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BUSINESS PLAN CONCEPT FOR THE PRODUCTION OF RUBBER-BASED NOISE REDUCTION WALLS IN SLOVAKIA FOR THE POTENTIAL OF WORN TIRES MATERIAL RECOVERY

Marek POTKÁNY, Lucia KRAJČÍROVÁ, Mária OSVALDOVÁ
Technical University in Zvolen

Abstract:
The automotive industry is one of the fastest growing sectors and therefore places demand on many other sectors and increases the need for cooperation. With the development of the automotive industry, tires have become an integral part of society and the everyday life of the individual. As a result of the company's development as a connection of transport, the demand for tires is increasing and the production of waste tires is also related to this. The use of end-of-life tires is almost endless and that is why tires are good to use in the circular economy. The circular economy is an economic system that aims to keep products and materials in use for longer, thus increasing their productivity and reducing waste. The paper presents a methodical concept of the plan for the extension of production capacities of rubber-based pressed products with the intention to produce noise reduction panels. The investment consists of the acquisition of the pressing machine and respective mould in the amount of € 180,000. Based on the selected assessment methods it can be stated that the NPV reaches + 69,360 €, Profitability index is 1.38, Internal Rate of Return is 23.8% and the payback period is estimated for 4 years and 4 months, at the considered production capacity of 14,000 m2/year.

Key words: *circular economy, noise reduction wall, recycling, rubber, tires*

INTRODUCTION

According to Czajczyńska et al. European Tire and Rubber Manufacturers Association (ETRMA), more than 1 billion vehicles drive currently all around the world [1]. Unless the interest in vehicles changes, their number will grow continually. By the year 2030, the number of vehicles worldwide could reach two billion regardless of whether it is a petrol engine or a different type. Wheels, and therefore also tires are inseparable components of the vehicles. As the number of vehicles increases, so does the number of discarded (worn) tires, and new ways for their further use are being sought. Around 6,000 tons of used tires per 1 million inhabitants are discarded every year in the industrialized countries. Nevertheless, only about 20% out of this big number are recycled by retreading – the rest is waste. For the production of tires, mainly petroleum-based rubber is used, i.e. a non-renewable and to some extent still difficult replaceable raw material. Circular economy based on the principle of reusability of the original raw material, i.e. its recyclability and material input into new products is extremely desirable in case of tires. The effect of their use thus gains a very significant environmental dimension. A circular economy according to pbl.nl, is an economic system of closed loops in which raw materials, components and products lose their value as little as possible, renewable energy sources are used and systems thinking is at the core. The issue of the circular economy in connection with various areas was addressed in the studies: Gigli et al. solve the problematic of tire recycling [2], Andrén and Hedin describe the production of asphalt with a mixture of rubber [3], Fischer and Pascucci explain the operation in textile industry [4] and Mair and Stern solve the problematic of cascading use of wood [5]. The objective of the paper is to present economic calculation for the capacities extension of the operational site in Slovakia involved in the recycling of worn tires into the form of rubber granulate, usable for final pressed rubber products to produce panels for noise reduction walls. The subject matter is interesting especially from the point of view of the untapped potential of the use of recycled tires in the context of the circular economy. The contribution to the science of this paper is in the presentation of the original idea of replacing traditional noise reduction walls materials (plastic, concrete or wood) with a rubber-based input, which is looking for its application in recycling.

LITERATURE REVIEW

Waste tires are an important source of secondary raw materials. The goal of the waste management programme of Slovak Republic for the years 2016-2020 is to reach the material recovery rate of tires at 80% with the 15% of energetic recovery and gradual reduction of landfilling at the level of maximum 1% by the year 2020. Slovakia has built sufficient processing capacities for the material recovery of waste tires (annual growth is estimated at 26,000 tonnes). One of the major processors is the waste management company Ave SK odpadové hospodárstvo Ltd. situated in the industrial zone Kechnec. It is involved in the waste tire material recovery, using the Danish technology Eldan, meeting the requirements of Bat and Batneec. The operational site provides collection, transport and recycling. The output product is the granulate in the fraction size of 0-4 mm and pressed products – rubber paving for children playgrounds, sports grounds, backfill for artificial lawns, for construction of ballistic panels, modified asphalts or noise reduction barriers. The company Dron Industries provides tertiary recycling of waste tires, waste plastics and elastomers R3. The company specializes in the processing of the waste tires and other rubber waste by chemical processing, so-called chemical depolymerization. The products (liquid fractions of Dron oil, solid fraction of Dron coke, gas Dron gas and Dron steel cords) are highly competitive and well marketable in view of the market requirements of the industry, energy production and regulatory environment [6].

