there is a need to establish a CLSC of ULABs to which the cluster, strongly agreed.

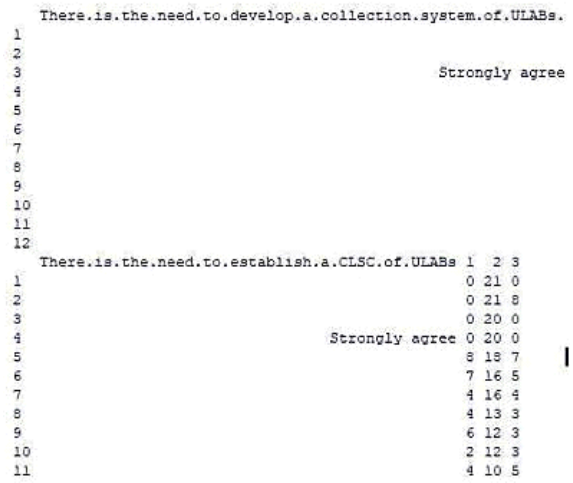
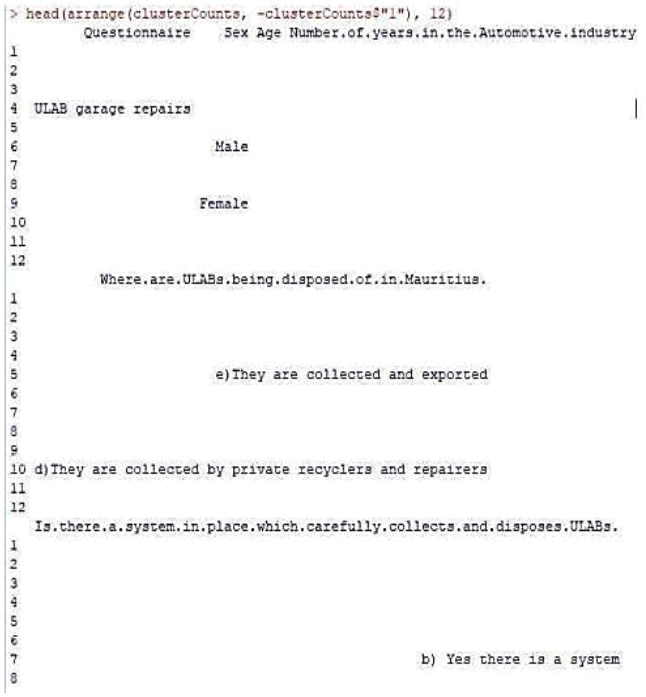


Figure 18. Characteristics of cluster2 for k3d

The largest cluster proved all the positive and accurate results of this method of data analysis. Figure 15, 16, 17 and 18 showed the outcome of the questionnaire responses for the largest of the 3 clusters and their explanations above.
Figure 19 shows the results of the questionnaire responses for the second largest of the 3 clusters, Cluster 1. Cluster 1 grouped 10 responses with a silhouette width of 0.25 Figure 10. The first section displays the demographic characteristics of the respondents and from which area of the ULAB industry they are from. In this case again, the cluster consists of respondents from the ULAB garage repairs. It is composed of both male and female respondents. The age of the respondents is not displayed. The second section again shows that there was an error for the response to the question of the number of years in the automotive industry, the results did not display the median response of the cluster. However this also being a trivial question, it can be ignored. For the third section of this cluster, the dominating response for those in this cluster, for the questionnaire question: Where are ULABs being disposed of in Mauritius?, is : e) they are collected and exported. However this particular question has two dominant responses, the other

