Guidance document on how to perform a shredder campaign and background information

Introduction: special note from EUROSTAT on shredder campaign (06/08/2020)

End of life vehicle (ELV) waste is treated in two successive phases:

- the dismantling and depollution phase, where the pieces and parts of the vehicle are taken off, separated and depolluted, and afterwards reused, recycled, processed for energy recovery or disposed
- then what remains of the car is undergoing the shredding process for tearing into pieces or fragmenting end-of life vehicles, including for the purpose of obtaining directly reusable metal scrap.

Within the treatment of end of life vehicle (ELV) waste arisen from shredding operations, country are supposed to provide in table 2 of the reporting questionnaire (*"Annual reporting of end of life vehicles"*) these data:

- the amounts of metals (ferrous or non ferrous), the shredder light fractions and other materials arising from shredding
- the type of operation for each category of waste material: recycling, energy recovery and disposal.

When the dismantling and depollution is resulting in a very limited percentage of ELV treated waste materials, the reporting of splits of materials processed during the shredding operations becomes very complex. For instance, a country reporting under the metal content assumption requires an accurate statistical analysis of the shredding process; therefore shredding campaigns are needed whenever no other accurate material measurement methodologies are applied, serving also the purpose of being a statistical instrument for estimating the quantities to be reported.

Therefore, countries who are reporting estimates based on the shredding campaigns, are warmly encouraged to provide in the methodological report, for instance, at least these information:

- The total weight of the vehicles included in the shredder campaigns according to the vehicles registration documents;
- The weights of materials resulting from the shredding campaign operations
- If and how the sample is representative for the whole ELV
- If available, also the splits for different vehicle categories is very appreciated.

More details can be found in the annexed documents "How to Perform a Shredder Campaign" and "Background Information" for which there are also equivalents on the DG ENV web site https://ec.europa.eu/environment/waste/elv/events_en.htm linked in the text

Development of a Guidance Document on "How to Perform a Shredder Campaign" and Shredder Campaign Background Information Document

or under these pages:

https://ec.europa.eu/environment/archives/waste/pdf_comments/shredder.pdf

https://ec.europa.eu/environment/waste/pdf/Shredder_campaign_background_info.pdf

GUIDANCE DOCUMENT ON “HOW TO PERFORM A SHREDDER CAMPAIGN”

Prepared by
ÖKOPOL GmbH
Institut für Ökologie und Politik
Nernstweg 32–34
D – 22765 Hamburg
www.oekopol.de
info@oekopol.de

Content

List of figures

Guidance Document on How to perform a shredder campaign

1 PURPOSE OF A SHREDDER CAMPAIGN

Directive 2000/53/EC on end-of life vehicles (ELV Directive) provides for recovery and recycling targets for ELVs (Article 7(2)). Details on the reporting are set out in the Commission Decision 2005/293/EC laying down detailed rules on the monitoring of the reuse/recovery and reuse/recycling targets set out in Directive 2000/53/EC of the European Parliament and of the Council on end-of-life vehicles. DG ESTAT has also developed a guidance document addressed to Member States on how to report on recycling and recovery targets.

Recital (8) of Commission Decision 2005/293/EC highlights the need of shredder campaigns to determine the output streams of a shredder related to end-of-life vehicles. Note 6 of that Commission Decision determines: "The output of end-of-life vehicle streams of a shredder shall be calculated on the basis of shredding campaigns in combination with the input of end-of-life vehicles to a shredder. The input of end-of-life vehicles to a shredder shall be calculated on the basis of weighing notes, receipts or other forms of bookkeeping. Member States shall report to the Commission on the number of shredder campaigns performed on their territory.”

2 PLANNING

Identification of partners involved in the shredder campaign is of high importance and should be done in a very early stage of the planning of the shredder campaign. There is for example an interconnection between the number and types of participating shredders and the number of ELVs to be shredded and statistical requirements might influence the choice of participating authorised treatment facilities (ATF).

A coordinator shall be determined who supervises the activities of the ATF and shredder and collects and evaluates the information from the participating institutions.

Supervision shall include

- Auditing during inspection and treatment of ELVs at the ATF
- Auditing during shredding is performed
- Check of data bases (ELVs, activity of ATF, mass balances of ATF and shredders)

The schedule of the shredder campaign is very much influenced by the number of participating ATF and shredders, the number of ELV to be treated and the time needed to acquire the ELV for the campaign. Recent shredder campaign in the MS took between 6 and 12 months time.

3 DETERMINATION OF THE ELV SAMPLE

In order to determine the sample of ELV to be treated in a shredder campaign, knowledge about arising of ELV must be available. Different approaches can be taken to get this information, e.g. (see also flow chart below)

i. The certificate of destruction (CoD), which shall describe the number of vehicles treated in ATF. Prerequisite for using the CoD-approach is that the number of issued CoD and the number of treated ELV match.
ii. Getting the information from the ATF via compulsory reports or questionnaires (the number of ELV treated is also part of the report of the Member State to the European Commission according to Commission Decision 2005/293/EC (Annex table 4)).
iii. Getting the information in an anonymous manner e.g. via an ATF-Association. This possibility should be evaluated if the approaches i to ii are not applicable. Like this the authorities get insight in the arising of ELVs and none of the individual ATF has to fear legal consequences. This approach can only be counted as an intermediate solution as the number of issued CoD and the number of arising ELV should coincide.
iv. Calculate the number of ELVs from the number of annually deregistered vehicles[1] minus exported vehicles and vehicles temporarily stored on non-public ground. Prerequisite for using this information is that the exported and temporarily deregistered vehicles can be identified with sufficient accuracy. Sometimes tax authorities can be helpful sources for information.
v. Determine the delta in the registered fleet of the two consecutive years before the shredder campaign. In this approach information about exported and temporarily deregistered vehicles are crucial as well.

[1] Either explicitly de-registered vehicles or differences in the fleet between two years.

