MULTICRITERIA CHOICE OF OPTIMAL DEVICE

Lappeenranta–Lahti University of Technology LUT

Master’s thesis in Chemical engineering

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D. Emela

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ABSTRACT

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Multicriteria choice of optimal device

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In all production or service-oriented processes there is continuous need for upgrading the quality of the produced goods or the service provided. Fast development of IT tools and electronic devices is among the most frequent grounds for decisions to improve such processes. The thesis focuses on specific production facility at the automotive industry. The potential for upgrading the process with new machine and the market offer alternatives is assessed. Those with selected criteria are evaluated and finally multicriteria ranking of such alternatives is prepared. Research methods include surveys and interviews with the company staff on needs and potentials for process upgrade, survey on devices available at the market, simulation of the use in the process, expert judgement of key criteria for selection and valuation of these criteria for defined alternatives, comparative analysis of several multicriteria ranking methods.

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SYMBOLS AND ABBREVIATIONS

Greek characters

υ - strategy coefficient

λ - maximum eigenvalue of the judgement matrix

Abbreviations

IATF 16949 - International Automotive Task Force 16949 (a technical specification aimed at the development of a quality management system which provides for continual improvement, emphasizing defect prevention and the reduction of variation and waste in the automotive industry supply chain and assembly process)

MCDA – multicriteria decision analysis

MCDM – multicriteria decision making

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1 INTRODUCTION

There are growing appeals for economic growth in line with sustainable development in the world. United Nations (2015) through its Sustainable Development Goals addresses “Responsible consumption and production”, encompassing the efficient management of natural resources, disposal of waste and pollutants as well as recycling and reducing waste.

Waste is an unwanted side effect of any manufacturing process resulting in higher production costs and thus decrement of the company’s profit. For that matter, the current focus of most companies is implementing activities that lead to waste prevention, reduction, or elimination. Institutions for waste handling are already established in most European countries, unlike Bosnia and Herzegovina, where recycling does not provide any added value to a business, and moreover, it can be more expensive and time consuming.

Waste in manufacturing processes can be generated by numerous factors: careless attitude of the worker, machine-related problems, measurement and control problems etc. In automotive industry, the majority of components for fuel systems are made of various types of plastic that ensures higher fuel efficiency and is highly recyclable. Unfortunately, due to high costs of recycling in Bosnia and Herzegovina, companies producing such fuel systems label pipes that do not fulfil the required standards as a waste, despite their enormous potential for recycling or reusing.

The concept of circular economy can certainly put automotive industry in Bosnia and Herzegovina to a more sustainable path of development. Circular economy represents the economic system that aims to eliminate waste through the complete value chain – manufacturing, production, and use. Its value lies in the preservation of raw materials and the total elimination of waste. In contrast, the currently used concept of linear economy manufacture raw materials into products that are used and later disposed of, finding the ultimate value in producing and selling only.

This thesis considers the field of circular economy as the main subject of its study. Extensive research on pipe recycling has been done in cooperation with company that is a system supplier for the modern automotive industry. The potential for upgrading a manufacturing process with a machine for pipe crushing and internal recycling is assessed. By enabling the circular economy model within the business, crushed piping can be melted and utilized as a raw material for the creation of new pipes. Market available machines are assessed and valuated for selected criteria. Multicriteria ranking of alternatives and market offering is executed. Finally, one alternative that ranked best by two methods is proposed for purchase.

2 PRODUCTION PROCESS

The company in question is engaged in production of piping systems for automotive industry. The production process, as shown in Figure 1, consists of:

- raw material production (extruded plastic pipes),
- assembly process and
- evaluation of the leakage conditions of the pipes.

All manufactured pipes are subject to strict quality controls in accordance with the IATF 16949 standard.

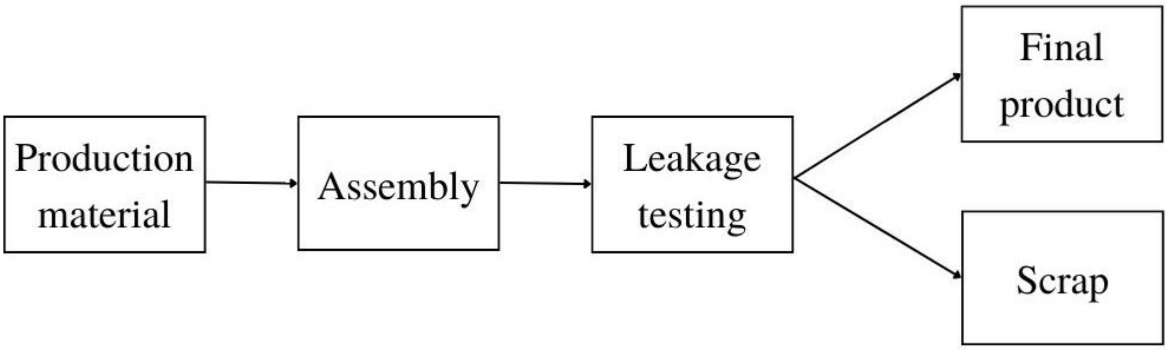

Figure 1 Production process flow

Quality assurance department monitors every production step and ensures that only the products that meet all the criteria defined by the customer are shipped further. Strict quality control implies that significant quantities of scrap are produced daily. In most cases, the causes of scraps are related to the inattention of the workers and machine defects (software and hardware). Figure 2 and Figure 3 shows scrap pipes that were damaged due to the machine defects. Figure 4 and Figure 5 illustrates defect caused by inattention of the workers, where the pipe that fulfils quality requirements is shown on the right of the damaged ones.

Figure 2 Production error due to machine defect

Figure 3 Production error due to machine defect

Figure 4 Production error due to worker inattention

Figure 5 Production error due to worker inattention

All piping systems have an annular cross section with a diameter in the range of 15 mm to 20 mm and a wall thickness of 2.5 mm on average. The length of the pipes varies from 1100 mm to 1500 mm. Material of piping systems are mostly polymers, type polyamide 6 and polyamide 12.

Assessment of daily waste production rate equals to 50 kg on average and it represents an opportunity to establish a circular business model that leads to more efficient resource use and trimmed operational waste.

As explained in Figure 1, the company currently use linear economy model. Raw material is taken, processed and production waste is disposed. Since company’s products are piping systems suitable for recycling, establishment of circular economy model would reduce company’s operational costs as well as acquire added value to the business itself.

2.1 Feasibility of recycling

Plastic waste in Bosnia and Herzegovina is landfilled and it takes up to hundreds of years to decompose. Besides being an eyesore, landfilled plastics release toxins and greenhouse gases into the air and earth. Recycling is one of the best ways to lower its polluting effect.

Generally, there are numerous of options to recycle and reuse plastic. In the case of plastic piping systems made of polyamide 6 and polyamide 12 materials, one way to recycle and reuse waste involves sorting, pre-treatment, melting, pelletizing and at the end, arbitrary manufacturing process.

The recycling process, as shown in Figure 6, begins with sorting, where external elements mounted on the pipe, such as couplings or clamping rings, are removed. When the pipe alone is ready, it undergoes shredding process, where its size is reduced to flake-like particles. The particles are later melted, cooled in water baths, and turned into pellets which are easier to manipulate when making new products. Finally, extrusion process takes place where new, recycled pipe is born.

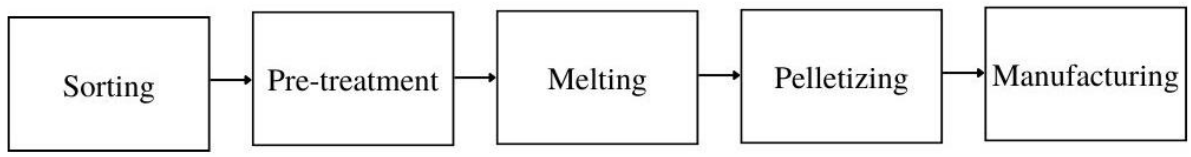

Figure 6 Plastic pipes recycling process

2.2 Pre-treatment process

Implementation of recycling process in the company supports a circular economy model that is based on using the scrap of one process as a raw material for another. In this thesis, the focus is on pre-treatment process of plastic pipes. As already mentioned, it encompasses size reduction of pipes into smaller particles. Size reduction machines can be classified as granulators and shredders, to name a few. Although one can assume that these machines perform the same tasks, this is not entirely the truth. Understanding distinction between these machines assures no costly mistakes are made in the procurement process.

Both granulators and shredders are machines that reduce larger components into smaller, more manageable pieces. The primary difference between granulator and shredder is the output size they produce. Shredder is a single-stage machine which produce particles with sizes ranging from 20 to 100 mm. Dual shaft shredders, which have no screens at the outlet, can generate particles with a wide range of sizes and shapes. Granulators are ideal machines for producing consistently uniform granules since they can repeatedly lower the size of the scrap until it passes through the 5 mm to 12 mm screen holes (Niaounakis, 2020).

Another major fact that distinguishes shredder and granulator is feeding. Granulators operate at high speed (from 415 rpm to 1460 rpm) with relatively low torque. Shredders, on the other hand, operate at lower speeds (3,6 rpm to 83 rpm) with high torque. With such design features, it is not ideal to feed a lot of large sized and high-density material at a time into granulator because it creates a lot of noise, lead to jam and can even potentially damage the granulator. Most granulators require feeding by hand or a conveyor. Shredders are quite the opposite, the more and heavier the scraps are, the easier it is to shred as the weight of the scrap on top of the hopper can force the lower scrap down to the cutters. Moreover, most shredders can automatically reverse the rotor to clean the jams that can occur from over feeding, particularly of thick material, or foreign matter like hard material. So, for shredders, feeding is straight forward. The material is fed into the hopper and then the machine will get the job done by itself (Niaounakis, 2020).

In some cases, these two types of size reduction machines can work together. Shredder performs coarse size-reduction task and then the shreds are further fed by conveyor into a granulator for final sizing to consistent, small, and uniform granules.

Foregoing research has revealed that scrap features are a decisive factor in choosing the right machine, including size of the input scrap and output particle size. Considering the pipe characteristics presented in Table 1, it can be concluded that pipes are not robust in dimensions.

Table 1 Pipe characteristics

Diameter	15 ÷ 20 mm
Wall thickness	2,5 mm
Length	1100 ÷ 1500 mm

Furthermore, in consultation with relevant machine producers it is concluded that for daily scrap throughput of 50 kg, feeding by conveyor would not be efficiently utilized and it would needlessly increase the machine dimensions. Hence, feeding by hand is the optimal machine setting. To further manipulate and process the particles smoothly, they should be small-sized. Accordingly, output particle sizes lower than 20 mm are certainly required.

To summarize:

- compact size of the pipes,
- hand feeding and
- output particle size lower than 20 mm

leads to the conclusion the optimal solution for pipe recycling is a granulator alone. Choosing a machine of any type is a complex task since there are numerous aspects and constrains to consider. For this purpose, the multicriteria decision aid is utilized.

3 LITERATURE REVIEW

There is a large volume of published studies describing the role of multicriteria decision analysis in equipment selection problems. Multiple methods are available for executing this analysis including analytical hierarchical process (AHP), the analytical network process (ANP), multicriteria optimisation and compromise ranking (VIKOR), elimination and choice translating reality (ELECTRE), the preference ranking organization method for enrichment of evaluation (PROMETHEE), technique for the order of prioritisation by similarity to ideal solution (TOPSIS), etc.