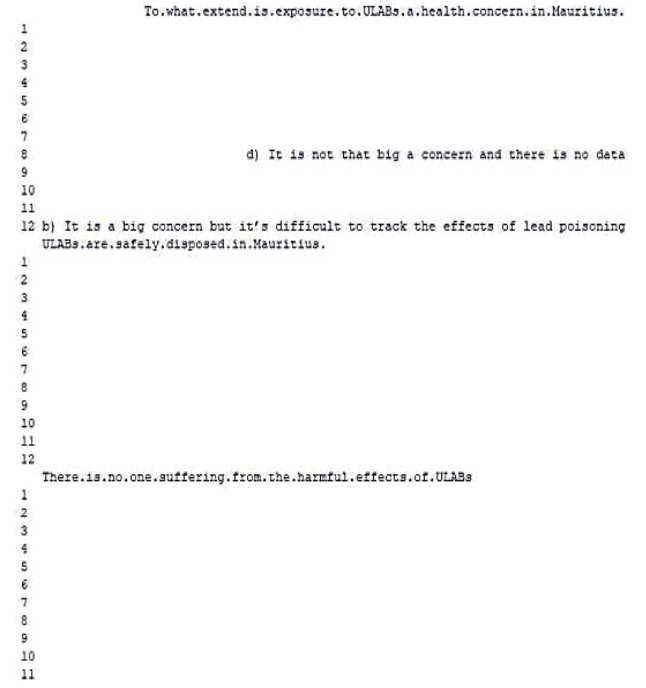
response is: d) They are collected by private recyclers and repairers. From these responses it is clear that the cluster answered that ULABs are being collected by private recyclers and repairs and they are being exported.



```
> head(arrange(clusterCounts, -clusterCounts$"1"), 12)
        Questionnaire    Sex Age Number.of.years.in.the.Automotive.industry
1
2
3
4  ULAB garage repairs                                                    |
5
6                       Male
7
8
9                      Female
10
11
12
          Where.are.ULABs.being.disposed.of.in.Mauritius.
1
2
3
4
5                       e)They are collected and exported
6
7
8
9
10 d)They are collected by private recyclers and repairers
11
12
   Is.there.a.system.in.place.which.carefully.collects.and.disposes.ULABs.
1
2
3
4
5
6
7                                                  b) Yes there is a system
8
```

Figure 19. Characteristics of cluster1 for k3

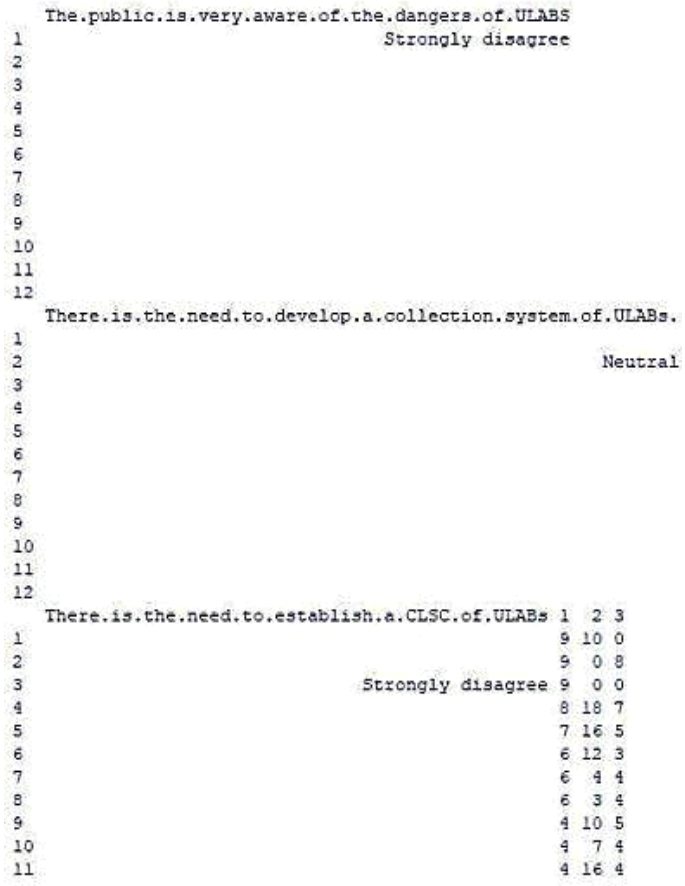
Figure 20 shows that the response of this cluster to the question: Is there a system in place which carefully collects and disposes ULABs. The cluster again displays two responses: b) Yes there is a system and c) No there is a very bad system. To what extent is exposure to ULABs a health concern in Mauritius?, The cluster again displays two responses:
d) It is not that big a concern and there is no data and b) It is a big concern but it's difficult to track the effects of lead poisoning. This combined becomes there is no data and its difficult to track the effects of lead poisoning.



```
                To.what.extend.is.exposure.to.ULABs.a.health.concern.in.Mauritius.
1
2
3
4
5
6
7
8                            d) It is not that big a concern and there is no data
9
10
11
12 b) It is a big concern but it's difficult to track the effects of lead poisoning
   ULABs.are.safely.disposed.in.Mauritius.
1
2
3
4
5
6
7
8
9
10
11
12
   There.is.no.one.suffering.from.the.harmful.effects.of.ULABs
1
2
3
4
5
6
7
8
9
10
11
```