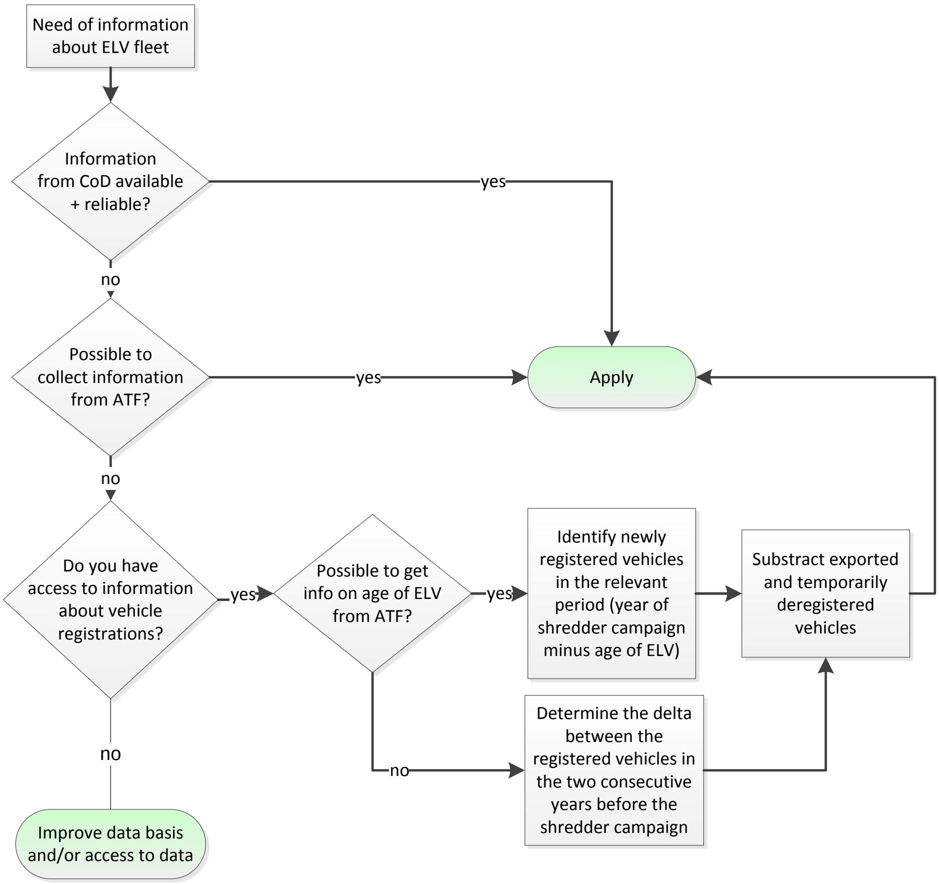


Figure 1: Decision tree: Information about ELV

The number of ELV included in a shredder campaign is related to a number of factors.

Accuracy (Letter in the formula below: L)
The accuracy of the results of the shredder campaign is not determined in the monitoring requirements. It depends, inter alia, on the number of ELVs included in the shredder campaign. If a given accuracy (e.g. ±5% see complementary report "Background information") cannot be achieved (for example because the number of ELV is too low in the shredder campaign due to budget restrictions), the achieved accuracy should be calculated and described in the report of the shredder campaign.

Total number of ELV (Letter in the formula below: N**)**
Approaches to determine the total number of ELVs in a MS are described at the beginning of this section .

Average weight of a fraction resulting from shredding of a ELV (Letter in the formula below: X_1) and **Variance of the weight of a fraction resulting from shredding of a ELV** (Letter in the formula below: S_1):
These factors are in fact results of the shredder campaign. In order to perform the required calculation results from previous shredder campaign might be applied. Due to very broad variances of the ELV weights in the recent shredder campaigns the resulting factor S_1 is very high. This results in a relatively high number of ELVs to be included in the shredder campaign to achieve a high accuracy. Thus it is proposed to use results from shredder campaigns in the Member State for the determination of S_1. If such data are not available it is proposed to perform a shredder campaign, where shredding of ELVs is done in batches (e.g. 100 ELVs per

batch) and document the output flows per batch. The results from those trials can be used as a basis for determination of S_1 in the next shredder campaign.

Normal distribution quantile (Letter in the formula below: u)
When the distribution of the observations is not known the test distribution of the variance of distribution is applied for normally distributed data. It is here the t-distribution. Due to the fact that the determination of the ELV number in the shredder campaign would be very complex and the difference between the results is usually small it is proposed to apply the normal distribution for the calculation. The value applied is 1.959964.

The formula to calculate the minimum number of ELVs in the shredder campaign (m) is as follows:

$$m = \left[\frac{-L\ X_1 N + \sqrt{L^2 X_1^2 N^2 + 4u^2 S_1^2 N}}{2\ u\ S_1} \right]^2$$

The result of the calculation shows the minimum number of ELVs to be included in the shredder campaign in order to achieve the required accuracy (RESULT A).

Shredders need a certain volume flow in order to be performed in normal operating conditions. That number differs between the shredders e.g. depending on the capacity of the shredders. A certain number of participating shredders is necessary in order to ensure that the campaign is representative for normal operation of all shredders over the year (see section 5 of this guidance document). By this a minimum number of ELVs is determined to be included in the shredder campaign (RESULT B). The higher number of ELVs from RESULT A and B shall be applied in the shredder campaign.

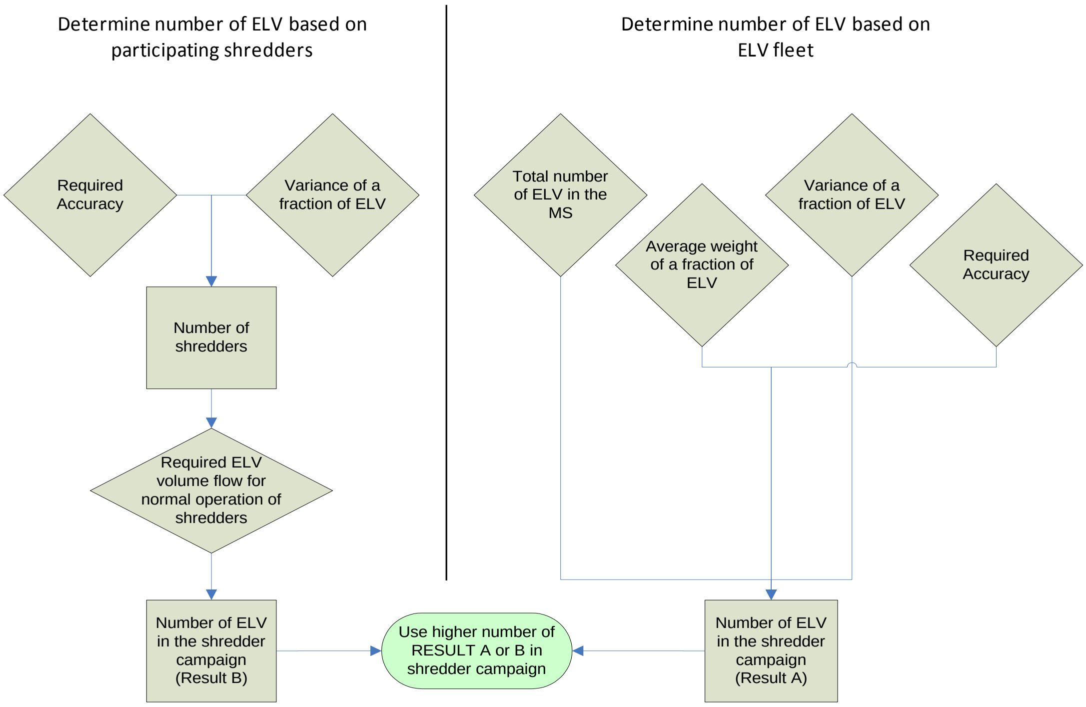


Figure 2: Approach to determine the ELV sample

After having determined the number of vehicles to be included in the shredder campaign it has to be decided which vehicles are to be included. The composition of the vehicles determine the relation of the output streams from the shredder campaign. Numerous criteria influence the composition of a vehicle. Usually no data basis is available to describe the actual composition of the ELV fleet. In recent shredder campaigns auxiliary criteria to determine differences in the composition of the ELVs have been applied e.g. make & model, mass, fuel type, age and condition of the vehicles (see complementary report "Background information").