The literature on equipment selection has highlighted several multicriteria decision analysis applications such as selection of construction equipment (Temiz and Calis, 2017), selection of milling machines (Dagdeviren, 2008), open pit mines equipment selection (Samanta et al., 2002), selection of the loading and hauling system's equipment (Bascetin, 2004; Bazzazi et al., 2011), hydraulic excavator selection (Alpay and Iphar, 2018), machine tool selection (Wiriyapirom, 2017), loader selection (Yavuz, 2015), electrical energy equipment selection (Maniya and Bhatt, 2013), mining equipment (Bodziony et al., 2019) etc.

Table 2 provides a summary of the multicriteria decision making methods that the researchers found most adequate for the equipment selection problem in question.

Table 2 Employed multicriteria decision making methods

Authors	Applied methods	Application objective
Temiz and Calis (2017)	AHP, PROMETHEE	Construction equipment selection
Dagdeviren (2008)	AHP, PROMETHEE	Milling machine selection
Samanta et al. (2002)	AHP	Mining equipment selection
Bascetin (2004)	AHP	Loading-hauling system’s equipment selection
Bazzazi et al. (2011)	VIKOR	Loading-hauling system’s equipment selection
Alpay and Iphar (2018)	TOPSIS, VIKOR	Hydraulic excavator selection
Wiriyapirom (2017)	AHP, PROMETHEE	Machine tool selection
Yavuz (2015)	AHP, Yager	Loader selection

Maniya and Bhatt (2013)	AHP, PSI	Electrical energy equipment selection
Bodziony et al. (2019)	AHP	Mining equipment selection

Among previously mentioned MCDM methods, VIKOR has proved that it can support the problem in this study (Bazzazi et al., 2011). However, the subjective initial weighting, which is challenging to evaluate, is a drawback of the VIKOR approach. Wibawa et al. (2019) studied the effects of AHP weighting in combination with VIKOR method. The results indicated that AHP-VIKOR outperformed VIKOR alone. In comparison to VIKOR, the AHP-VIKOR result is more precise and consistent. Temiz and Calis (2017) proved that AHP weighting method produce consistent results. Dagdeviren (2008), who used this approach to address a company problem regarding equipment selection, supports this viewpoint. The management of the company in question considered the suggested model acceptable and effective for other equipment procurement processes as well.

The majority of the research on MCDM related equipment selection focuses on evaluating just one decision making method with a single issue (Samanta et al., 2002; Bascetin, 2004; Bazzazi et al., 2011). This is a problem since different methods might provide different outcomes when used to solve the same problem, thus it's crucial to consider how well each method works with a certain kind of selection problem (Malczewski and Rinner, 2016). In their review of selecting the hydraulic excavator, Alpay and Iphar (2018) suggest that if a decision process involves subjectivity, it is advisable to compare the consistency of the outcomes using at least two different multicriteria decision making approaches.

The literature on AHP method (Samanta et al., 2002; Bascetin, 2004; Bodziony et al., 2019) has highlighted that application of the AHP method can assist engineers in evaluating the alternatives effectively. The decision makers could use AHP method models because they are clear, simple to understand and transparent.

During literature review, articles presenting implementation of VIKOR combined with AHP method utilized to determine criteria weights were scarce. Consequently, this study will examine whether using the MCDM method VIKOR along the AHP for criteria importance weighting will assist decision makers in making well-informed choices and obtaining the optimum alternative in selection of equipment. Additionally, AHP method will be implemented to examine the consistency of the outcomes of the VIKOR method.

4 MULTICRITERIA DECISION AID

The process of selecting the best practical solution in accordance with the defined criteria is known as multicriteria optimization. Practical issues are frequently characterized by diverse non-commensurable and conflicting criteria, and it may not always be possible to find a solution that simultaneously optimizes each of those criteria. Therefore, the solution is a group of non-inferior solutions or a compromise solution depending on the decision maker's preferences (Opricovic and Tzeng, 2004).

4.1 VIKOR method

The VIKOR method (srp. VIšekriterijumsko KOmpromisno Rangiranje) was developed as a multicriteria decision making method to solve a discrete decision problem with conflicting and impossible-to-measure criteria (Opricovic and Tzeng, 2004).

The focus of VIKOR method is ranking and selecting from a set of alternatives, determining compromise solution for a problem with conflicting criteria and thus, helping the decision maker to reach a final solution. Determining the positive and negative ideal points in the solution space is the fundamental principle behind the VIKOR approach, as seen in (2). Based on the "closeness" to the "ideal" solution, it evaluates a multicriteria ranking index. The compromise ranking can be determined by comparing the relative closeness measure to the ideal alternative when each alternative is assessed in respect to each criterion (Yazdani and Graeml, 2014; Mardani et al., 2016).

Based on the Lp-metric D, the following is the distance measurement to the ideal solution:

$$D(Aj) = \sqrt[p]{\sum_{i=1}^{N} Ci \cdot \frac{f_{ij}^{+} - f_{ij}}{f_i^{+} - f_i^{-}}} \tag{1}$$

where:

$$f_i^{+} = max\, f_{ij}\ (i = 1,2,\ldots,n)$$
$$f_i^{-} = min\, f_{ij}\ (i = 1,2,\ldots,n) \tag{2}$$

where:

- f_{ij} - values of j^{th} criteria of i^{th} alternative and

- c_i - criteria weights,

where it is requested that each particular criterion be maximized.

Two Lp-metric variants serve as the basis for VIKOR, for p=1 and p=∞:

$$S_j = \sum_{i=1}^{N} Ci \cdot \frac{f_{ij}^{+} - f_{ij}}{f_i^{+} - f_i^{-}} \tag{3}$$

and

$$R_j = \max\left(C_i \cdot \frac{f_{ij}^{+} - f_{ij}}{f_i^{+} - f_i^{-}}\right) \tag{4}$$

and then creates different 2D space RS of alternatives with the following definition of the L1 metric Q:

$$Q(A_j) = Q_j = \nu\, QS_j + (1-\nu)\, QR_j = QR_j + \nu\,(QS_j - QR_j) \tag{5}$$

where:

$$QR_j = \frac{(R_j - R^{+})}{(R^{-} - R^{+})} \quad and \quad QS_j = \frac{(S_j - S^{+})}{(S^{-} - S^{+})} \tag{6}$$

and

$$S^{+} = min\, S_j, \quad S^{-} = max\, S_j, \quad R^{+} = min\, R_j \quad and \quad R^{-} = max\, R_j \tag{7}$$

The "strategy coefficient" (coefficient υ) always falls within the range [0, 1], with values higher than 0.5 placing more emphasis on meeting the majority of the requirements and lower values placing more emphasis on minimizing individual deviations from the ideal solution. (Vučijak et al., 2016)

VIKOR method, for the compromise alternative proposes the one first ranked for υ = 0.5, while also satisfying the following criteria:

- The necessary advantage over the following ranked alternative is achieved. This is true if $Q(A_j) - Q(A_i) \geq DQ$ is valid for ν=0.5, while DQ = min (0.25, $\frac{1}{M-1}$) (0.25 indicates advantage in case of number of alternatives is too low), and M represents alternatives number,

- To own a position that remains stable with the change of "strategy coefficient" υ, indicating that one or more of these requirements is true:

  - With υ = 1, the ideantical alternative is ranked first,
  - With υ = 0, the ideantical alternative is ranked first, or (8)
  - With υ = 0.25 and υ = 0.75, the ideantical alternative is ranked first.

If the alternative ranked first satisfies both requirements, it is not significantly superior to the second option, and both are therefore viewed as compromise solution. If it doesn't fit the first requirement alone, it nevertheless qualifies as a compromise solution along with all of the other options listed that also don't meet the first requirement. The second-ranked alternative is to be suggested only as a compromise if the alternative ranked first does not meet only the second requirement (Pašić et al., 2009).

4.2 Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) disaggregates a complex decision problem into different hierarchical levels (Saaty, 1987). The weight for each criterion is judged in pairwise comparison and priorities are calculated by the Eigenvector method. Evaluation of weights for alternatives is provided by pairwise comparisons of alternatives by individual criteria. In addition, AHP with applied paired comparisons simplifies judgements and calculations and it shows consistency or inconsistency of decisions (Jalaliyoon, 2012).

Phases of conducting an AHP, as suggested by Saaty (1987) are as follows:

- The issue is organized into a hierarchy of objectives, criteria, and alternatives. A hierarchy shows a connection between items on one level and those on the level just underneath it. Every element in the hierarchy is connected to every other element, at the very least indirectly, thanks to this interaction that permeates the hierarchy's lowest levels. Figure 7 shows a generic hierarchic structure.

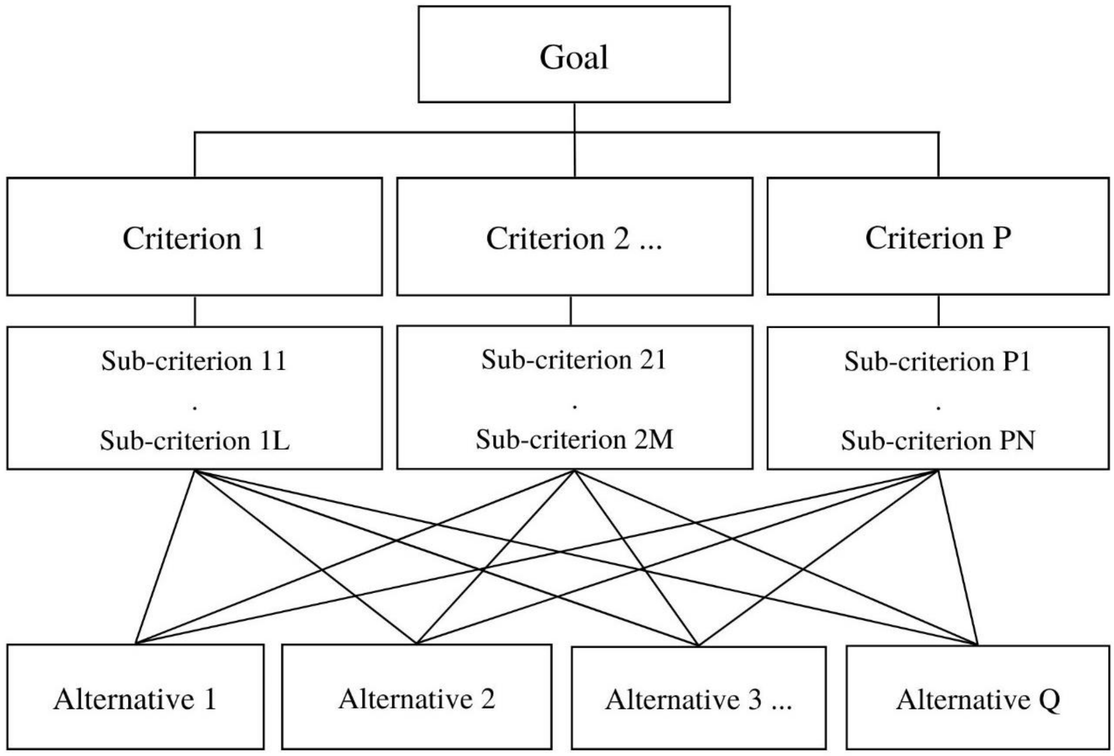

Figure 7 Generic hierarchical structure (Bhushan and Rai, 2014)

- To conduct pairwise comparison a questionnaire should be designed and distributed among the respondents (decision-makers, expert users etc.) to acquire their opinion. It can be collected in a format as shown in Figure 8. „X“ in the column marked „Strong importance“ indicates that A is strong compared with B in terms of criterion on which the comparison is being made. Comparisons are made for each criterion. Each decision maker enters their grade for individual criteria and then individual judgements of each respondent is converted into group judgements using the geometrical average. The benchmark reference is illustrated in Table 3, according to Saaty (1980).