Figure 20. Characteristics of cluster1 for k3b

Figure 21 shows that the questionnaire question: The public is aware of the dangers of ULABs? displayed: Strongly Disagree. The response for this cluster to the question: There is a need to develop a collection system of ULABs? Figure 21 showed they were neutral from the Likert-type scale. Figure 21 shows that the question was rephrased and asked whether there is a need to establish a CLSC of ULABs? to which the cluster strongly disagreed. These, however, are the questionnaire responses from the medium smaller of the three clusters which groups 10 out of 40 responses.



```
   The.public.is.very.aware.of.the.dangers.of.ULABS
1                                  Strongly disagree
2
3
4
5
6
7
8
9
10
11
12
   There.is.the.need.to.develop.a.collection.system.of.ULABs.
1
2                                                    Neutral
3
4
5
6
7
8
9
10
11
12
   There.is.the.need.to.establish.a.CLSC.of.ULABs 1  2 3
1                                                 9 10 0
2                                                 9  0 8
3                                Strongly disagree 9  0 0
4                                                 8 18 7
5                                                 7 16 5
6                                                 6 12 3
7                                                 6  4 4
8                                                 6  3 4
9                                                 4 10 5
10                                                4  7 4
11                                                4 16 4
```

Figure 21. Characteristics of cluster1 for k3c

Figure 22 shows the results of the questionnaire responses for the smallest of the 3 clusters, Cluster 2. Cluster 2 grouped 8 responses with a silhouette width of 0.44, Figure10. The first section displays the demographic characteristics of the respondents and which area of the ULAB industry they are from. In this case again, the cluster consists of respondents from ULAB garage repairs. It is composed of Female respondents. The age of the respondents is not displayed.
The second section again shows that there was an error in the response to the question of the number of years in the automotive industry, the results did not display the median response of the cluster. However, this also being a trivial question, it can be ignored. For the third section of this cluster, the dominating response for those in this cluster, for the questionnaire question where are ULABs being disposed of in Mauritius? is : e) they are collected and exported. However this particular question has two dominant responses, the other response is d) They are collected by private recyclers and repairers. From these responses the cluster answered that ULABs are being collected by private recyclers and repairs and they are being exported. The responses are exactly the same as cluster1.

```
> head(arrange(clusterCounts, -clusterCounts$"3"), 12)
       Questionnaire    Sex Age Number.of.years.in.the.Automotive.industry
1
2
3
4
5
6  ULAB garage repairs
7                      Female
8
9
10
11
12
          Where.are.ULABs.being.disposed.of.in.Mauritius.
1
2
3
4
5
6
7
8                        e)They are collected and exported
9  d)They are collected by private recyclers and repairers
10
11
12
   Is.there.a.system.in.place.which.carefully.collects.and.disposes.ULABs.
1
2
3
4
5
6
7
8
9
10                                                b) Yes there is a system
```

Figure 22. Characteristics of cluster3 for k3

Figure 23 shows that the questionnaire question: The public is aware of the dangers of ULABs?: displayed: Neutral. The response for this cluster to the question: There is a need to develop a collection system of ULABs? Figure 23 showed they were neutral from the Likert-type scale. Figure 23 show that the question was rephrased and asked whether there is a need to establish a CLSC of ULABs to which the cluster, again gave a neutral response. These however are the questionnaire responses from the smallest of the three clusters which groups 8 out of 40 responses. This cluster grouped a few neutral responses, the clearest picture of the data is from the largest cluster. The most accurate representation of the data is from the largest cluster. The median responses from this cluster are more reliable and trustworthy information