An important element within the determination of the sample of ELVs is the differentiation between M1 and N1 vehicles. Due to their predominant purpose of transporting goods the composition of N1 vehicles and in particular N1 class III differs from those of M1 vehicles (higher shares of metal). Therefore the share of M1 and N1 in the overall number of ELV must be identified in any case when the ELV sample for the shredder campaign shall be determined.

The composition of some vehicles entering the AFT differs e.g. due to accidents (burned down vehicles), missing parts, additional parts or dirt and waste. Usually no data basis is available on the condition of ELVs in the MS when arriving at the ATF. Thus, expert judgement (e.g. enquiries of experiences of ATF) should be applied to decide whether the input of the shredder campaign must be adapted to those conditions.

Based on data on the metal content of vehicles (see complementary report "Background information") it can be expected that there is no significant proportion of the metal content. Those data suggest also that the significance of the relation between model and metal share is low. Data uncertainty exist due to the fact that a limited share of models is covered by the data.

With this background two (alternative) approaches are recommended:

a) Replicate the ELV fleet in the ELV sample based on the vehicles makes and models;
b) If this is not possible (e.g. due to difficulties to acquire the specific ELV in the shredder campaigns' time frame) differentiate the sample of ELV in the shredder campaign as a minimum by the criterion M1/N1 vehicles and to use the M1-ELVs and the N1-ELVs on an "as received" basis. With the background of the data about the differences in the metal content of the vehicles (see the complementary document "Background information") this approach seems to be justified.

4 ATF

The activity of the authorised treatment facilities (ATF) in the shredder campaign shall reflect the daily practice in the Member State. Evidence about practice of the ATF can be drawn from the reporting tables according to the annex to Decision 2005/293/EC respectively the reporting of the Member States to the European Commission.

If such evidence would not be applied (or is not available) the participating ATF must be chosen in a way that they are representative for the activity in the Member State. The resulting (high) number might conflict with budget restrictions for the shredder campaign.

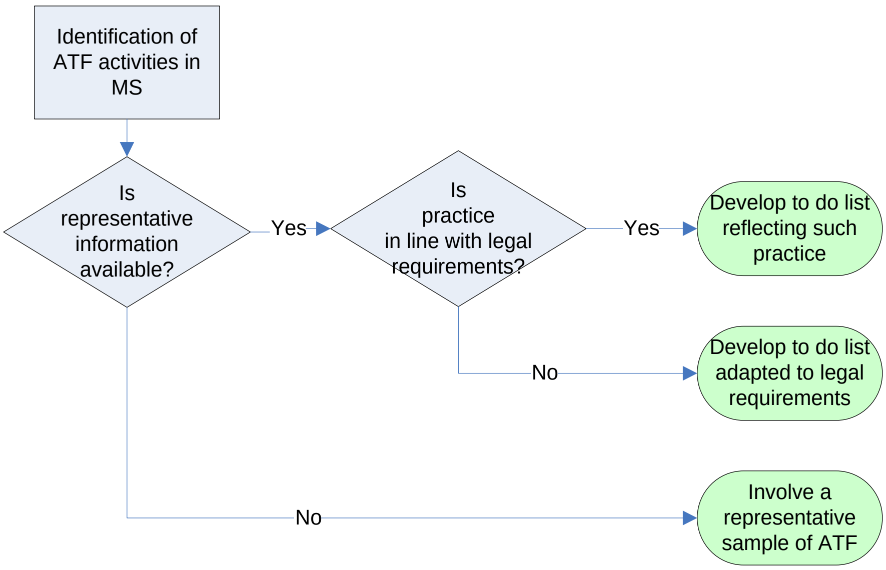


Figure 3: Decision tree "Activity of the ATF"

If the "to do list" approach is taken the number of participating ATF is arbitrary.

Participating ATF need to be able to perform state of the art depollution (equipment available) and dismantling. Sufficient size to store dismantled and depolluted ELVs is important as well as availability of weighbridge / scales for ELVs, dismantled parts and parts / fluids from depollution (sometimes mobile scales are a solution in case of ATF without installed scales).

Incoming ELVs must be checked for missing parts. If parts are missing it should be considered whether this is an exceptional situation or represents usual ("representative") situation.

Substitution of the part (from another ELV) for the campaign might be considered if parts are too often missing or if representativeness of the sample is endangered.

Weighing of the incoming ELVs at the ATF should be done after removal of possible waste or additional (non-representative) parts and replacement of missing parts (if realised).

Regarding the weight of the ELV Note 4 of the Annex to Commission Decision 2005/293/EC should be considered.

Identification of the ELV throughout the depollution and dismantling process shall be ensured (e.g. by spraying an ELV identification number on the car body).

Condition of the ELV, performed activities and weights must be documented. An example of a documentation sheet is shown in the Annex to this report.

All dismantled parts must be weighed. Accuracy of the scales shall be recorded in order to document reliability of the results of the shredder campaign. In case weighing of fluids is difficult (e.g. because the fluids are collected in an automatic system with tanks) filling level of tanks shall be checked before and after depollution of ELV which are included in the campaign.

Regarding the weight of the depolluted and dismantled ELVs Note 4 of the Annex to Commission Decision 2005/293/EC determines: "The weight of the de-polluted and dismantled end-of-life vehicle (body shell) (Wb) shall be determined on the basis of information from the receiving treatment facility." Anyhow, in the course of shredder campaigns individual weighing of the hulk (body shell) at the ATF facility is usually the preferable option in order to enable an overall input-output picture (weighing at shredder facilities is often done on a "per container basis" and not for each individual ELV).

All weights shall be documented in the protocol in order to prove accordance with the dismantling depth identified as "representative" practice in the MS.

5 SHREDDER

5.1 Choice of participating shredders

Different technologies exist for breakup of ELVs and installations show a broad range of size/capacity. The breakup process is combined with a variety of material separation steps. With this a variety of output streams may result from processing of ELVs.

In an early stage of planning a shredder campaign a comprehensive overview of the technologies applied for breakup of ELVs in the Member State shall be elaborated. It can be expected that shredding is by far the predominant technique[2]. Information can be available from the national associations representing shredder companies and/or from lists of installations permitted to treat ELVs.

Performance of shredders is influenced by operational settings (e.g. air flow rate), environmental conditions (e.g. humidity) , the condition of the shredder (e.g. condition of the hammers

[2] According to the quality reports only very few countries report a relevant amount of metal parts dismantled by ATF and directed to smelters without passing the shredder facilities.

in a hammer mill) and, if applicable, the effort (staff) to maintain a "sorting desk". Currently no data are available which allow quantifying the effect of such factors on the performance of the shredders. Concluding, shredders must be selected for the shredder campaign in a way that their number reflects a representative picture of all active shredders in a Member State.

The identification of the participating shredders shall be done according to the D'Hondt method based on the number of shredders in the Member State (for details see complementary report "Background information").

In some cases it is not possible that the required number of shredders participate in the shredder campaign (e.g. due to budget restrictions or willingness of the shredder operators). In those cases the resulting effect for data accuracy shall be reported.