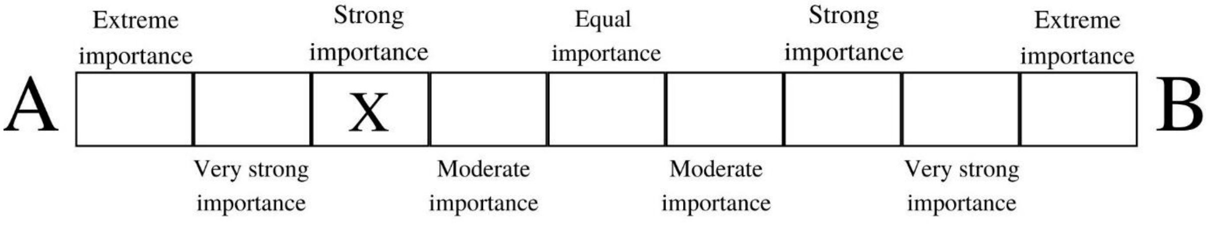

Figure 8 Format for pairwise comparison

Table 3 The fundamental scale (Saaty, 1980)

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgement strongly favour one activity over another
5	Essential or strong importance	Experience and judgement strongly favour one activity over another
7	Very strong importance	An activity is strongly favoured, and its dominance demonstrated in practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgements	When compromise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared to activity *j*, then *j* has the reciprocal value when compared with *i*	

- The pairwise comparison matrix is extracted from the data collected from the interviews. The squared matrix's diagonal elements are equal to 1. If the value of the element (i,j) is greater than 1, the criterion in the ith row is preferable to the criterion in the jth column; otherwise, the jth column's criterion is preferable to the ith row's criterion. The matrix's (j,i) element is the (i,j) element's inverse.
- The principal eigenvalue of the comparison matrix and the associated normalized right eigenvector show the relative weights given to the various comparison criteria. The consistency ratio of the matrix of order n is evaluated. If value fails to accomplish the required minimum, the answers to comparisons may be re-examined. Saaty (1987) suggests that the value of consistency ratio should be lower than 0.1. The consistency ratio, CR, is calculated as:

$$CR = \frac{CI}{RI} \quad (9)$$

Consistency index, CI, is calculated as:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (10)$$

where:

λ_{max} – maximum eigenvalue of the judgement matrix,

n – number of criteria.

The value of random consistency index, RI, is obtained from Table 4 below.

Table 4 The value of Random consistency Index (Golden, 1990)

Dimension	RI
1	0
2	0
3	0.5799
4	0.8921
5	1.1159
6	1.2358
7	1.3322
8	1.3952
9	1.4537
10	1.4882

- To obtain local ratings with regard to each criterion, the weighted average of the ratings for each alternative is multiplied by the weights of the sub-criteria. The weights of the criteria are then compounded by the local ratings, which are subsequently aggregated to provide the global ratings.

Based on the assessed relative importance of each alternative to a common criterion, the AHP method generates weighted values for each alternative.

5 CASE STUDY

5.1 Criteria selection

The criteria for decision process are decided with a team constituted from two most relevant decision makers within the company (industrial engineer and project manager), and additionally an expert who is a production engineer with over 15 years of experience in recycling. Criteria are selected as follows:

- **Height** – Considering the hall layout, machine should not be robust in dimensions. Due to the manual feeding process, the height of the machine, expressed in millimetres, should be minimised.
- **Weight** – To meet inconsistent number of orders for distinct parts, change of the hall layout is frequent. To be able to respond to these challenges, machine should be easy to manipulate by employees. Machines are relocated manually, with electric hand pallet truck of which maximum load capacity is 1000 kg on average. The weight of the machine should not exceed load capacity of an electric hand pallet truck, thus all machines weighting more than 1000 kg will not be considered nor included in ranking. From previous observations, it is clear that weight of the machine, expressed in kilograms, should be minimised.
- **Screen mesh size** – Screen mesh size is used to control the final product size and it is dependent on machine size and material composition. Smaller screen holes and a thinner screen will result in more uniform particle sizes and the maximum throughput when operating at slower rotor speeds. A range of Ø3 mm to Ø20 mm of the screen mesh size is available on the market. The granulate particles should be as fine as possible, thus the screen mesh size, expressed in millimeters, should be minimised.
- **Number of rotor blades** - The overall design of the knives can impact the quality of the final granulate and the efficiency of the equipment. Knives can be positioned on a fixed bed or on a granulator's rotor. For increased efficiency of the equipment and quality of the final granulate, number of rotor blades of the granulator should be maximised.
- **Number of stator blades** – According to the prior criterion, for increased efficiency of the equipment and quality of the final granulate, number of stator blades of the granulator should be maximised.

- **Cleaning time** – Granulator, due to its purpose, can get clogged easily. Time needed to disassemble and clean the granulator should be as low as possible for manufacturing process to run smoothly. Expressed in minutes, cleaning time of the machine should be minimised.

- **Changeability** – Relates to the repair friendliness of the machine design. Changeability implies disassembling of the machine is possible in a simple, fast, and non-destructive way with no special tool requirements. This is achieved by screw or plug-in connection types. All parts should be easily accessed for regular maintenance: greasing the rotor bearings, checking the rotating blade and bed knife wear, on a regular basis or as needed replacing the blades or bed knives, sharpening the knives to the proper angle, etc. It is evaluated by opinion of an expert and should be maximised. Expert is selected based on expertise and years of experience: over fifteen years in recycling and seven years in automotive industry. The measuring scale equals from one to ten, where one represents poor changeability and ten signifies exceptional changeability.

- **Energy consumption** – Adhering to the ISO 50001:2018 standard that reflects following a systematic approach in achieving continual improvement of energy performance, the company aims to purchase new machines that are energy efficient. Since the granulator will require feeding by hand, staff will be appointed to this workplace. Due to the company efforts to reduce the number of non-essential workers in night shifts, recycling will be done only during the day shift. The specific energy consumption will be expressed per one shift which equals to 8 hours, and it should be minimised.

- **Cost** – Cost plays an important role in decision making. It is expressed in EUR and should be minimised. Relevant types of costs in choosing a new machine are procurement, operational and maintenance costs. This criterion implies procurement cost, while operational costs are included into energy consumption previously listed. Maintenance costs are not taken into account since they are not provided by the suppliers and there is no reliable data available on other sites.

Further criteria that are considered are approximately equal for all the alternatives, for that reason they are not included in multicriteria ranking.

- **Warranty** – The warranty period is 12 months for all alternatives. There is one alternative with warranty period of 13 months, but this difference is insignificant, hence this criterion is considered but not included in ranking.

- **Discharge unit** – Following the 5S methodology, all workstations should remain clean at all times. For that reason, discharge unit should be able to collect all the excess material or dust. All alternatives offer customizable discharge unit solution.
- **Knives clearance** – The performance of size reduction depends on the space between rotating and stationary knives. Cleaner, more efficient cuts come from reduced clearance. All alternatives secure corresponding satisfactory clearance.
- **Knives material** – Knives are made of high-quality knife-grade steel with high durability, where blades can withstand wear as well as shock.
- **Hopper dimensions** – Hopper is used to feed the crushing chamber with plastic material to be recycled. Every alternative offers customizable hopper dimensions that are suitable for pipes that company produces.

Table 5 below represents a list of selected criteria. Additionally, column three indicated if criteria should be maximised or minimized.

Table 5 Criteria selected for analysis

Criteria		Preference
Height	Criteria 1	Minimised
Weight	Criteria 2	Minimised
Screen mesh size	Criteria 3	Minimised
Number of rotor blades	Criteria 4	Maximised
Number of stator blades	Criteria 5	Maximised
Cleaning time	Criteria 6	Minimised
Changeability	Criteria 7	Maximised
Energy consumption	Criteria 8	Minimised
Cost	Criteria 9	Minimised

5.2 Alternatives overview

An extensive research of market available granulators was conducted over a period of two months. A quotation is requested for alternatives agreed with relevant decision makers, which corresponds to the needs of the company. A total of six suppliers submitted their quotations.

Appendix 1 contains all obtained offers and Table 6 summarizes information received from suppliers.

Table 6 Alternatives overview

	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**	**Alternative 6**
Product	PS-C-M-2541	GSE 300/300	S 20/40L-(V)	D25.38s Standard	150-21 DeltaTECH	G17-22-3K-ARK
Supplier	Prosino	ZERMA	Dreher	Wanner	RAPID	CMG
Criteria 1 Height	1310 mm	1880 mm	1225 mm	1732 mm	1790 mm	1457 mm
Criteria 2 Weight	420 kg	900 kg	500 kg	430 kg	220 kg	190 kg
Criteria 3 Screen mesh size	Ø10 mm	Ø8 mm	Ø5 mm	Ø6 mm	Ø5 mm	Ø5 mm
Criteria 4 Number of rotor blades	12	3	6	18	9	9
Criteria 5 Number of stator blades	2	2	4	2	2	2
Criteria 6 Cleaning time	10 min	15 min	10 min	30 min	20 min	35 min
Criteria 7 Changeability	5	6	9	9	7	8
Criteria 8 Energy consumption	60 kWh	60 kWh	60 kWh	44 kWh	17,6 kWh	17,6 kWh
Criteria 9 Cost	€ 5.056,52	€ 12.950,00	€ 14.746,25	€ 11.045	€ 7.300	€ 14.180,7

5.3 Criteria weight generation using Analytical Hierarchy Process

This method is used to determine the appropriate weight for each criterion. Excel was used to execute this approach. To begin with, the opinions of most-relevant decision makers are considered. The fact that Saaty's scale of intensity of importance contains nine grades and there are nine criteria in this case study, allows simplification of the interviewing process. Project manager and industrial engineer from the company are interviewed to express their preference in criteria ranking. Interviewees are asked to rank the criteria according to their own professional preference and opinion of relevance in buying a new granulator. The ranking process is done individually and any possibility of affecting each other's opinion is eliminated.

Table 7 represents the ranking of criteria according to their evaluations. Arithmetic mean is used to unify the received inputs. The importance is ranked from one to nine, where first ranked represents the most important one and ninth ranked represents the least important one.

Table 7 Criteria ranking

Criteria		**Rank**
Changeability	C7	1
Number of rotor blades	C4	2
Number of stator blades	C5	3
Screen mesh size	C3	4
Energy consumption	C8	5
Cost	C9	6
Cleaning time	C6	7
Weight	C2	8
Height	C1	9

Table 8 displays the outcomes of the pairwise comparisons for the nine primary criteria. Criteria are arranged according to Table 3. The importance of one criterion over another is evaluated according to obtained inputs. Diagonal elements are always equal to one since the criterion is compared to itself and its significance does not variate.

Table 8 Pairwise comparison of criteria importance

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	1	1/2	1/6	1/8	1/7	1/3	1/9	1/5	1/4
C2	2	1	1/5	1/7	1/6	1/2	1/8	1/4	1/3
C3	6	5	1	1/3	1/2	4	1/4	2	3
C4	8	7	3	1	2	6	1/2	4	5
C5	7	6	2	1/2	1	5	1/3	3	4
C6	3	2	1/4	1/6	1/5	1	1/7	1/3	1/2
C7	9	8	4	2	3	7	1	8	6
C8	5	4	1/2	1/4	1/3	3	1/8	1	2
C9	4	3	1/3	1/5	1/4	2	1/6	1/2	1

Normalized values of pairwise comparison are calculated and represented in Table 9, while weighted coefficients describing criterion's relative importance is shown in Table 10. Figure 9 presents graphical form of criteria weights.