Recommendations

The need has been communicated by many members of the automotive industry and those of the health industry, of a new and safer system for the collection of ULABs. A system can be developed which is country wide, which uses all the safety measures, such as the UN approved safety containers for the collection of ULABs. Locations to place bins for the safe collection of the ULABs can be calculated using the UFL problem, and these locations, the entire network, can be optimized to reduce the costs of collection and drive prices low so that those who are in the business of buying them can buy them at the same price or a lower price for their exportation. This is also done so that the waste can be treated first, for the safety of the public. These safety bins and selected collection points can be the places that the public is informed of the dangers of the ULABs. For example if a few calculated service stations are the selected collection points, safety bins for the ULABs are placed there, and these areas, are where the public will be informed, using banners and bill boards that inform the public of the dangers of the ULABs. Companies that are in the business of buying these items will supply the necessary finance, to buy the ULABs at these safely constructed location points, and will provide the necessary collection logistics and transportation of these hazardous materials. Since this is a whole country wide business, many companies that are registered and qualified can contend to have their collection points calculated according to their logistics, location and budget. Public awareness was also highly recommended by many members of the automotive industry.

In face to face interviews many members of this industry disclosed that the public is not informed of the dangers of this industry, some would confess that many dealers venture into the ULAB industry as a business, not knowing the risk of environmental contamination and the dangers that are involved. This information, of the risks that the public is facing is critical and should be communicated country wide. The public has a right to know of the dangers of the hazardous materials they are using such as ULABs, they should be informed of how to safely keep them when used up and how to safely dispose them.

Every new vehicle battery should be traceable from the day it is imported to the day it is disposed, this is done to ensure that it is safely disposed at the end of its life cycle. Those interviewed are convinced that ULAB information is not as readily available in the Republic of Mauritius as is should be. Qualitative findings proved that many members of the automotive industry, recommended that strict regulations on who can buy or who can collect the ULABs from the homes of the private users, must be placed and enforced. They reported that there are many unregistered dealers, who are not authorized to do the collection and who are not obeying any standards. The unregistered dealers are not complying to all the required health and safety regulations, placing their employees and their families at risk. Some will continue to do this work because it is their livelihood, however enforcing some regulations, that ensure the collection is conducted with high safety standards, and regulations by the law, that the people who are in the business of collecting the ULABs are qualified and knowledgeable, will do more in terms of the safety of the environment and the community.

The Key findings of the survey were:

- Respondents strongly agreed that the collection system in place is not safe and risks the lives of the employees collecting them and their families.
- The public is also at risk from the yearly collection system because of the lengthy in-house storage before the collection and exportation.
- Members of this industry disclosed that the public is not informed of the health dangers of this industry, thus there is a lack of public awareness.
- Qualitative findings proved that many members of the automotive industry recommended that strict regulations on who can buy or who can collect the ULABs from the homes of the private users, must be placed and enforced.
- During face-to-face interviews and in the questionnaires, many members of the automotive industry and those of the health industry disclosed the need for a new and a safer system for the collection of ULABs.
- The results showed that 55% of the respondents strongly agreed that there is a need to develop a new collection system.

A summary of the quantitative results from the ESMvere method

The highest, best clustering of the k-median algorithm was from 3 clusters k=3, this had a silhouette width of 0.35. The best cluster grouped the questionnaire responses into 3 clusters of size 22, 10, 8.

Questionnaire responses from the largest cluster of 22:

Is there a system in place which carefully collects and disposes ULABs?

- No, there is a very bad system ULABs are safely disposed in Mauritius?
- Disagree

There is the need to develop a collection system of ULABs?
- Strongly agree

There is a need to establish a CLSC of ULABs?
- Strongly agree

The public is very aware of the dangers of ULABs?
- No

To what extent is exposure to ULABs a health concern in Mauritius?
- It is a big concern but its difficult to track the effects of lead poisoning There is no one suffering from the harmful effects of ULABs?
- Neutral

The results showed that 55% of the respondents strongly agreed that there is a need to develop a safer collection system. Stronger emphasis has been placed by the Ministry of Environment, Solid Waste Management and Climate Change of Mauritius, on collection with the intention to export as opposed to collection with the intention to recycle,. The safe collection of the ULABs should be a nationwide government project as every person's health is at risk. Accurate planning is required which minimizes or eliminates lead exposure from ULABs.