5.2 Setting system boundaries

System boundaries must be fixed for the shredder campaign. This is to be done based on the situation in the Member State in order to have a situation in the shredder campaign that reflects the daily practice in the Member State. Usually pre-treatment will be covered by the shredder campaign in order to get indication about the effects from pre-treatment on the composition of shredder input (see above). Decision must be taken regarding separation steps after the breakup process.

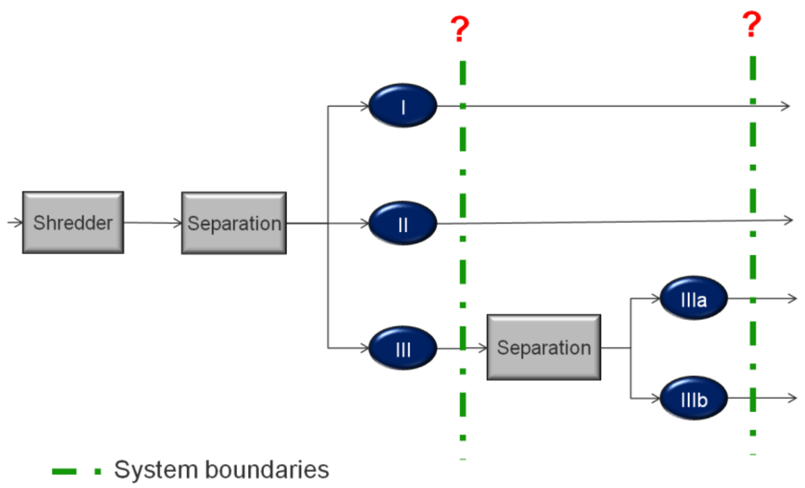


Figure 4: System boundaries

In almost all European shredders at least the fractions Fe, SLF and SHF are produced. Usually further separation into Fe, NFM, SLF and residual SHF is performed.

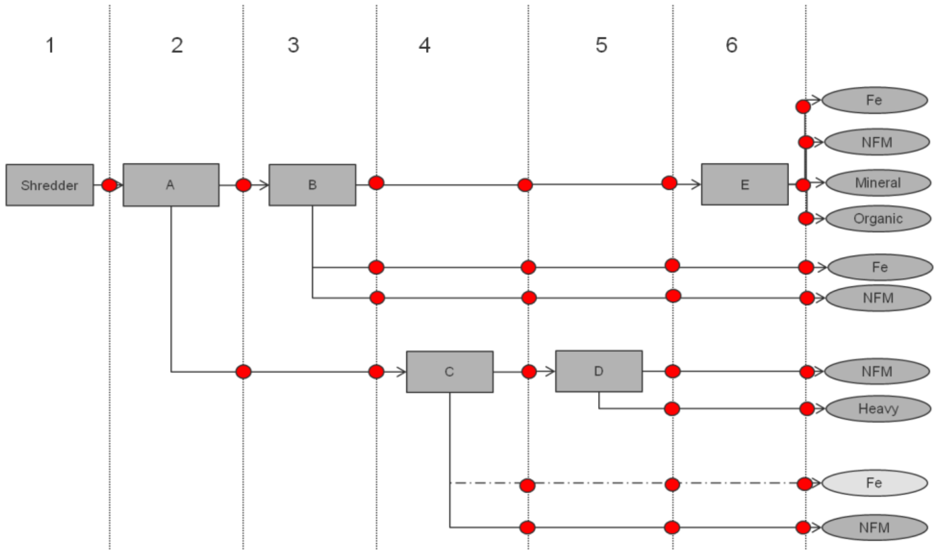


Figure 5: Exemplary processing chain for ELV

Setting of system boundaries shall be done in a way that the shredder campaign provides results which are representative for the daily practice of the whole of the shredders in the Member State.

When for example no further treatment of the SHF is performed in the Member State such treatment shall not be an element in the campaign. If all SLF is further treated in PST this should be included in the shredder campaign.

Participating shredders must have sufficient space to store dismantled and depolluted ELVs and weighbridge / scales for hulks and output fractions. The distances between participating installations will influence transport costs.

5.3 Shredding

The shredder and the storage areas shall be cleaned before and after the campaign in order to cover all materials.

The incoming ELV shall be stored in a specific area until sufficient material is available for stable operation conditions of the shredder. Which amount of material is necessary for stable operation conditions shall be identified together with the shredder operator.

In case irregular conditions occur, these shall be documented in the shredder protocol and considered in the course of the evaluation of the shredder campaign.

Weighing of the incoming hulks should (preferably) already be done at the ATF sites. Output fractions shall be weighed and all weights shall be documented in the protocol.

Transferability of the results of the shredder campaign to the overall situation in the Member State should be evaluated inter alia by checking the composition of the output streams. Standards and/or industry specifications for output fractions should be used as a basis for the evaluation where possible. For ferrous scrap European Steel Scrap Specification and the ISRI Scrap Specifications[3] have been mentioned as most important specifications (query in the year 2012). For other fractions no specifications seem to be applicable in a similar way.

[3] Institute of scrap recycling industries

6 DOKUMENTATION OF THE SHREDDER CAMPAIGN

The documentation of the shredder campaign shall be submitted together with the other explanatory documents to Eurostat, during the course of the yearly data submission and comprise, as a minimum, the following topics:

- Description of the ELVs included in the shredder campaign (number, composition of the sample, approach taken to determine number and composition of the ELV sample),
- Description of depollution and dismantling activities (approach to determine activities to be performed at the ATF, number of participating ATF and approach to identify/determine such ATF, dismantling performance and missing/additional parts),
- Mass balance of depollution, dismantling and shredding (and PST if included in the shredder campaign) including evaluation of the composition of the output fractions,
- Performed inspections,
- Evaluation of accuracy.

Partly it will not be possible to achieve highest data accuracy at all points. In the evaluation of the shredder campaign problems, deviations from planning and possible data inaccuracy shall be described. Key questions can be:

- Was the ELV sample in the shredder campaign representative for the whole ELV fleet (including condition of ELV)?
- Have depollution and dismantling been performed as planned?
- Did problems or irregular conditions occur during the shredder campaign?

An exemplary monitoring sheet for a shredder campaign can be found in the complementary report "Background information".

7 FREQUENCY

The need for performing shredder campaigns will be determined by development and/or implementation of new shredding and/or separation technologies and by changing composition of the ELV.

Regarding the breakup process of the shredders itself there is currently no breaking new technical development seen. New developments seem to develop regarding the treatment of the output fractions of the shredder (mainly SLF and residual SHF). Thus, the frequency of shredder campaigns must reflect the setting of system boundaries. When few separation steps are included (narrow system boundaries) a low frequency of shredder campaigns is justified and vice versa.

When system boundaries are set in a way that only the most common separation steps are included (resulting in the output fractions Fe, NFM, SLF, residual SHF after separation of NFM) a frequency of 4 years is appropriate to reflect possible changes in the composition of the ELV.