Table 9 Normalized values of pairwise comparison

	C1	C2	C3	C4	C5	C6	C7	C8	C9
C1	0,0222	0,0137	0,0146	0,0265	0,0188	0,0116	0,0403	0,0104	0,0113
C2	0,0444	0,0274	0,0175	0,0303	0,0220	0,0173	0,0454	0,0130	0,0151
C3	0,1333	0,1370	0,0873	0,0707	0,0659	0,1387	0,0908	0,1037	0,1358
C4	0,1778	0,1918	0,2620	0,2120	0,2634	0,2081	0,1816	0,2074	0,2264
C5	0,1556	0,1644	0,1747	0,1060	0,1317	0,1734	0,1210	0,1556	0,1811
C6	0,0667	0,0548	0,0218	0,0353	0,0263	0,0347	0,0519	0,0173	0,0226
C7	0,2000	0,2192	0,3493	0,4239	0,3951	0,2428	0,3631	0,4149	0,2717
C8	0,1111	0,1096	0,0437	0,0530	0,0439	0,1040	0,0454	0,0519	0,0906
C9	0,0889	0,0822	0,0291	0,0424	0,0329	0,0694	0,0605	0,0259	0,0453

Table 10 Final evaluated criteria weights

Criteria	Criteria weights
Criteria 1 Height	0,01882
Criteria 2 Weight	0,02581
Criteria 3 Screen mesh size	0,10703
Criteria 4 Number of rotor blades	0,21449
Criteria 5 Number of stator blades	0,15149
Criteria 6 Cleaning time	0,03683
Criteria 7 Changeability	0,32000
Criteria 8 Energy consumption	0,07257
Criteria 9 Cost	0,05296

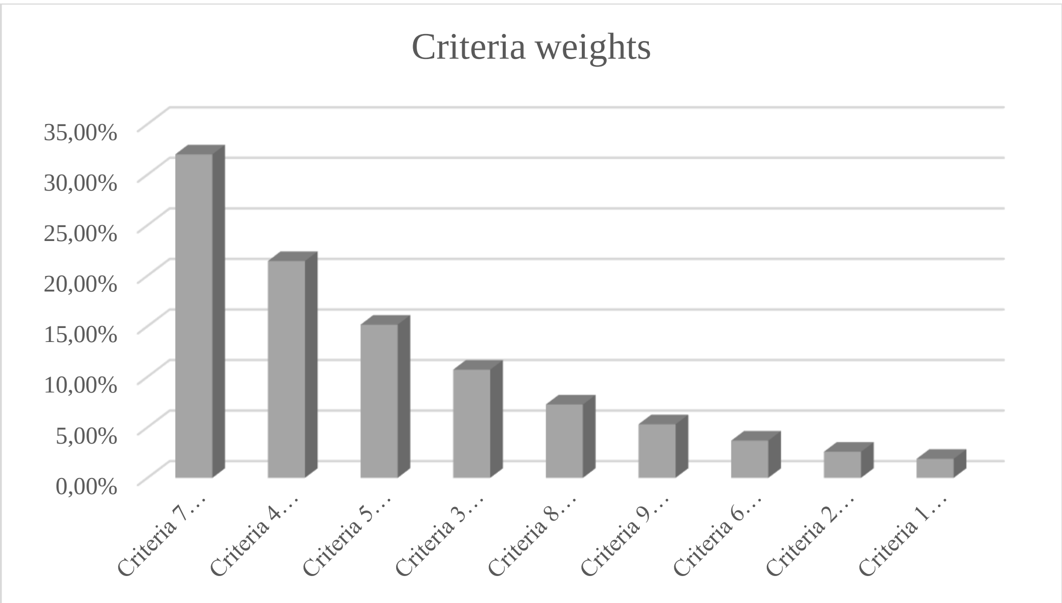

Figure 9 Criteria weights

Finally, consistency ratio is calculated and presented in Table 11. Consistency ratio equals to less than 10%, meaning grading of the criteria is done consistently.

Table 11 Consistency ratio

Consistency ratio	5,94%
λ_{max}	9,688754635
Consistency index	0,086094329
Random consistency index	1,45
CI / RI	0,0593754

5.4 VIKOR method

After determination of criteria weights, alternatives ranking by VIKOR method follows. Initially, a matrix containing criteria and alternatives is presented in Table 12, also containing information if criteria is maximized or minimized.

Table 12 Initial matrix

C/A	A1	A2	A3	A4	A5	A6	Min/Max
C1	1310	1880	1225	1732	1790	1457	-1
C2	420	900	500	430	220	190	-1
C3	10	8	5	6	5	5	-1
C4	12	3	6	18	9	9	1
C5	2	2	4	2	2	2	1
C6	10	15	10	30	20	35	-1
C7	5	6	9	9	7	8	1
C8	60	60	60	44	17,6	17,6	-1
C9	5057	12950	14746	11045	7300	14181	-1

Followingly, every criterion f_i that must be minimized is swapped with $-f_i$ that must be maximized, and shown in Table 13.

Table 13 Maximum matrix

	A1	A2	A3	A4	A5	A6	Min	Max	Range
C1	-1310	-1880	-1225	-1732	-1790	-1457	-1880	-1225	655
C2	-420	-900	-500	-430	-220	-190	-900	-190	710

C3	-10	-8	-5	-6	-5	-5	-10	-5	5
C4	12	3	6	18	9	9	3	18	15
C5	2	2	4	2	2	2	2	4	2
C6	-10	-15	-10	-30	-20	-35	-35	-10	25
C7	5	6	9	9	7	8	5	9	4
C8	-60	-60	-60	-44	-17,6	-17,6	-60	-17,6	42,4
C9	-5056,5	-12950	-14746	-11045	-7300	-14181	-14746,3	-5056,5	9689,7

Equation (2) and the weights from Table 10 are used to normalize the criteria values as indicated in Table 14.

Table 14 Normalized values

C/A	A1	A2	A3	A4	A5	A6
C1	0,00244	0,01882	0,00000	0,01457	0,01623	0,00667
C2	0,00836	0,02581	0,01127	0,00873	0,00109	0,00000
C3	0,10703	0,06422	0,00000	0,02141	0,00000	0,00000
C4	0,08580	0,21449	0,17159	0,00000	0,12870	0,12870
C5	0,15149	0,15149	0,00000	0,15149	0,15149	0,15149
C6	0,00000	0,00737	0,00000	0,02946	0,01473	0,03683
C7	0,32000	0,24000	0,00000	0,00000	0,16000	0,08000
C8	0,07257	0,07257	0,07257	0,04518	0,00000	0,00000
C9	0,00000	0,04314	0,05296	0,03273	0,01226	0,04987

Using the preceding formulas (5), (6), and (7), Table 15 displays derived QS, QR, and Q values, with Q values given for various “strategy coefficient” values υ (υ = 0.25, υ = 0.50, υ = 0.75).

Table 15 QS, QR and Q values

	A1	A2	A3	A4	A5	A6
S	0,74769	0,83791	0,30839	0,30357	0,48451	0,45355
R	0,32000	0,24000	0,17159	0,15149	0,16000	0,15149
QS	0,83116	1,00000	0,00902	0,00000	0,33862	0,28068
QR	1,00000	0,52524	0,11928	0,00000	0,05048	0,00000

Q (υ=0,25)	0,95779	0,64393	0,09172	0,00000	0,12251	0,07017
Q (υ =0,5)	0,97889	0,58458	0,10550	0,00000	0,08650	0,03509
Q (υ=0,75)	0,96307	0,62909	0,09516	0,00000	0,11351	0,06140

Table 16 Alternatives final ranking

Rank	υ = 0,5	υ = 0,25	υ = 0,75
1	A4	A4	A4
2	A6	A6	A6
3	A5	A3	A3
4	A3	A5	A5
5	A2	A2	A2
6	A1	A1	A1

5.5 Analytical Hierarchy Process

Table 17-43 shows the evaluation of each alternative's importance in relation to a common criterion. The consistency ratio is also assessed.

- **Height**

Table 17 The evaluation of criteria with respect to height criterion

C1	A1	A2	A3	A4	A5	A6
A1	1	1/5	2	1/3	1/4	1/2
A2	5	1	6	3	2	4
A3	1/2	1/6	1	1/4	1/5	1/3
A4	3	1/3	4	1	1/2	2
A5	4	1/2	5	2	1	3
A6	2	1/4	3	1/2	1/3	1

Table 18 Normalized values of relative weights

C1	A1	A2	A3	A4	A5	A6	Row average	Column sum	Product
A1	0,065	0,082	0,095	0,047	0,058	0,046	0,065	15,500	1,015
A2	0,323	0,408	0,286	0,424	0,467	0,369	0,379	2,450	0,929
A3	0,032	0,068	0,048	0,035	0,047	0,031	0,043	21,000	0,912
A4	0,194	0,136	0,190	0,141	0,117	0,185	0,160	7,083	1,136
A5	0,258	0,204	0,238	0,282	0,233	0,277	0,249	4,283	1,066
A6	0,129	0,102	0,143	0,071	0,078	0,092	0,102	10,833	1,110

Table 19 Consistency check

Consistency ratio	**2,72%**
λ_{max}	6,168904
Consistency index	0,033781
Random consistency index	1,24
CI / RI	0,027243

- **Weight**

Table 20 The evaluation of criteria with respect to weight criterion

C2	A1	A2	A3	A4	A5	A6
A1	1	1/4	1/3	1/2	2	3
A2	4	1	2	3	5	6
A3	3	1/2	1	2	4	5
A4	2	1/3	1/2	1	3	4
A5	1/2	1/5	1/4	1/3	1	2
A6	1/3	1/6	1/5	1/4	1/2	1

Table 21 Normalized values of relative weights

C2	A1	A2	A3	A4	A5	A6	Row average	Column sum	Product
A1	0,092	0,102	0,078	0,071	0,129	0,143	0,102	10,833	1,110
A2	0,369	0,408	0,467	0,424	0,323	0,286	0,379	2,450	0,929

A3	0,277	0,204	0,233	0,282	0,258	0,238	0,249	4,283	1,066
A4	0,185	0,136	0,117	0,141	0,194	0,190	0,160	7,083	1,136
A5	0,046	0,082	0,058	0,047	0,065	0,095	0,065	15,500	1,015
A6	0,031	0,068	0,047	0,035	0,032	0,048	0,043	21,000	0,912

Table 22 Consistency check

Consistency ratio	**2,72%**
λ_{max}	6,168904
Consistency index	0,033781
Random consistency index	1,24
CI / RI	0,027243

- **Screen mesh size**

Table 23 The evaluation of criteria with respect to screen mesh size criterion

C3	A1	A2	A3	A4	A5	A6
A1	1	1/8	1/8	1/8	1/8	1/8
A2	8	1	1/5	1/5	1/5	1/5
A3	8	5	1	2	1	1
A4	8	5	1/2	1	1/2	1/2
A5	8	5	1	2	1	1
A6	8	5	1	2	1	1

Table 24 Normalized values of relative weights

C3	A1	A2	A3	A4	A5	A6	Row average	Column sum	Product
A1	0,024	0,006	0,033	0,017	0,033	0,033	0,024	41,000	0,994
A2	0,195	0,047	0,052	0,027	0,052	0,052	0,071	21,125	1,502
A3	0,195	0,237	0,261	0,273	0,261	0,261	0,248	3,825	0,949
A4	0,195	0,237	0,131	0,137	0,131	0,131	0,160	7,325	1,173
A5	0,195	0,237	0,261	0,273	0,261	0,261	0,248	3,825	0,949
A6	0,195	0,237	0,261	0,273	0,261	0,261	0,248	3,825	0,949

Table 25 Consistency check

Consistency ratio	**8,33%**
λ_{max}	6,516332
Consistency index	0,103266
Random consistency index	1,24
CI / RI	0,083279