Conclusion

A new data analysis method was developed that uses the hamming distance variant of the k-median clustering technique to cluster the responses of questionnaires. The method uses the silhouette plots value to determine the best choice of k. The main innovation of the new data analysis method is how the set of questionnaire questions are structured on the dataset, which is a Microsoft excel spread sheet with a comma separated values (CSV) file extension. The method is derived from a marketing segmentation method; however, it has been remodified with some complex modifications to suit the analysis of data. It gives a hamming distance median sentence like responses from each cluster. The study's key contribution is the practical adaptation of theoretical k-median frameworks to address environmental challenges, offering a replicable model for data analysis and hazardous waste management in other contexts. It highlights the potential for mathematical modelling to drive practical solutions to global environmental challenges. The results gave valuable information that proved the need for a new ULAB collection system.

Conflicts of Interest: The author declare no conflicts of interest regarding the publication of this paper.

REFERENCES

1. Cunningham, G. (2015). Data smart, ch2, customer segmentation with r using k-medians clustering. *https://rstudio.pubs.static.s3.amazonaws.com/75036b3e83952e88e4c98ad4fffbee571260f.html* pp. 2019–02–12.
2. NTA, N. L. T. A. (2019). National land transport authority vehicles registered 2008 - 2019. *http://nta.govmu.org/English/Documents/Statistics2019/Oct202019/Website20-20Vehicles20Registered202008- 201920September202019).pdf* pp. 2020–01–04.
3. BeForward (2019). Which African countries have the most cars on the road? *https://blog.beforward.jp/regional-topics/africa/cars-capita-africa-country-cars-road.html* pp. 2020–01–06.
4. Statsmauritius (2019). Estimated resident population by geographical district and sex - republic of Mauritius 1, 2011 - 2019(mid-year estimates). http://statsmauritius.govmu.org/English/CensusandSurveys/Pages/census/Census- 2011.aspx pp. 2020–01–04.
5. Voynick, S. (2011). Trade and environment a teaching case: The Basel ban and batteries. *Institute for trade and commercial diplomacy*.
6. Kowlesser, P. (2017). Overview of solid waste management in Mauritius. *Environment*.
7. PAGE, (2017). Industrial Waste Assessment in the Republic of Mauritius: Opportunities for Industrial Symbiosis.
8. *Partnership for Action on Green Economy*.
9. Phoolchund, H. (1995). Occupational and environmental health in Mauritius: a review of trends and recent studies. *Elsevier Science Ltd* pp. pp.251–255.
10. Baggioni, A. G., and Surendran, S. A penalized criterion for selecting the number of clusters for K-medians Journal of Computational and Graphical Statistics, 2024•Taylor & Francis
11. Moshkovitz, M., Dasgupta, S., Rashtchian, C. and Frost, N., 2020, November. Explainable k-means and k- medians clustering. In *International conference on machine learning* (pp. 7055-7065). PMLR.
12. Manish Suyal, Sanjay Sharma (2024). A Review on Analysis of K-Means Clustering Machine Learning Algorithm based on Unsupervised Learning. Journal of Artificial Intelligence and Systems,6, 8–95. https://doi.org/10.33969/AIS.2024060106.
13. Anand, A. and Lee, E.,(2024) Separating k-Median from the Supplier Version University of Michigan, Ann Arbor *arXiv preprint arXiv:2401.13819v[csDS]24 Jan 2024*.
14. Whelan, C., Harrell, G. & Wang, J. (2015). Understanding the k-medians problem. *International Conference Scientific Computing* pp. pp.219–222.
15. Ministry of industry (2019) Authorized Dealers in Importation and Sale of Second-hand Motor Vehicles. Retrieved October 27,2020, www.commerce.govmu.org/Documents/Departments/TradeDivision/List20of20Showrooms.pdf

Appendices Appendix A

The R language code that follows is a detailed series of steps that were used to analyze a data-set of questionnaire responses, gathered for the survey of this study.