Guidance document on “How to perform a shredder campaign”

Background information

Prepared by
ÖKOPOL GmbH
Institut für Ökologie und Politik
Nernstweg 32–34
D – 22765 Hamburg
www.oekopol.de
info@oekopol.de

Content

This document provides additional information to the guidance document on how to perform a shredder campaign.

1 EXAMPLE OF A MONITORING SHEETS FOR A SHREDDER CAMPAIGN

Description	Internal ELV identification number		
	Make		
	Model		
	Year of first registration		
	VIN		
	Fuel type	Petrol	Diesel
	Gear	manual	automatic
	Air condition	yes	no
	Glass roof	yes	no
	Catalytic converter	yes	no
	Number of doors	3	5

Condition of ELV	Motor in ELV?	yes	no
	Gear box in ELV?	yes	no
	Spare wheel in ELV?	yes	no
	Tools in ELV?	yes	no
	Vehicle damaged?	yes	no
	Additional parts?	yes	no

Weight of the arriving ELV (kg)	

Weight of materials from depollution and dismantling (kg)	
Battery	
Glass	
Plastic parts	
Metal parts	
Tyres	
Lead balance weights	
Catalytic converters	
Total Liquids	
Engine/Transmission/Rear Differential Oil	
Oil Filter	
Coolant	
Brake/ Clutch/ Power Steering Fluids	
Screen Wash Fluid	
Shock Absorber Fluid	
Air Conditioning Refrigerant	
Other Fluids	

Weight of the leaving hulk (kg)	

List of hulks leaving the ATF

Internal ELV identification number	Date	Plate number of transporter	Comments
…			
...			
...			

List of hulks arriving at shredder

Plate number of transporter	Date	Storage area	Comments
…			
...			
...			

2 STATISTICAL GUIDE TO THE IMPLEMENTATION OF A SHREDDER CAMPAIGN

Contributed by: Klaus Felsenstein, Institute of Statistics and Probability Theory, Vienna University of Technology

Planning and analysis of a shredder balance need statistical methods. Appropriate formulas and terms are explained here. Sample calculations showing the practical implementation of the formulas and methods are performed including realistic examples. The sample calculations are intended as a pattern but not as specific calculation based on real data.

2.1 Representative Sample

One fundamental issue is drawing the optimal representative sample. Under which conditions satisfies a sub-population (sample) a required accuracy set in advance? In answering that question, a accuracy criterion has to be stated firstly.

The decision derived from a statistical test depends upon the significance level (usually 5%). The result is called *significant* if the null hypothesis is rejected. A statistical estimator should always be accompanied by a confidence interval with a preselected coverage probability (usually 90 % or 95 %). The accuracy requirement is now formulated for this confidence interval. The sample is considered to be representative if the length of the interval does not exceed a preselected value.

2.2 Confidence Interval

In principle, a confidence interval *I* is a region containing an unknown parameter G together with the estimate $\check{G}$ with a coverage probability of at least

$$P[G \in I] = 1 - \alpha \ .$$

2.2.1 Absolute Deviation

Let *G* be the value of interest (total sum) for the population of size N. G_m denotes the estimate of *G* calculated from a sample of size *m*. Then the confidence interval for *G* reads as

$$\hat{G} \ \pm t(m-1; 1-\alpha/2) \ \frac{N-m}{\sqrt{m}} \ S \ \ .$$

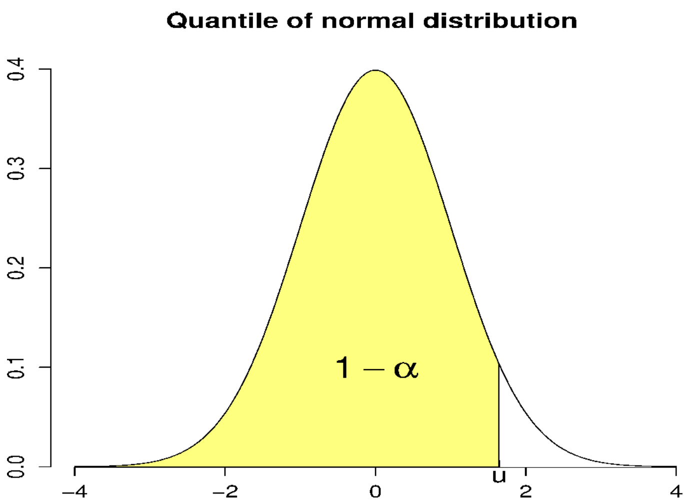
S means the standard deviation of one single observation and $t(m - 1{,}1 - \alpha / 2)$ means the $1 - \alpha /2$ -quantile of the *t* -distribution with $m - 1$ degrees of freedom. The extrapolated value for *G* is

$$\hat{G} \ = \ \frac{G_m * N}{m}.$$

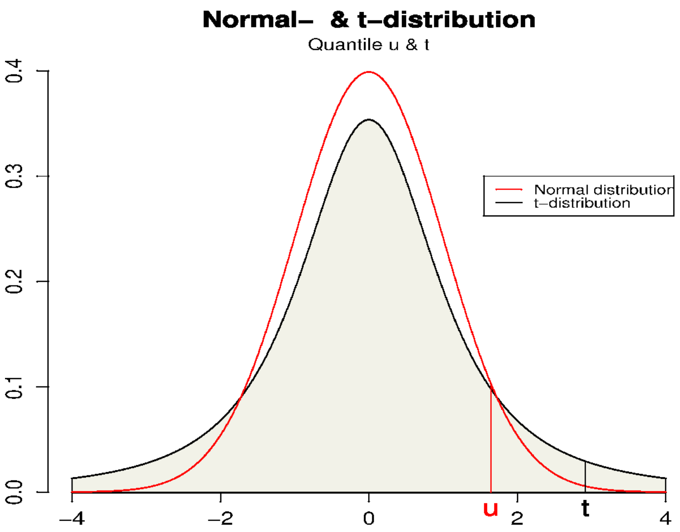
Justification for using the *t* -distribution:

If the standard deviation of the observed random variable is unknown the correct testing distribution is the *t* -distribution assuming a normally distributed dataset. The *t* -distribution approaches the normal distribution with increasing degrees of freedom. Therefore, the deviation of results using *t* -quantiles or normal quantiles becomes negligible provided the number of degrees of freedom is very high.

The following figure shows the density of the standard normal distribution including the 1 - alpha -quantile *u* for α = 5 % . Consequently, *u* is referred to the 95 % quantile of the standard normal distribution.



Compared to the normal distribution the *t*-distribution shows larger deviations. The following figure shows the density of the standard normal distribution and the *t*-distribution (with 2 degrees of freedom). The 95% quantiles of both distributions are denoted by *u* and *t*.



Example:

The population consists of N = 90,000 vehicles. The quantity of interest is the total amount of a specific fraction G contained in the population. A sample of m = 500 is drawn and the entire amount in the sample is G_m = 400. The calculated standard deviation (fraction amount per vehicle) is S = 0.4. The result of the extrapolation is

$$\check{G} = 72.000$$

Inserting the quantile $t(499,0.975) = 1.964729$ leads to the confidence interval

$$I = [68.854 ; 75.146]$$

The stochastic forecast lies between 68.854,- and 75.146,- *t* with probability of 95 %.