- **Number of rotor blades**

Table 26 The evaluation of criteria with respect to number of rotor blades criterion

C4	A1	A2	A3	A4	A5	A6
A1	1	5	4	1/2	2	4
A2	1/5	1	1/2	1/6	1/4	1/4
A3	1/4	2	1	1/5	1/4	1/2
A4	2	6	5	1	4	4
A5	1/2	4	4	1/4	1	2
A6	1/4	4	2	1/4	1/2	1

Table 27 Normalized values of relative weights

C4	A1	A2	A3	A4	A5	A6	Row average	Column sum	Product
A1	0,238	0,227	0,242	0,211	0,250	0,340	0,252	4,200	1,057
A2	0,048	0,045	0,030	0,070	0,031	0,021	0,041	22,000	0,903
A3	0,060	0,091	0,061	0,085	0,031	0,043	0,062	16,500	1,016
A4	0,476	0,273	0,303	0,423	0,500	0,340	0,386	2,367	0,913
A5	0,119	0,182	0,242	0,106	0,125	0,170	0,157	8,000	1,259
A6	0,060	0,182	0,121	0,106	0,063	0,085	0,103	11,750	1,206

Table 28 Consistency check

Consistency ratio	**5,70%**
λ_{max}	6,353427
Consistency index	0,070685
Random consistency index	1,24
CI / RI	0,057004

- **Number of stator blades**

Table 29 The evaluation of criteria with respect to number of stator blades criterion

C5	A1	A2	A3	A4	A5	A6
A1	1	1	1/2	1	1	1
A2	1	1	1/2	1	1	1
A3	2	2	1	2	2	2
A4	1	1	1/2	1	1	1
A5	1	1	1/2	1	1	1
A6	1	1	1/2	1	1	1

Table 30 Normalized values of relative weights

C5	A1	A2	A3	A4	A5	A6	Row average	Column sum	Product
A1	0,143	0,143	0,143	0,143	0,143	0,143	0,143	7,000	1,000
A2	0,143	0,143	0,143	0,143	0,143	0,143	0,143	7,000	1,000
A3	0,286	0,286	0,286	0,286	0,286	0,286	0,286	3,500	1,000
A4	0,143	0,143	0,143	0,143	0,143	0,143	0,143	7,000	1,000
A5	0,143	0,143	0,143	0,143	0,143	0,143	0,143	7,000	1,000
A6	0,143	0,143	0,143	0,143	0,143	0,143	0,143	7,000	1,000

Table 31 Consistency check

Consistency ratio	**0,00%**
λ_{max}	6
Consistency index	-1,78E-16
Random consistency index	1,24
CI / RI	-1,43E-16

- **Cleaning time**

Table 32 The evaluation of criteria with respect to cleaning time criterion

C6	A1	A2	A3	A4	A5	A6
A1	1	2	1	4	3	5
A2	1/2	1	1/2	3	2	4
A3	1	2	1	4	3	5

A4	1/4	1/3	1/4	1	1/2	2
A5	1/3	1/2	1/3	2	1	3
A6	1/5	1/4	1/5	1/2	1/3	1

Table 33 Normalized values of relative weights

C6	A1	A2	A3	A4	A5	A6	Row average	Column sum	Product
A1	0,305	0,329	0,305	0,276	0,305	0,250	0,295	3,283	0,968
A2	0,152	0,164	0,152	0,207	0,203	0,200	0,180	6,083	1,094
A3	0,305	0,329	0,305	0,276	0,305	0,250	0,295	3,283	0,968
A4	0,076	0,055	0,076	0,069	0,051	0,100	0,071	14,500	1,032
A5	0,102	0,082	0,102	0,138	0,102	0,150	0,112	9,833	1,106
A6	0,061	0,041	0,061	0,034	0,034	0,050	0,047	20,000	0,938

Table 34 Consistency check

Consistency ratio	1,70%
λ_{max}	6,105499
Consistency index	0,0211
Random consistency index	1,24
CI / RI	0,017016

- **Changeability**

Table 35 The evaluation of criteria with respect to changeability criterion

C7	A1	A2	A3	A4	A5	A6
A1	1	1	1/5	1/4	1/2	1/3
A2	1	1	1/4	1/3	1	1/2
A3	5	4	1	1	3	2
A4	4	3	1	1	2	1
A5	2	1	1/3	1/2	1	1
A6	3	2	1/2	1	1	1

Table 36 Normalized values of relative weights

C7	A1	A2	A3	A4	A5	A6	Row average	Column sum	Product
A1	0,063	0,083	0,061	0,061	0,059	0,057	0,064	16,000	1,024
A2	0,063	0,083	0,076	0,082	0,118	0,086	0,084	12,000	1,014
A3	0,313	0,333	0,305	0,245	0,353	0,343	0,315	3,283	1,035
A4	0,250	0,250	0,305	0,245	0,235	0,171	0,243	4,083	0,991
A5	0,125	0,083	0,102	0,122	0,118	0,171	0,120	8,500	1,022
A6	0,188	0,167	0,152	0,245	0,118	0,171	0,173	5,833	1,012

Table 37 Consistency check

Consistency ratio	**1,57%**
λ_{max}	6,097122
Consistency index	0,019424
Random consistency index	1,24
CI / RI	0,015665

- **Energy consumption**

Table 38 The evaluation of criteria with respect to energy consumption criterion

C8	A1	A2	A3	A4	A5	A6
A1	1	3	3	1/3	1/3	1/3
A2	1/3	1	3	1/3	1/3	1/3
A3	1/3	1/3	1	1/3	1/3	1/3
A4	3	3	3	1	1/2	1/2
A5	3	3	3	2	1	1
A6	3	3	3	2	1	1

Table 39 Normalized values of relative weights

C8	A1	A2	A3	A4	A5	A6	Row average	Column sum	Product
A1	0,094	0,225	0,188	0,056	0,095	0,095	0,125	10,667	1,337
A2	0,031	0,075	0,188	0,056	0,095	0,095	0,090	13,333	1,200

A3	0,031	0,025	0,063	0,056	0,095	0,095	0,061	16,000	0,973
A4	0,281	0,225	0,188	0,167	0,143	0,143	0,191	6,000	1,146
A5	0,281	0,225	0,188	0,333	0,286	0,286	0,266	3,500	0,932
A6	0,281	0,225	0,188	0,333	0,286	0,286	0,266	3,500	0,932

Table 40 Consistency check

Consistency ratio	**8,40%**
λ_{max}	6,520718
Consistency index	0,104144
Random consistency index	1,24
CI / RI	0,083987

- **Cost**

Table 41 The evaluation of criteria with respect to cost criterion

C9	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
A1	1	5	7	4	2	6
A2	1/5	1	4	1/2	1/4	2
A3	1/7	1/4	1	1/5	1/6	1/2
A4	1/4	2	5	1	1/2	4
A5	1/2	4	6	2	1	5
A6	1/6	1/2	2	1/4	1/5	1

Table 42 Normalized values of relative weights

C9	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**Row average**	**Column sum**	**Product**
A1	0,443	0,392	0,280	0,503	0,486	0,324	0,405	2,260	0,914
A2	0,089	0,078	0,160	0,063	0,061	0,108	0,093	12,750	1,187
A3	0,063	0,020	0,040	0,025	0,040	0,027	0,036	25,000	0,898
A4	0,111	0,157	0,200	0,126	0,121	0,216	0,155	7,950	1,234
A5	0,221	0,314	0,240	0,252	0,243	0,270	0,257	4,117	1,056
A6	0,074	0,039	0,080	0,031	0,049	0,054	0,055	18,500	1,008

Table 43 Consistency check

Consistency ratio	**4,80%**
λ_{max}	6,297896
Consistency index	0,059579
Random consistency index	1,24
CI / RI	0,048048

Since consistency ratio amounts to less than 10% for every step, it signifies alternatives are graded consistently with respect to each criterion.

Local ratings with respect to each criterion are obtained by multiplying the ratings of each alternative by the weights of the sub-criteria and aggregating the results, as shown in Table 44.

Table 44 Average row values with weights

	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**Weights (Ci)**
1	0,065494	0,379357	0,043443	0,160434	0,248830	0,102441	0,01882
2	0,102441	0,379357	0,248830	0,160434	0,065494	0,043443	0,02581
3	0,024235	0,071104	0,248193	0,160081	0,248193	0,248193	0,10703
4	0,251581	0,041054	0,061558	0,385818	0,157356	0,102632	0,21449
5	0,142857	0,142857	0,285714	0,142857	0,142857	0,142857	0,15149
6	0,294808	0,179873	0,294808	0,071149	0,112477	0,046884	0,03683
7	0,063990	0,084495	0,315183	0,242698	0,120230	0,173404	0,32000
8	0,125380	0,089964	0,060797	0,191022	0,266419	0,266419	0,07257
9	0,404671	0,093113	0,035917	0,155161	0,256628	0,054510	0,05296

The global ratings are shown in Table 45, and the final ranking is shown in Table 46, after the local ratings have been multiplied by the weights of the criterion and aggregated.

Table 45 Global criteria ranking

	A1	**A2**	**A3**	**A4**	**A5**	**A6**
1	0,00123	0,00714	0,00082	0,00302	0,00468	0,00193
2	0,00264	0,00979	0,00642	0,00414	0,00169	0,00112
3	0,00259	0,00761	0,02656	0,01713	0,02656	0,02656
4	0,05396	0,00881	0,01320	0,08275	0,03375	0,02201

5	0,02164	0,02164	0,04328	0,02164	0,02164	0,02164
6	0,01086	0,00662	0,01086	0,00262	0,00414	0,00173
7	0,02048	0,02704	0,10086	0,07766	0,03847	0,05549
8	0,00910	0,00653	0,00441	0,01386	0,01933	0,01933
9	0,02143	0,00493	0,00190	0,00822	0,01359	0,00289
SUM	0,14394	0,10011	0,20832	0,23105	0,16387	0,15270

Table 46 Alternatives final ranking

A4	A3	A5	A6	A1	A2
0,231053442	0,208321639	0,163870275	0,152704783	0,143937327	0,100112533

6 RESULTS AND DISCUSSION

The ranking by S and R norms is shown in Table 47 and was calculated using the preceding formulas (3) and (4). A4 is ranked first and A3 is ranked second for the L1/S norm (representing total L1 norm distance to the ideal alternative), but for the L_∞/R norm (representing maximal component distance to the ideal alternative), A4 and A6 have the same value and thus, the same ranking.

Table 47 QS, QR and Q values in VIKOR method

	A1	A2	A3	A4	A5	A6
S	0,74769	0,83791	0,30839	0,30357	0,48451	0,45355
R	0,32000	0,24000	0,17159	0,15149	0,16000	0,15149
QS	0,83116	1,00000	0,00902	0,00000	0,33862	0,28068
QR	1,00000	0,52524	0,11928	0,00000	0,05048	0,00000
Q (υ=0,25)	0,95779	0,64393	0,09172	0,00000	0,12251	0,07017
Q (υ =0,5)	0,97889	0,58458	0,10550	0,00000	0,08650	0,03509
Q (υ=0,75)	0,96307	0,62909	0,09516	0,00000	0,11351	0,06140

In order to test the stabile position of the first ranked alternative (based on the requirements stated in (8)), Q values are also generated for the values of "strategy coefficient" $\upsilon = 0.25$ and $\upsilon = 0.75$. Table 48 provides a ranking of all six scenarios based on these variables.