The R Language Code

1. //Read data from the csv file:
   • ulab<-$read.csv(".ulabdata.csv")$
2. //Remove meta data.
   • ulabUB<- $t(ulab[,-c(1,2,3,4,5,6,7,8,9,10,11,12)])$
3. //Replace blank entries with zeros.
   • ulabUB[$is.na(ulabUB)$]<-0
4. //Convert data frame to a Matrix.
   • ulabMatrix<-$as.matrix(ulabUB)$
5. //Partition the data into clusters.
   • partition<-$skmeans(ulabMatrix,2)$
6. //Print respondent names.
   • clusterCounts<-
   t(aggregate(ulabUB,by=list(partitioncluster),sum)[,2:56])
7. View the characteristics of each cluster.
   • clusterCounts<-$cbind(ulab[,c(1:12)],clusterCounts)$
8. Print the silhouette clusters.
   • silhoutte_k2 <-silhouette(partition)
   • summary(silhoutte_k2)

Appendix B Questionnaire

SECTION A: DEMOGRAPHIC INFORMATION: (Tick the appropriate)

1. Name.....

Female	Male

2. Age

30 years and below	31-40 years	41-50 years	51years+

3. Number of years in the Automotive Industry

0 – 5years	6-10 years	11-15 years	16-20 years	21years +

4. Area of Occupation (Tick on closest description)

ULAB importers	
ULAB reseller	
ULAB garage repairs	
ULAB disposal	
Health personnel	
Other (s) - specify	

1. Where are ULABs being disposed of in Mauritius?
   a) They are being collected by local government and dumped at Landfill Mare Chicose
   b) They are sent to Lachaumire bambous Hazardous waste facility by?.....
   c) They are left to the private citizens to dispose, in house, garage, backyard
   d) There collected by private recyclers and repairers
   e) They are collected and exported

2. Is there a system in place which carefully collects and disposes ULABs?
   a) Yes there is a good system
   b) Yes there is a system
   c) No there is a very bad system
   d) No there is no system at all
   e) We have no idea
3. To what extend is lead exposure form ULABs a health concern in Mauritius?
   a) It is a very big concern many patients, deaths, and reports annually
   b) It is a big concern but it's difficult to track the effects of lead poisoning
   c) It is not that big a concern and there is data
   d) It is not that big a concern and there is no data
   e) There are seriously no victims of this

4. How many ULABs are brought to the hazardous waste collection facility each year?.....
5. Are there currently any recycling companies for failed or used up vehicle batteries?
   .....
   .....
   .....
6. Does Mauritius have an excessive importation of vehicle batteries?
   .....
7. What is the average number of vehicles imported every year?
   .....
   .....
8. What is the average number of vehicle batteries imported every year?

For the questions to follow, may you rank your opinion on a Likert scale of 1-5 as guided below:

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	2	3	4	5

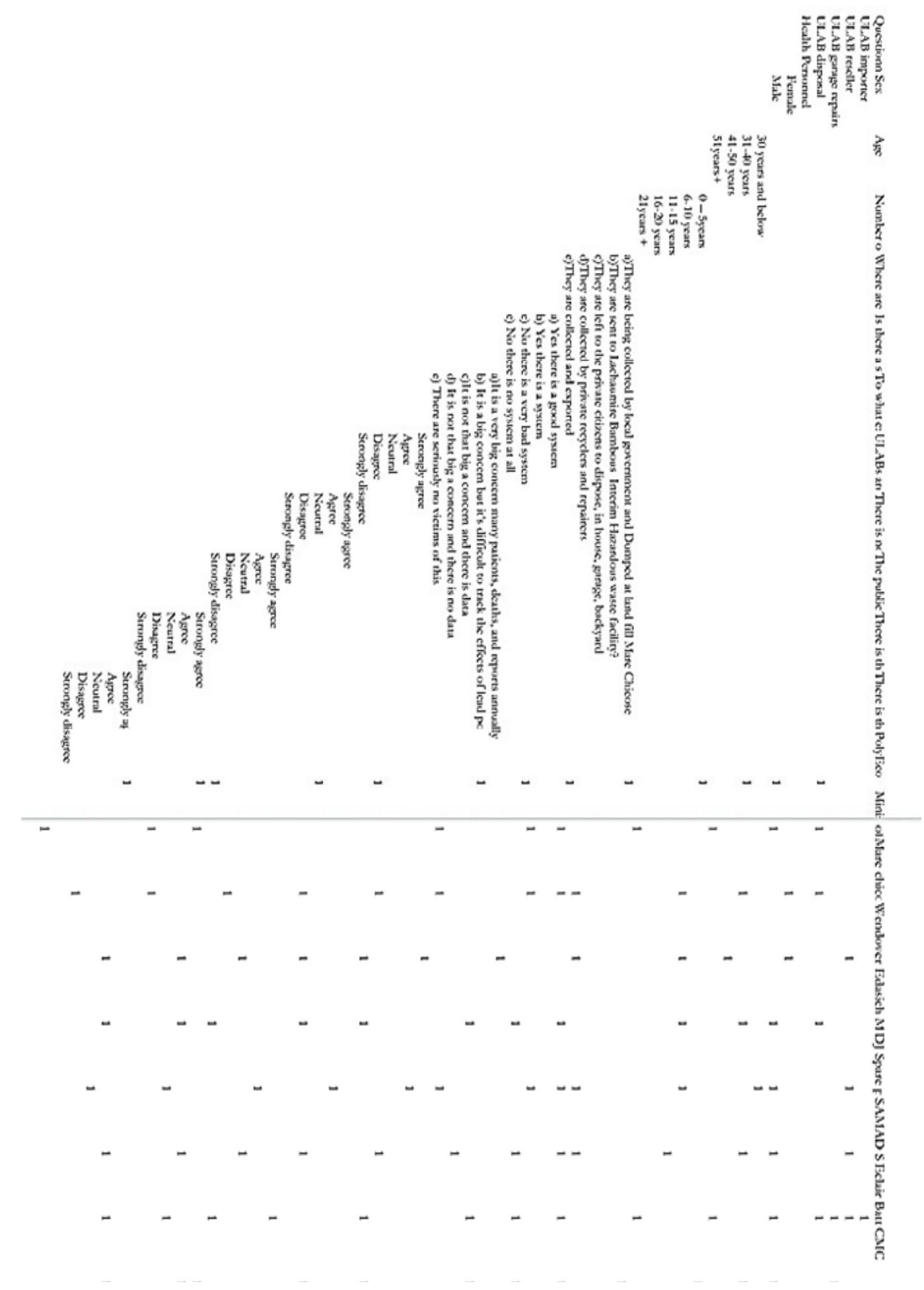
ULABs, health, Pollution

	1	2	3	4	5
ULABS are safely disposed in Mauritius					
The is no one suffering from the harmful effects of ULABs					
The public is very aware of the dangers of ULABS					
There is the need to develop a collection system of ULABs					
There is the need to establish a CLSC of ULABs					

Recommendations ULABs Research

.....
.....
.....
.....
.....
.....
.....
.....

Appendix G Dataset



NTA	Showa Ins	Canal Mo	DAN MO	Prestige Au	Autocity L	Best Deal	CARCLUB	DBB Moto	Autocom	Delise Ltd	Simran Au	Nand Mot	Mohamme	Mahazar C	Toyota (M	Express Au	Uniquecars	Fast Cars	ITSSL Mot	Stuttgart
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1		1	1			1		1		1		1	1				1
1				1			1	1		1		1		1			1	1	1	
	1							1				1				1				
1		1		1	1		1			1			1				1			
			1			1					1				1			1		1
									1					1					1	
1	1	1		1			1	1		1					1			1		
					1							1				1				
			1			1			1		1								1	
													1				1			1
														1						
1			1	1	1		1													
									1		1			1		1			1	1
1	1	1	1	1	1	1	1	1		1		1	1		1		1	1		
								1		1		1	1				1		1	
1	1	1	1	1	1		1		1		1			1	1	1		1		1
						1														
1	1	1	1	1	1	1	1		1		1	1			1		1	1	1	
								1		1			1	1		1				1
																1	1	1	1	1
1	1	1	1	1	1	1	1													
1	1	1	1	1	1	1	1									1	1	1	1	1
																1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					
1	1	1		1	1	1	1													
			1																	
								1	1	1	1	1	1	1	1	1	1	1	1	1
	1		1	1	1	1	1													
1		1																		
																1	1	1	1	1

****