2.2.2 Relative Estimation

Comparing different populations requires confidence intervals for percentages. The above confidence interval can be converted into a confidence interval for the relative variation (in percent).

$$P\left[\,|\frac{\Delta G}{\hat{G}}| \;=\; \frac{|G-\hat{G}|}{\hat{G}} \;\leq \frac{L}{\hat{G}}\right] \;=\; 1-\alpha\;.$$

where *L* is the (one-sided) length of the confidence interval.

$$L \;=\; t(m-1;1-\alpha/2)\;\frac{N-m}{\hat{G}\sqrt{m}}\;S. \qquad (1)$$

Example:

Under the conditions considered in the last example from the previous section we obtain a confidence interval for the proportion of the fraction with length $L = 4.34$ %.

The share of the fraction lies between 75.66% and 84.34% (1t total weight of ELV) with a probability of 95%.

2.3 Optimal Design

The accuracy of the results of a shredder campaign of size *m* can be recognized by equation (1). This equation can be used to formulate conditions of accuracy in the sense of a representative sample. It is the one-sided length *L* of the confidence interval that determines the required number *m* in equation (1). Certain priori information is necessary for the calculation of *m* as follows.

Actually, the values of *Ğ* and *S* are available only after performing the campaign. In advance, approximations for *Ğ* and *S* are required. Let X_1 be the average value of one unit (ELV) and S_1 be the approximation for the standard deviation of one unit.

These estimates can be obtained out of former surveys or expert information. Therefore, equation (1) reads

$$L \;=\; \frac{t(m-1;1-\alpha/2)\;(N-m)\;S_1}{\sqrt{m}\;X_1\;N}\;. \qquad (2)$$

After specifying the desired accuracy L the equation (2) m can be solved for sample size m .

By replacing the t -quantile by the quantile of the standard normal distribution which is independent of m we can solve the equation approximately.

$$m = \left[\frac{-L\ X_1 N + \sqrt{L^2 X_1^2 N^2 + 4u^2 S_1^2 N}}{2\ u\ S_1} \right]^2 . \quad (3)$$

Example:

Task: How many vehicles should be scrapped from the total population of N = 90,000 vehicles so that the given accuracy of the proportion estimate can be achieved? The accuracy is +- 5 % , therefore L = 0.05 . The average of fraction weight is assumed as X_1 = 0.8 and the

standard deviation of weight is S=0.4 . An application of numerical methods leads to the solution of the equation by

$$m = 383.29 .$$

At least 384 vehicles should be weighed in the shredder campaign. Inserting the quantile of the standard normal distribution instead of the t -quantile leads to

$$m = 380.9012 .$$

The difference in both solutions is marginal, but it can be seen that the unknown standard deviation (using the *t*-distribution) effects on the result.

2.4 Calculation of Mean and Standard Deviation

The presented approach requires the specification of a single weight X_1 and the associated standard deviation S_1. From a practical point of view the determination of individual weights in a shredder campaign is not possible.

Estimates of the individual weight X_1 and the standard deviation from multiple shredder campaigns are calculated as follows.

Let Y_i be the total weight of the fraction in the shredder campaign *i* out of a series of *k* such shredder campaigns. The total number of vehicles of all *k* shredder campaigns is

$$N = \sum_{i=1}^{k} N_i \ .$$

The average weight of an ELV is then calculated as the simple arithmetic mean,

$$Z_i = \frac{Y_i}{\sqrt{N_i}}$$

The values

$$S_z := \sqrt{\frac{1}{k-1}\sum_{i=1}^{k}(Z_i - \bar{Z})^2}$$

are calculated in order to obtain an estimation of the standard deviation. The arithmetic mean of these values is $\bar{Z}$ and the standard deviation of Z_i is S_z.

Empirical standard deviation:

$$S_z := \sqrt{\frac{1}{k-1}\sum_{i=1}^{k}(Z_i - \bar{Z})^2}$$

This estimate is an approximation of the standard deviation of a single weight.

$$S_1 = S_z.$$

Example:

The following table shows the results of $k = 5$ shredder campaigns

Shredder i	Number of ELV N_i	Input (t)	Proportion of fraction	Weight of fraction (t) Y_i
1	400	367.186	77%	282.733
2	931	670.770	77%	516.492
3	1153	926.436	77%	713.356
4	100	95.805	79%	75.686
5	304	195.958	75%	146.969

The total number is $N = 2888$. Now the estimate of the weight of a single vehicle becomes

$$X_1 = \frac{1735.524}{2888} = 0.6008 .$$

The random variables Z_i are

$Z_1 = 14.1367$ $Z_2 = 16.9274$ $Z_3 = 21.0083$ $Z_4 = 7.5686$ $Z_5 = 8.4292$

and the calculation of the empirical standard deviation gives

$$S_z = 5.6868 = S_1.$$

The standard deviation becomes high since the average weights of ELVs in the shredder campaigns vary up to 56.55 %. The mean weights in the shredder campaigns are

0.7068 0.5548 0.6187 0.7569 0.4834 .

2.5 Optimal division

After determining the accuracy and the resulting specific number of samples m an algorithm for the detailed division provides an optimal allocation to the classes. For an appropriate allocating, several concepts are applicable.

A proportional allocation (*cross-table design*) provides the distribution of the sample according to the frequency in the classes and factors. The division should correspond closely to the frequencies in all directions and all factors and layers. The percentage deviations of the proportions in classes and factors should be divided as evenly as possible.

On the other hand, a hierarchical or multistage selection process follows a fixed order of allocation. In the first step we allocate the numbers to the classes optimally. Afterwards we allocate the numbers to the layers and factors best possible. This creates an algorithm which reflects the allocation in the population as realistic as possible.

Both, a proportional and a hierarchical division require an algorithmic method for an integer allocation of *m* units according to the relative frequencies. A simple rounding to integers is not effective since the maximum error may reach up to the half of the total number.

The optimal integer allocation is managed by the method of *d'Hondt*. The d'Hondt method leads to a minimal residual error of the allocation compared to the exact proportion.

2.5.1 D'Hondt Method

The problem to solve: An integer number of units *M* has to be divided to *k* classes such that the proportion of the division matches the share of *representatives* of the total sum closely.

Initially, all representatives are divided successively by 1,2,3, ..., *M* which results in a matrix with *M* * *k* entries. These numbers are largest to smallest sorted. The *M* largest numbers are selected from the matrix. Now each class receives as many units as it contributes to the set of the *M* largest numbers. This process also ensures that exactly *M* units will be allocated.