Table 48 Alternatives final ranking in VIKOR method

Ranking	υ = 0,5	υ = 0,25	υ = 0,75
1	A4	A4	A4
2	A6	A6	A6
3	A5	A3	A3
4	A3	A5	A5
5	A2	A2	A2
6	A1	A1	A1

When the requirements outlined in (8) are applied, it becomes clear that the stability of position ranked first is not proved since for $\upsilon = 0.5$ it is not correct that $(A_j) - Q(A_i) \geq DQ$, where DQ =

min (0.25, $\frac{1}{5}$) = $\frac{1}{5}$ = 0.2 and Q(A6) - Q(A4) = 0.035. Moreover, neither assessing Q(A5) - Q(A4) nor Q(A3) - Q(A4) satisfies requirement (8). The first four ranked options, A4, A6, A5, and A3, should be taken into consideration after taking the first ranked requirement stability check defined with (8) into account.

Since final ranking by VIKOR method takes more than one alternative into consideration, results obtained by AHP method will support the decision on final choice of optimal solution. Table 49 displays results obtained by AHP method. The results indicate that A4 is the best ranked alternative, followed by A3 and A5. This leads to conclusion that alternative A4 can be chosen as an optimal solution for the given equipment selection problem.

Table 49 Alternatives final ranking AHP

A4	A3	A5	A6	A1	A2
0,231053442	0,208321639	0,163870275	0,152704783	0,143937327	0,100112533

Finally, when considering all the established criteria, applied methods indicate that optimal alternative is Wanner's D25.38 granulator. By entering a purchasing process, previously linear economy model would navigate towards new, circular economy model that would, among environmental benefits, bring added value to the company. The potential new product process flow is displayed in Figure 10.

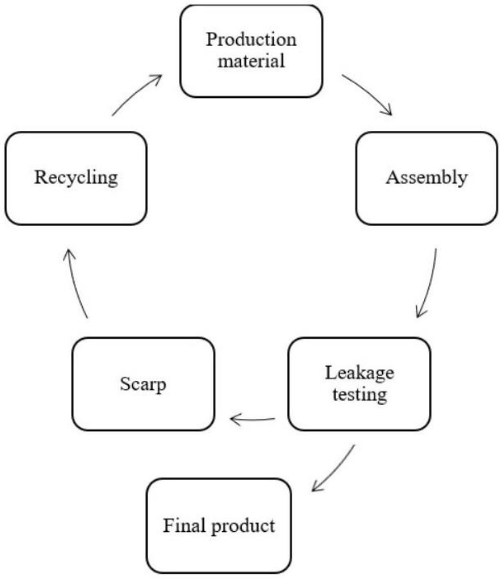

Figure 10 New production process flow

7 CONCLUSION

A circular economy and making use of by-products in industry is the way forward. Re-using the recovering by-products of the industrial processes brings many advantages: the impact of industry on the environment is reduced, depleting natural resources are saved, new and sustainable business is created and together it contributes to a better and more sustainable society.

This thesis contributes to implementation of circular economy model within a company in Bosnia and Herzegovina. The production process is upgraded with a granulator that enables recycling of piping systems labelled as scrap. Market available granulators are assessed by commonly established criteria, using a multicriteria decision aid.

The proposed approach uses the VIKOR and AHP decision-making methodologies. The proposed approach differs significantly from the existing literature on equipment selection with the structure presented. AHP is used to weight the criteria that will be taken into consideration when choosing the equipment, while VIKOR, with the support by AHP, is used to rank the alternatives. Ranking by VIKOR method revealed there is more than one alternative to consider, while AHP method ranking prevail alternative A4 as the optimal solution for the equipment selection problem in question. In case results obtained by VIKOR and AHP methods differ, it is recommended to apply one more MCDM method to decide for final solution.

The obtained results show that the combination of AHP for determining criteria weights, and AHP and VIKOR as MCDM methods, may be successfully implemented for the eventual granulator selection processes. This is a significant contribution to the field of equipment selection, and it might even be recommended as a phase in the general procurement procedure after an earlier detailed assessment of the particular requirements.

Similar applications have shown both VIKOR and AHP to be quite effective independently, and they have several advantages over other approaches like ANP, ELECTRE, and others. However, it is important to examine the applicability and effectiveness of other multicriteria decision making techniques in this field, which is a recommendation for further research.

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Appendix 1. Alternatives overview

Alternative 1

Our Air extraction and collection system will collect the final particles from the granulator to a bag. You can watch the demo operation videos from below Youtube links:

1. Plastic bags is crushed by this series machine and final particles are collected by air extraction and collection system: https://www.youtube.com/watch?v=fo7R_J6b7Xk

2. HDPE pipes are crushed by another machine and final products are collected by air extraction and collection system: https://www.youtube.com/watch?v=yx5lhRSmV6c

Model 2541 machine will use screen mesh to control the final product size. We recommend Ø10mm for your hard plastic pipes. You can also choose Ø6~20mm for the screen mesh size.

Here is the quotation for above mentioned machines:

Price for Small Sized Granulator Model PS-C-M-2541(incl one more opening for pipe feeding)	US$3,950 EX-works
Price for material collection system(4KW motor power)	US$1,150 EX-works
—	—
Remarks	Screen mesh size: Ø10mm
Payment Term	50% down payment, 50% before the shipment.
Delivery Time	30 days for production upon receipt of down payment

Price Validity	60 days from the date of offer
Warranty	13 months starting from shipping date

Please check if above recommend machines are the right machines you are looking for. we will proceed the shipping cost calculation later.

Best Regards,

Sally Dai

From: Devedzic, Emela

Date: 2022-06-17 13:59

To: sales@sinobaler.com

Subject: RE: PROSINO shredders and granulators

Dear Sally,

I am looking to shred hard plastic pipes that end up as a waste at our production facility. We produce fuel piping for the automotive industry. Unfortunately, I am not allowed to send any pictures nor talk about specific materials since we develop it in the company.

Shredder or granulator is needed in order to get the pipe material ready for further processing. The pipes are, on average, 20 mm in diameter and 1400 mm in length. They do not contain any material other than the one mentioned before.

The aim for productivity is 50 kg/day and there are no specific requirements of the output material size at the moment. The most important thing is to get the pipes ready for melting and pelletizing process.

Considering this input data, what do you recommend - a shredder or a granulator? What options do you have regarding the loading and discharge of the material?

There is the company address in the footer, and the number is 0038761057547. Can you also estimate the transportation costs to our facility, please?

Thank you and have a nice day!

Srdačan pozdrav / Mit freundlichen Grüßen / With kind regards

Emela Devedzic
Projekt menadzer / Project manager

aft bosnia

aft bosnia d.o.o. Živinice
Industrijska zona Ciljuge II, br. 28
75270 Živinice, BA

E-Mail: E.Devedzic@aft-bosnia.com

Alternative 2

As you can see the machine is very compact with integrated blower system.

Technical data, Zerma GSE 300/300:

Motor drive: 7.5 kW

Rotor diameter: 300 mm

Rotor width: 300 mm

Cutting chamber: 400 x 290 mm

with control panel

with integrated suction system: blower, pipe work, cyclone

see also: https://www.amis.de/en/machine/granulator-zerma-gse/

Price: 12.950,-- €

Actual delivery time: 6 – 8 working weeks

For further informations please don`t hesitate to contact us.

Best regards

Thorsten Wickert

Vertrieb | Sales

|| Besuchen Sie uns auf Facebook! || NEWSLETTER Anmeldung ||

AMIS Maschinen-Vertriebs GmbH

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Mobil: +49 (0) 172.749 4034

E-Mail: thorsten.wickert@amis.de

Internet: www.amis.de

Geschäftsführer: Thomas Ottenthal

Registergericht: Mannheim, HRB 341152

UST-Ident-Nr.: DE 162855213

Steuer-Nr.: 44077/00725 Finanzamt Sinsheim

Alternative 3

HEINRICH DREHER GMBH & CO. KG

MASCHINENBAU

Aft bosnia d.o.o.Zivinice
Emela Devedzic
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e-mail: info@dreher-aachen.de
http://www.dreher-aachen.de

IHR ZEICHEN	IHR SCHREIBEN	UNSER ZEICHEN	DATUM
		JF/jf	27.06.2022

Budget-Quotation: 8.887-22

Dear Emela Devedzic

Referring to your price inquiry, we are pleased to submit a quotation for a DREHER granulator, type:

S 20/40 L-(V)

DREHER granulators are world-wide known for its outstanding performance and solid construction. Due to a reliable cutting action, shortest rotor cutting blade replacements and cleaning terms, DREHER granulators guarantee the best and the most efficient economically use.

Please find all technical and commercial details and information below

For any further questions, do not hesitate to contact me.

With kind regards

Joachim Frank
Sales

Heinrich DREHER GmbH & Co KG

KOMMANDITGESELLSCHAFT HEINRICH DREHER GMBH & CO. Kg; HRA AACHEN 1297
PERSÖNLICH HAFTENDE GESELLSCHAFTERIN: HEINRICH DREHER VERWALTUNGS-GMBH, HRB AACHEN 2703 *
GESCHÄFTSFÜHRER: DIPL.-ING. KARL-HEINZ DREHER – DIPL.ING. NICO DREHER

Budget-Quotation: 8.887-22

Application :	
Material to grind:	**not defiend**
Geometry:	**not defined**
Temperature:	**not defined**
Feeding:	**by onsite system**
Regrind transport:	**by onsite system**
Screen:	**5 mm,**
Capacity / Performance:	**max. 50 kg/h**

Pos 1. DREHER-granulator

According to EU-Machine directive, with EU declaration of conformity and CE-label

Type:	**S 20/40 L-(V)**
Drawing:	**will follow after PO**
Painting Granulator:	**RAL 7035, grey**
Painting Electrical cabinet:	**RAL 7035, grey**

Construction

- Divided cutting chamber
- Top part pivotable
- Main construction supported by two guide rollers and two fixed rollers
- Solid construction
- Material collection bin with an onsite vacuum suction device
  - Outlet diameter 46mm

Cutting chamber

- Inclined 30° to the backside- this secures an optimized cutting action
- Fast and easy access to the cutting chamber in case of knife-change, material- or colour-change

Full-Rotor

- Processed out of a solid bar of steel, means high torque
- diameter: 200 mm
- Useful width: 400 mm
- Rotor blades: 3 rows, two knives per row
- Stator blades: 2 rows, two knives per row
- Due to the fixed and invariable position of the rotor cutting blades an adjustment after changing or regrinding of the blades is not necessary.

Screen

- Screen with 5 mm square hole perforation

Drive

- Electric motor, efficiency class IE3
- 7,5 kW (1.500 min^{-1})
- Reinforced bearings
- Protection IP 54
- Power transmission by V-belt drive.

Electric control panel placed on the Granulator

- Colour RAL 7035
- Execution according to actual technical rules, EN and IEC-directives and norms especially DIN EN 60204 (VDE0113)
- Control of granule aspiration unit is optionally integrable

Price:	**Euro**	**11.080,-**

Options

Pos 2. Set of spare knives

- Rotor blades: 3 rows (6 pieces)
- Stator blades: 2 rows (4 pieces)

Price:	**Euro**	**1.000,-**

Pos 3. Spare screen

- 5 mm square hole perforation

Price:	**Euro**	**470,-**

Price overview

Pos.	Description	Price
1	Granulator S 20/40 L-(V)	11.080,00 €
2	Spare knifes	1.000,00 €
3	Spare screen	470,00 €
	Total	12.550,00 €
17,5%	Material price surcharge	2.196,25 €
	Sub total	14.746,25 €
6,0%	Energy surcharge	753,00 €

Installation – Guidelines

Construction site preparation

To be ensured by the customer:

1. Before delivery, the installation area of the granulator-system must be freely accessible, clean, and levelled. The installation area must meet all requirements regarding the weight of the granulator (load capacity).
2. Light and power sources, which are required for the installation, must be available.
3. The way between the unloading point and the installation area must be sufficiently clear to ensure that the granulator can be moved safely and easily.

De-loading

To be ensured by the customer:

1. The unloading of the granulator is in the customer's responsibility.
    a. This also includes the supply of a crane or a suitable forklift or similar.
2. After unloading, the customer must ensure that the granulator will be temporarily stored in a safe and weather-protected area until the Dreher assembly supervisor arrives.
3. Dreher recommends moving the system to its final position, only in presence of the Dreher assembly supervisor.

Supervisor

Definition and responsibility

1. The responsibility of the supervisor is to advise the customer or third parties (commissioned by the customer), regarding a professional and safe installation of the granulator system and to advise the customer or third parties (commissioned by the customer), in case of deviations from the installation plan, the operating instructions, assembly errors or quality defects.
2. The Dreher assembly supervisor will be supported by a customer fitter and a customer electrician during the installation.
3. All lifting gears needed for the installation, such as cranes, forklifts and lifting platforms are to be provided by the customer in time.
4. The Dreher supervisor's daily working hours, including arrival and departure, are max. 10 hours.
    a. Overtime will be charged according to the attached hourly standard rates.
    b. The daily rate for the supervisor is 1,150 euros. Hotel and meals included.
        i. Costs for flights and ground-transport excluded
        ii. Travelling hours (Dreher – customer - Dreher) excluded

General

All deviations from the points described above, requested by the customer or the company Dreher, must be clarified before the contract is concluded

Conditions of quotation

Please take into consideration, that all the prices are based on the bespoken technical specifications. Modifications later on of the design or the interpretation of the granulator and the peripherals have to be taken in consideration in terms of price.
Commercial basis of our quotations and orders are our general sales and delivery conditions from 15.05.2020

Quote validate	the quote conditions and prices are contractually committed when placement of order within 14 days after date of quotation.
Delivery time	the delivery takes place: as agreed, actually 24-26 weeks, for manufacturing plus delivery time to your plant. after complete technical clarification and reception of payment. **Except delay of delivery caused by suppliers**
Warranty	Warranty service takes place only, if installation and start-up is performed by DREHER or staff trained by DREHER. The guarantee period amounts to 12 months. The guarantee period starts latest 3 months after information for ready of delivery. The warranty contains the free replacement delivery of defective parts, so far as the defect is not lead to faulty maintenance, improper attendance or external effects. The warranty does not include wear parts and personnel expenses. Warranty claims exist after full payment of the delivered installation.
Pricing	The shipment is based according to INCOTERMS, edition 2020, ex works, packing excluded
VAT (value added tax)	All prices are plus legal VAT the day of invoice.
Payment	50% at confirmation of order 50% at date of invoice, before shipment

COVID-19 special regulation Due to the effects of Covid-19, it is coming currently to massive temporary delivery difficulties of our suppliers. As a result, this can also lead to difficulties for us in the context of the performance of service. We endeavor to counteract this exceptional situation with all means available to us.
For this reason, all offers relating to designated dated and delivery times are subject to change and represent only a non-binding information about the current state of planning.
By order, the dates and delivery times mentioned in our order confirmation are only valid under the condition that our supplier meet the delivery commitments.
Any kind of penalties on dates in the terms and conditions of purchase and order documents cannot be accepted by us at this time.
This also applies to all dates in offers and other appointments.
We ask you for your understanding for these extraordinary measures.

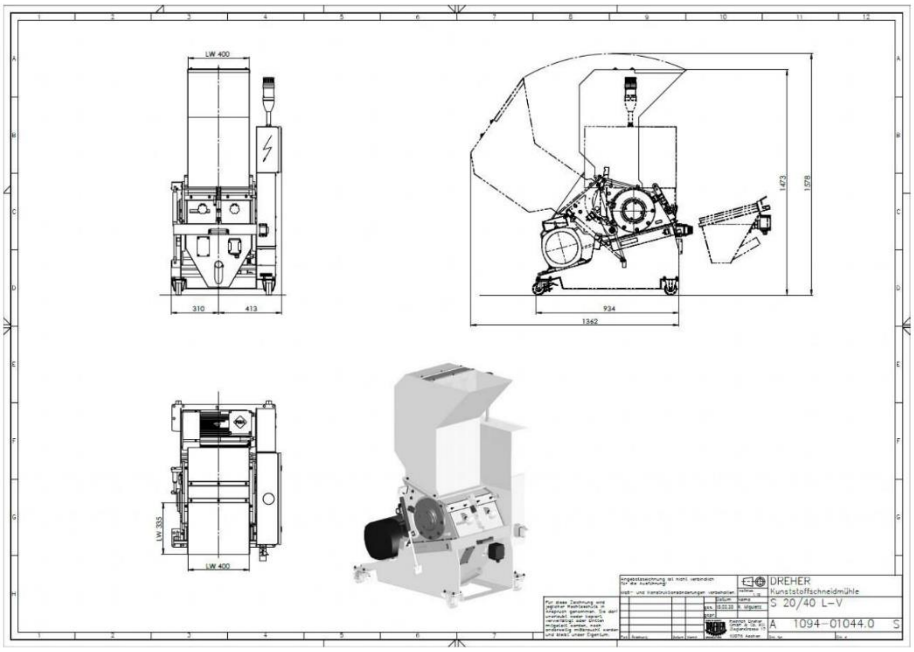
We hope, you agree on this quotation and we would be happy to execute your order. For any further question do not hesitate to contact us.

With kind regards

Mit freundlichen Grüßen

Joachim Frank
Verkauf

Heinrich DREHER GmbH & Co KG
Zieglerstraße 17
D-52078 Aachen
Tel. ++49 241 51563-63
Fax. ++49 241 526006
Mobile: ++49 162 24447-63
mailto: joachim.frank@dreher-aachen.de
web: www.dreher-aachen.de


LW 400
310
413
1473
1578
934
1362
LW 335
LW 400
DREHER
Kunststoffschneidmühle
S 20/40 L-V
A 1094-01044.0 S

Alternative 4

LAKARA d.o.o.
stroji, proizvodna oprema, servis

E: info@lakara.si
W: www.lakara.si
T: + 386 31 702 029

LAKARA d.o.o.
Zminec 20A
SI - 4220 Škofja Loka

Datum: 27.06.2022
Kraj izdaje: Škofja Loka
Veljavnost: 27.07.2022
ID za DDV kupca: PIB210255000003

aft bosnia d.o.o. Živinice

Industrijska zona Ciljuge II, br.28

BiH-75270 Živinice
Bosna in Hercegovina

Stran: 1

Ponudba: 2250685

Na podlagi vašega povpraševanja vam nudimo:

Poz	Oznaka	Naziv blaga / storitve	Količina	EM	Cena / EM brez DDV	Cena / EM brez DDV	Znesek brez DDV	%DDV
1	W-D2-00	**Granulator Dynamic 25.38s Standard**	1,00	kos	9.400,00	9.400,00	9.400,00	0,00
		Granulator, moveable on castors, easy to manipulate and can be opened without the use of tools for quick cleaning. Selfmonitoring electrical control with electrically redundant safety devices (safety limit switches), direct start. Control integrated into the pully wheel cover, 4 m connecting cable with CEE 32A/6h plug. V-belt drive and pully wheel with integrated gyrating mass, oversized rotor bearing. Solid cutting chamber housing with tangential material in-feed character, segmented, staggered rotor with scissors cutting action and aggressive pull-in character, hardened inserts inside the cutting chamber to prevent from wear. Infeed hopper made from sound deadening sandwich sheet metal. Granule suction box with 16 l Volume, including suction pipe with horizontal outlet O 80 mm. Motor power: 5,5 kW (alternative 7,5 kW) power supply: 3 x 400 V / 50 Hz, others on demand Cut. chamber opening: 250 mm x 385 mm Rotor speed: 330 rpm (alternative 530 rpm) Rotating knives: 9+9 pcs. Fixed Knives: 2 pcs. (reversible tip) Screen sizes 6 mm standard, alternatively 4, 5, 8, 10 or 12 mm.						
2	W-D2-05	**D25.38 mounted on high stand**	1,00	kos	560,00	560,00	560,00	0,00
		sack filling box with stopper slide and fixing strap						
3	W-D2-11	**Screen with improved wear resistance**	1,00	kos	80,00	80,00	80,00	0,00
		by nitration-hardening						
4	W-D2-44	**surcharge for Stator knife D25.38**	1,00	kos	45,00	45,00	45,00	0,00
		on the back side of the cutting chamber with modified shape to avoid that thin material can stay and raise on the knife.						
5	W-TZ-D1	**Surcharge for D-Series & CLE Series**	1,00	kos	600,00	600,00	600,00	0,00
		The strong increase in material prices and procurement costs force us to introduce a costs of materials surcharge for our products. If the price and procurement situation eases, we will reduce the surcharge accordingly or, in the best case, not charge it at all. This surcharge therefore represents an upper, maximal price surcharge with reference to the currently prevailing procurement situation for the quoted machine.						
6	W-D2-P2	**Granulator D-series packed on a pallet**	1,00	kos	110,00	110,00	110,00	0,00
		with outside rotor blades gor Tange cial collection.						
7	P0003	**Strošek transporta**	1,00	kos	250,00	250,00	250,00	0,00
		Nemčija - Slovenija (4220 Škofja Loka)						

SKUPAJ BREZ DDV	11.045,00	
SKUPAJ BREZ DDV	**11.045,00**	
DDV 0,00 % od osnove 11.045,00	**0,00**	
S K U P A J	**11.045,00**	**EUR**

E: info@lakara.si
W: www.lakara.si
T: + 386 31 702 029

LAKARA d.o.o.
Zminec 20A
SI - 4220 Škofja Loka

DELIVERY TIME:
KW30/2022

Without customs costs for import into BiH.
Need to be considered in addition.

Plačilo izvršite na TRR št. SI56 0312 8100 1015 448 odprt pri SKB banka, d.d.

Pri plačilu se sklicujte na številko: SI00 2250685.
Koda namena: SUPP

V primeru, da se odločite za nakup, Vas prosimo, da pošljete naročilnico, potrdite nakup oziroma znesek ponudbe nakažete na naš transakcijski račun v skladu z navedenimi plačilnimi pogoji.

Ponudbo pripravil:
Bokal Peter
+386 40 857 695

Alternative 5

NOMIS D.O.O.

Adresa: Gospodarska 3a, 10255 Stupnik
Tel./Fax: +385 1 6535 130 • **Tel:** +385 1 6535 012
E-mail: nomis@nomis.hr • **Web:** www.nomis.hr
OIB: 94628161061 • EORI: HR94628161061

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aft bosnia d.o.o.
Industrijska zona Ciljuge II
75270 Živinice
Bosna i Hercegovina
Gđa. Emela Ddevedžić

Datum: 27.06.2022.

Ponuda br.: 512/22

Poštovani,

Prema Vašem upitu,
slobodni smo Vam ponuditi našu ponudu, koja je sastavljena nakon analize Vaših zahtjeva.

OSNOVNI PODACI

<u>Mljevenje gotovih proizvoda:</u>
Konačan proizvod: ....samljeveni material
Proizvodni materijal:.. razno
Kapacitet: .... razno

OPIS ODABRANOG RJEŠENJA

Predlažemo vam slijedeću opremu prema Vašim zahtjevima:

Rapid 150-21 DeltaTECH High built rearfeed

NOMIS d.o.o.

Ponuda 512/22	27.06.2022.	Valuta: EUR

Rapid Granulator 150-21 DeltaTECH **6.435,00**

Sklop za mljevenje:

Otvor za mljevenje 150 x 205 mm, čelična konstrukcija sa 2 fiksna noža montirana u kučište, Mreža/sito promjera rupa 5 mm.