Example:

A sample of *M* = 20 ATF should be selected out of 4 classes. The numbers for classes and the (geometric) centers of the classes are:

number of ATF	center	representative	type
34	50	1700	small
45	550	24750	medium
12	5500	66000	big
8	15000	120000	very big

We choose the total amount of the class, (number * center) as representatives. The matrix contains 80 entries.

division matrix

[1]	1700.00	24750.00	66000.00	120000.00
[2]	850.00	12375.00	33000.00	60000.00
[3]	566.67	8250.00	22000.00	40000.00
[4]	425.00	6187.50	16500.00	30000.00
[5]	340.00	4950.00	13200.00	24000.00
[6]	283.33	4125.00	11000.00	20000.00
[7]	242.86	3535.71	9428.57	17142.86

[8]	212.50	3093.75	8250.00	15000.00
[9]	188.89	2750.00	7333.33	13333.33
[10]	170.00	2475.00	6600.00	12000.00
[11]	154.55	2250.00	6000.00	10909.09
[12]	141.67	2062.50	5500.00	10000.00
[13]	130.77	1903.85	5076.92	9230.77
[14]	121.43	1767.86	4714.29	8571.43
[15]	113.33	1650.00	4400.00	8000.00
[16]	106.25	1546.88	4125.00	7500.00
[17]	100.00	1455.88	3882.35	7058.82
[18]	94.44	1375.00	3666.67	666.67
[19]	89.47	1302.63	3473.68	6315.79
[20]	85.00	1237.50	3300.00	6000.00

The largest 20 of the entries of this matrix have no entries in the first column (class *small*.)

The second column (class *medium*) contains 2 numbers among the largest 20. The third column (class *big*) contains 6 numbers. The remaining 12 numbers are found in the third column (class *very big*).

The optimal division 0-2-6-12 is not possible because the last class includes only 8 ATF.

In this case we apply the procedure under constraints. That means we choose all of the last class and divide only 12 units to the remaining 3 classes. The matrix is now:

division matrix

[1]	1700.00	24750.00	66000.00
[2]	850.00	12375.00	33000.00
[3]	566.67	8250.00	22000.00
[4]	425.00	6187.50	16500.00
[5]	340.00	4950.00	13200.00
[6]	283.33	4125.00	11000.00
[7]	242.86	3535.71	9428.57
[8]	212.50	3093.75	8250.00
[9]	188.89	2750.00	7333.33
[10]	170.00	2475.00	6600.00
[11]	154.55	2250.00	6000.00
[12]	141.67	2062.50	5500.00

The sorted values of this matrix have no entries in the first column among the largest 20 .

The second column contains 3 and the third contains 9 . Then the optimal choice under constraints is 0 - 3 - 9 - 8 if all 4 classes are included.

2.6 Concentration

Starting with a sample of (positive) observations $x_1, \ldots, x_n$ we discuss the distribution of the total sum $\sum_{i=1}^{n} x_i$ on individual classes. The observations are assigned to *k* classes. m_i represents the geometrical center of the class and H_i means the absolute frequency. The centers are sorted,

$$m_1 \leq m_2 \leq \ldots \leq m_k \; . \quad (4)$$

Assume the series of observations mean the output of shredder plants. Then the first class contains the smallest shredders ascending to the biggest shredders in the last class. If few large companies contribute nearly the entire turnover of this industry, then the market is highly concentrated.

The *Lorenz-curve* is a graphical representation of the cumulative distribution. Here the cumulative relative frequencies of the classes are compared to the share of total output.

The Lorenz curve consists of points (x_i, y_i)

$$x_i = \sum_{j=1}^{i} h_j \qquad \text{for } i = 1, \ldots, k$$

and

$$y_i = \frac{\sum_{j=1}^{i} m_j H_j}{\sum_{j=1}^{k} m_j H_j}.$$

h_i is the relative frequency of class *i*.

The arranging in (4) gives

$$y_i \leq x_i,$$

and the points of the Lorenz curve lie below the first median $y = x$. The points (0/0) and (1/1) are added to the curve.

In case of low concentration all classes have nearly the same contribution and the points lie close to the line y = x. But if the concentration is high, meaning that one class has almost the entire contribution to the total, then the Lorenz curve approaches the corner point (1/0).

Therefore, the area between the Lorenz curve and the line *y* = *x* serves as measure of concentration in the market. To achieve a real measure (varying between 0 and 1) the measure of concentration is calculated in terms of twice the area. This coefficient is named *Gini coefficient* or *Lorenz measure*. The formula of the Gini coefficient reads

$$LK = \sum_{i=1}^{k}(x_{i-1} + x_i)(y_i - y_{i-1}) - 1$$

with $x_0 = 0$.

Example:

The measurement of concentration in 4 classes of shredders is calculated using the following table:

Frequency Hi	Center mi	Representative	Type
29	5000	145000	small
15	15000	225000	medium
7	25000	175000	big
5	40000	200000	large

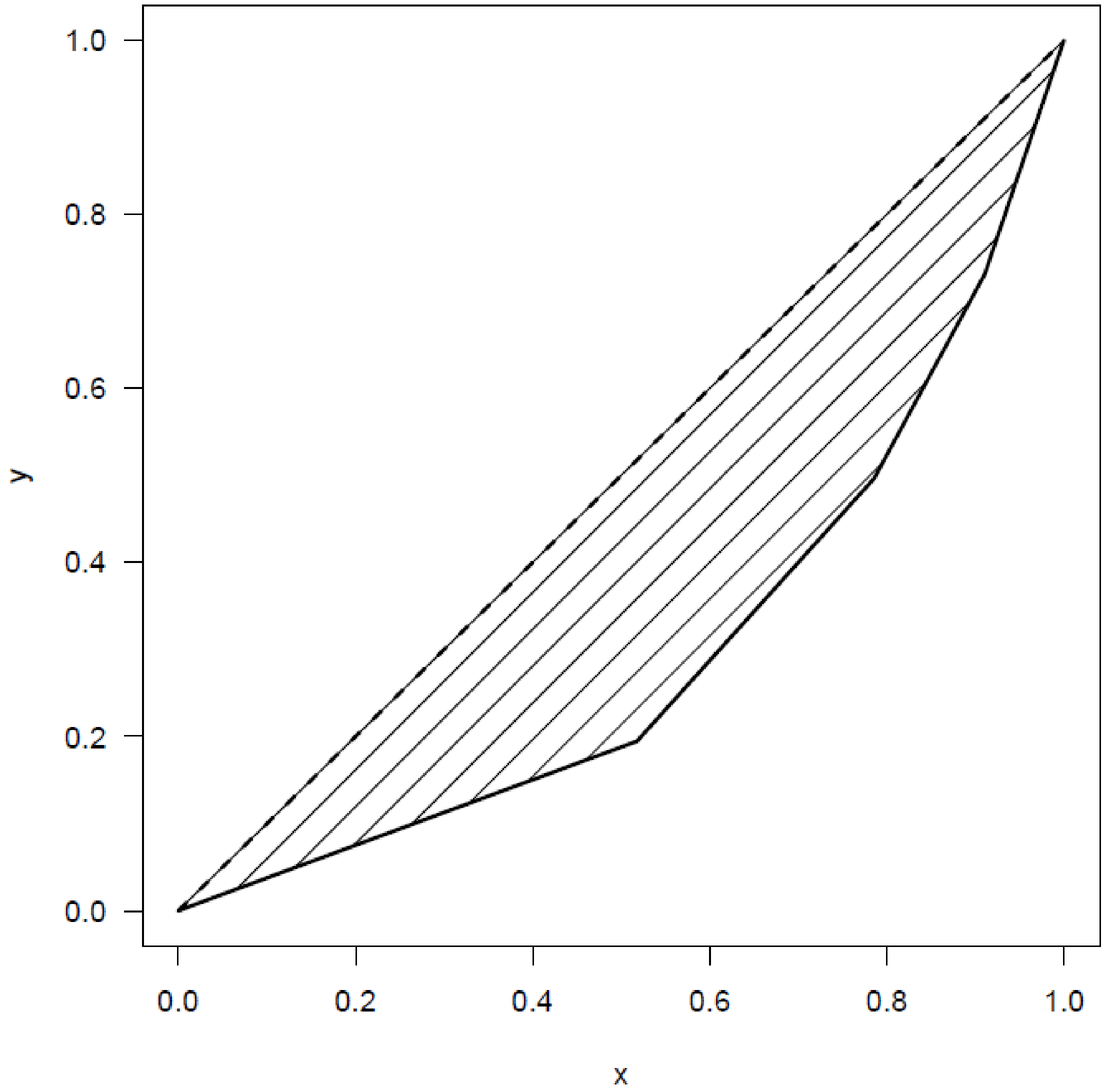
The coordinates of the points of the Lorenz curve are

xi	yi
0	0
0.5178571	0.1946309
0.7857143	0.4966443
0.9107143	0.7315436
1.0000000	1.0000000

The Gini coefficient is LK = 0.4059 , the concentration of 40.6 % reaches an average level.

The following plot shows the Lorenz curve for the actual data.

Lorenz curve for shredders



To find the optimal selection of *M*=20 shredders according to the last table we use the d'Hondt method under constraints. The large shredders should completely be included. Therefore, the matrix contains 3 columns and 15 units will be selected.

division matrix

[1]	145000.00	225000.00	175000.00
[2]	72500.00	112500.00	87500.00
[3]	48333.33	75000.00	58333.33
[4]	36250.00	56250.00	43750.00
[5]	29000.00	45000.00	35000.00
[6]	24166.67	37500.00	29166.67
[7]	20714.29	32142.86	25000.00
[8]	18125.00	28125.00	21875.00
[9]	16111.11	25000.00	19444.44
[10]	14500.00	22500.00	17500.00
[11]	13181.82	20454.55	15909.09
[12]	12083.33	18750.00	14583.33
[13]	11153.85	17307.69	13461.54
[14]	10357.14	16071.43	12500.00
[15]	9666.67	15000.00	11666.67

The optimal selection out of the classes is described by the next list.

Number	sample size	type
29	4	small
15	6	medium
7	5	big
5	5	large

3 AUXILIARY CRITERIA

Auxiliary criteria to determine differences in the composition of vehicles (exemplary).

Makes and models: The term "make" and "model" refers to the Certificate of Conformity (CoC) according to Annex IX of the Type-approval Directive 2007/46. As of May 2011 the make of a completed vehicle is entered in Annex IX Part 1 entry 0.1 of the CoC and the model is indicated under 0.2.1 *commercial name* of the CoC. They can also be found on the registration documents under D1 *make* and D3 *commercial descriptions* of Annex I, Part I of Directive 1999/37/EC on the registration documents for vehicles. Both directives are regularly subject to changes, therefore the detailed reference to the Annex where the terms are to be found can be outdated quickly and should be verified.

Mass: The mass distribution of vehicles is a criterion which is independent of individual makes and models.

Fuel type: In general it is expected that vehicles with diesel engines weigh more than vehicles with petrol engines. In fact the effect from different versions and variant of the same model often override the effect from e.g. heavier diesel engines. Data from 107 models (30 diesel, 77 petrol) showed differences in the metal content of the vehicles of less than 1%[1].

Age of the vehicle: When looking at timelines it can be observed that the composition of vehicles has changed over the years. In the context of a shredder campaign parameters are of importance which influence the relation of the output fractions of a shredder (e.g. metal/non-metal relation). The age of ELV changes from MS to MS.

Condition: The composition of some vehicles entering the AFT differs e.g. due to accidents (burned down vehicles), missing parts, additional parts or dirt and waste. (Comment: This section deals with the vehicles before entering the ATF. Regarding the effects from dismantling and depollution.)

M1/N1: An important element within the determination of the sample of ELV is the differentiation between M1 and N1 vehicles. Due to their predominant purpose of transporting goods the composition of N1 vehicles and in particular N1 class III differs from those of M1 vehicles (higher shares of metal). Therefore the share of M1 and N1 in the overall number of ELV must be identified in any case when the ELV sample for the shredder campaign shall be determined.

[1] 77 petrol models with a metal content of 75.67% (average) (range 73% - 79.6%); 30 diesel models with an average metal content of 75.89% (range 72.50% - 79.40%).

4 METAL SHARES IN VEHICLES

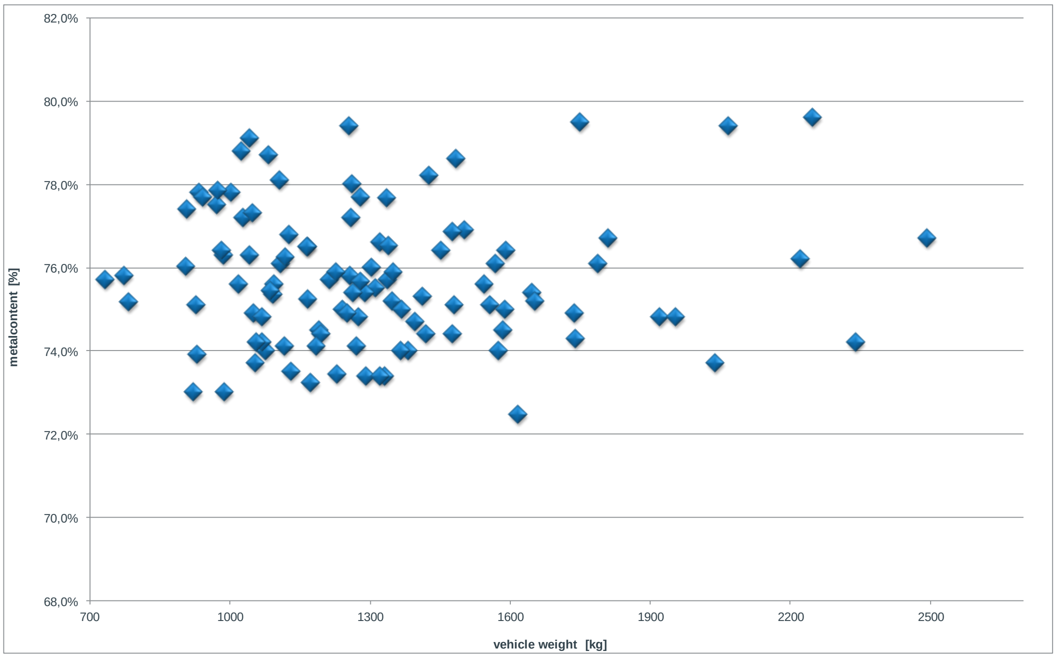


Figure 1: Metal content of 107 vehicle models of 10 manufacturers (source: ACEA per.com. 10.07.2012)