Rotor:

Složivi tip sa 9 rotirajućih kazetnih noževa. Specijalni alat za teške proizvode. Ležajevi su SKF kuglični tip. Pogonjen preko sustava Poly V-remena sa rotorskom koturom sa nakupljajućom energijom.

Motor, Simens visoke efikasnosti / Prijenos za teške uvjete rada

2,2 kW, 925 okr/min. Stupanj zaštite IP 54. Glavni napon 380 V, 50 Hz, 3 faze.

Ulazni spremnik materijala **385,00**

Ulazni spremnik materijala u rearfeed izvedbi za lakše ubacivanje dugačkih materijala.

Baza/Okvir: High built izvedba **560,00**

Za bolji radni položaj za čišćenje i održavanje, te također uključuje i prirubnicu za spajanje vreće za punjenje samljevenog materijala. Dodatno je moguće montirati i spremnik materijala od 45 l.

Vrijednost robe:	**7.380,00**
Popust:	**- 380,00**
Troškovi transporta:	**300,00**

Sveukupan iznos:	**7.300,00**

UKUPAN IZNOS	
Rapid 150 – 21 DeltaTECH High built rearfeed izvedba	**7.300,00 EUR**

Plaćanje:	**20% prilikom narudžbe, 60% prije isporuke,**
	20% 30 dana nakon isporuke
Datum isporuke:	**14 – 16 radnih tjedana od datuma narudžbe**
Isporuka:	**skladište CPT Živnice**
Garancija:	**12 mjeseci**
Opcija ponude:	**31.07.2022.**

Ponudu izradio: Marko Tojagić **U Zagrebu, 27.06.2022.**

NOMIS d.o.o.
Gospodarska 3a
10255 Stupnik
Tel./Fax: 00385 (0) 1 65 35 130
www.nomis.hr

Alternative 6

MEGA SYSTEMS BH

MEGA SYSTEMS BH d.o.o.
Kakanjska 4, 71300 Visoko
Bosna i Hercegovina

tel/fax: +387 (0)32 731-421
mob: +387 (0)62 330-293

e-mail: megasystemsbh@gmail.com
URL: www.megasystems.ba

PDV broj: 218899460006
ID broj: 4218899460006

Ponuda 060-2022/SF

Datum	27.06.2022. god
Za	AFT BOSNIA d.o.o. Živinice
	g. Emela Devedžić
Predmet	Ponuda Granulator G 17-22-3K-ARK

Poštovani,
Zahvaljujemo se na Interesu i dostavljamo vam ponudu:

1. Granulatora G17-22-3K-ARK

Nova generacija granulatora visoke preciznosti serije G17

Najveća fleksibilnost primjene

CMG je lansirao novu seriju granulatora malih dimenzija i visoke preciznosti. Nova serija posjeduje nekoliko vrlo inovativnih i jedinstvenih atributa i svi doprinose postizanju najvišeg stepena produktivnosti, kvaliteta kod ponovnog mljevenja (homogene dimenzije čestica i odsutnost prašine), učinkovitosti rada i najbolje fleksibilnosti kod primjene. U svojoj standardnoj konfiguraciji granulatori G17 primjenjivi su na procese brizganja i puhanja. U konfiguraciji ET1 ili ET2 prikladni su za ekstruziju. Raspon kapaciteta granulacije je od 5 kg/h do 90 kg/h.

Precizno rezanje

Nova CMG serija G17 granulatora dizajnirana je za postizanje najhomogenijeg oblika i dimenzija kod ponovnog mljevenja, uz malo ili nimalo prašine. Još jedna vrlo jedinstvena prednost ove nove linije je mogućnost proizvodnje ponovno mljevenog materijala s vrlo malim dimenzijama. Velika prednost dimenzionalno malog ponovno mljevenog materijala je mogućnost dodavanja većih postotaka primarnom (djevičanskom) materijalu bez utjecaja na kvalitetu gotovog proizvoda. Sistemi malog kapaciteta, strojevi za injekcijsko presanje ili ekstruderi, opremljeni su zavojnicama za plastifikaciju malog promjera, koji ne mogu obraditi granule čija je dimenzija veća od onih u primarnim (djevičanskim) granulama.

Karakteristike izvedbe

Još jedna izvanredna osobina G17 je mogućnost primjene s balansiranim rotorom punog preseka ili rotorom otvorenog tipa. Ovisno o primjeni, osigurava se najprikladnija konfiguracija rotora. Također, i rotorski i stacionarni noževi su podesivi, kako bi se postigao najviši nivo preciznosti rezanja. Ova karakteristika daje dodatnu jedinstvenost liniji G17.

Jednostavnost održavanja i pristupačnost

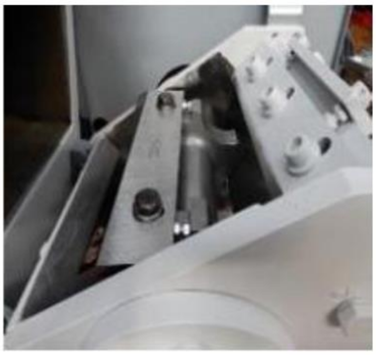
Cijeloj G17 jedinici može se pristupiti, očistiti i vratiti u rad za nekoliko minuta. Svi dijelovi su dostupni bez potrebe za alatom i mogu se očistiti usisavačem.

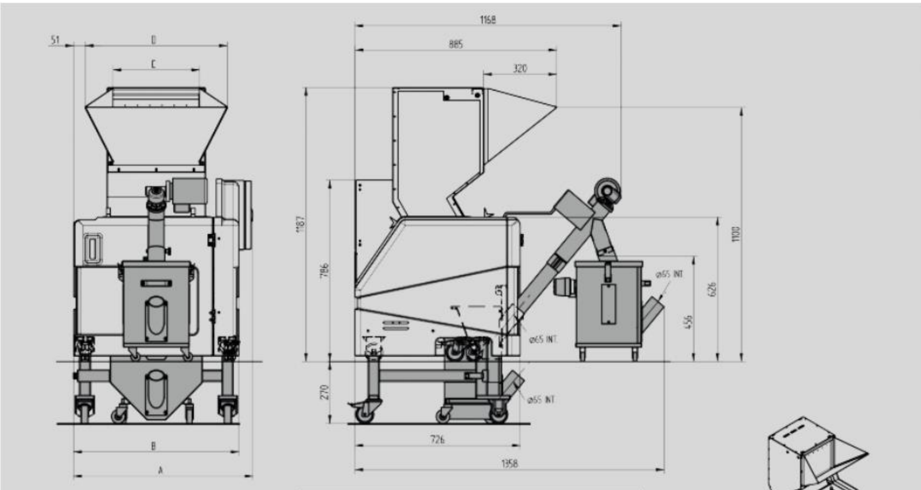
Najtiši od svih

Nova vrlo specifična zvučno izolacijska školjka serije G17 dizajnirana je za prijenos zvučnih valova prema apsorpcijskim pločama kako bi se postigo nivo buke znatno ispod industrijski prihvatljive (EN12012-1).

Certificirane kontrole snage

Svi modeli G17 opremljeni su upravljačkim ormarima s certifikatom IP55. Također, svi CMG sistemi za mljevenje certificirani su i usklađeni sa direktivom o mašinama 2006/42 / CE i isporučuje se sa CE certifikatom.





	A	B	C	D
G17-22	675	575	230	475
G17-38	825	725	380	625

	mm	n°	n°	mm	RPM	KW	Ø mm	Kg/H
G17-22	230 x 310	9 (3)	2	170	155(275)	2,2 (3,0-4,0)	5	30-50
G17-38	380 x 310	15 (3)	2	170	155(275)	2,2 (3,0-4,0)	5	50-90

***zatamnjeni dijelovi na skici su predmet posebne narudžbe (opcije)**

Tehnički podaci

• Dizajniran za rad uz presanje (injektiranje i puhanje).
• Četiri standardna modela, preko 30 dostupnih verzija.
• Dostupan s otvorenim rotorom ili sa raspoređenim rotorom.
• Mala brzina rotora (155 ili 275 o/min).
• Standardno sito od nehrđajućeg čelika.
• IP55 upravljački ormar i elektromotor.
• Brzo otvaranje i lako čišćenje.
• Nivo buke unutar europskih normi EN 12012-1.

Uz C.M.G. granulator, model G17-22-3K-ARK isporučuje se:

- Rezervoar za punjenje, pogodan za punjenje ručno, transporterom i robotom
- Plastične pokrivke otvora za punjenje radi sprječavanje efekta povratka materijala i smanjenja buke
- Preklopni lijevak sa sistemom otvaranja na bravice bez upotrebe alata
- Komora za sječenje sa „akcijom prethodnog sječenja makazama” (sječenje pod duplim uglom), pogodna za izlivnice, klizače i nepravilne komponente, sa bočnim krajnjim diskovima, koji se obrću skupa sa rotorom (veličina komore za sječenje 170x230mm)
- Poprečni rotor, koji ima tri (3) noža (rotor ø170 mm) pokretan V-remenom i remenicom velikog prečnika
- Osovina rotora oslonjena sa kugličnim ležajevima tipa 2RS (dvostruko zatvorenim za doživotno podmazivanje).
- Ležajevi opremljeni "V-prstenom" za zaptivanje
- Svi CMG noževi su čelični H.C.H.C l (56-58 HRC) AISI-D2
- Nosač sita za lako čišćenje
- Prednji uklonjivi, reverzibilni zaštitni poklopac od nerđajućeg čelika AISI-304, ø5 mm. rupe
- Uklonjiva kutija za odlaganje za sakupljanje mljevenog materijala (kapacitet 5,5 l)
- Elektromotor 2,2 kW 4 pola (3 KS)
- Granulator je postavljen na 4 plastična točka d=80mm, od kojih su dva okretna sa kočnicom
- Sigurnosni prekidač za siguran pristup komori za sječenje
- IP55 zaštićeni električni ormar, C.E. norme, sa „Prevent“ električnom sigurnosnom kontrolnom jedinicom,
- Sve naljepnice ili tablice o bezbjednosti i održavanju na engleskom jeziku
- Potrebno električno napajanje 400V/3 faze 50 Hz.
- Neto težina granulatora 190 kg.
- Granulator je u skladu sa direktivom o mašinama 2006/42 / CE i isporučuje se sa CE certifikatom.

Cijena: 23.780,00 KM + PDV = 27.822,60 KM

Cijena je kalkulisana na paritetu fco Živinice, neistovareno. U cijenu je ukalkulisana instalacija i obuka, uputstvo na engleskom i jednom od jezika u BiH i CE certifikat o usklađenosti. Kupac je u obavezi osigurati napajanje el.enrgijom na mjestu instalacije.
Garancija: 12 mjeseci od isporuke. Habajući i električni dijelovi su isključeni iz garancije.
Plaćanje: po dogovoru, uobičajeno 30% avans kod narudžbe, 70% pred isporuku
Rok isporuke: 12 sedmica
Opcija ponude: 15 dana.

Servis i rezervni dijelovi u BiH, u garantnom i postgarantnom roku, osigurani preko naše firme.

Cijene potrošnih i najčešće potrebnih rezervnih dijelova **G17-22-3K-ARK**

Cijena seta	
Roto Noževi set	€ 505,00
Fiksni noževi set	€ 350,00
Set zavrtnjeva za fiksne I roto noževe	€ 45,00
Sito promjera rupa 5mm	€ 300,00
Sito promjera rupa 6 mm	€ 310,00
Sito promera 8mm	€ 310,00

Cijena je proizvođačka, bez pakovanja i transporta

S poštovanjem,

Direktor:
Ferhatović Adnan