The most common technological procedure of waste tires mechanical processing is the washing, rough shredding, fine crushing, material separation (metal, textile, rubber), granulation, sieving and packaging. Rubber granulate gained by the processing of used tires is denominated as SBR – styrene-butadiene rubber. It is possible to produce rubber granulate from waste tires in various ways. The most common production procedure is the multiple mechanical tires crushing under normal temperature. The tires are taken from the storage area and brought to the recycling facility (line). Before placement on the roller conveyor, the extractor removes steel bead wires from the tire to avoid damage and prolong the lifetime of the crusher. In the event of mud contamination, the tires are cleaned before being placed on the roller conveyor. Clean tires are positioned on the roller conveyor, belt conveyor moves them into the crusher, where the tire is chopped into approximately 50 × 75 mm pieces (first crushing stage, so-called shredding). Material with larger dimensions is transported back to the crusher by the return belt conveyor. This process (shredding) repeats until material meets the size requirements.

It is followed by the second crushing stage, so-called granulation when the tire chips advance on the second belt conveyor into the crusher, from which granular particles with a size of 18 to 20 mm come out. In this crushing process, the granular particles are separated from the metal component from the tire on a magnetic separator and the textile particles are separated from the tire through the ventilation system. The separation of the metal and textile components follows after each partial crushing. Another crushing stage is the milling when the granular particles are crushed into various sizes. The last crushing stage is the screening, when the final material is separated according to the fractions, e.g. 0-1 mm, 1-3 mm, 2.8-4.0 mm and subsequently filled into the super sacks or big bags with the weight of 0.5 t or 1 t and finally shipped to the customers. The technology evaluated in this paper is based on this principle.

Environmental impact is also an important evaluation factor. The following part provides a literature review of the published selected LCA studies (life cycle assessment) related to tires. Clauzade et al. compared 9 different methods of waste tires recovery in the LCA studies (cement plants – fuel substitution, foundries – substitution of foundry coke, steelworks – substitution of anthracite or scrap metal, municipal heating – fuel substitution, retention tanks – replacement of concrete or plastic block, infiltration tanks – substitution of gravel, mouldings – substitution of polyurethane in anti-vibration mats, synthetic turf – replacement of EPDM elastomer and riding floors – substitution of sand) applied in the territory of France [7]. The results of the study indicated that all assessed methods reached better environmental indicators than methods with original products. Feraldi et al. performed the LCA study and compared environmental impacts related to the material recovery (mechanical crushing) and energy recovery (incineration in cement plants) of the waste tires in the territory of USA [8]. The results of this study suggest that material recovery of waste tires is a more favourable way of waste tires disposal in terms of environmental impacts. Piotrowska et al. used three different methods to assess impact categories in the LCA study for passenger car tires [9]. The results of the study show that the most significant impact in terms of emissions was recorded for the air (96%) and the highest energy consumption was determined for the phase of tire usage. In order to reduce the environmental impacts of tires on the environment, the authors of the study emphasize the need to increase the energy efficiency of recycling methods. However, the mechanical recycling phase is also significant.

The European Union's goal is to constantly achieve better overall environmental performance of the main products during their life stages and therefore adopts new policies such as the extended producer responsibility (EPR) principle Uruburu et al. [10]. The use of end-of-life tires is almost endless, Revelo et al. describe how used tire became material which is a green solution to an increasing worldwide problem [11]. Dobrotă et al. perceived the conditions necessary to achieve a circular economy is improve technology process of recycling tire waste [12]. The use of end-of-life tires in construction as well as their overview of physical and mechanical properties were presented in study by Fazli et al. [13].

METHODOLOGY

The methodology is based on the application of practical information of the Slovak producer of recycled rubber products. The output of the mechanical recycling of the waste tires recovery process is the rubber granulate (Fig. 1) of various dimensions, which is an important raw material for the production of further pressed products, e.g. rubber mats for safe children playgrounds and sports grounds, anti-vibration mats, noise reduction absorbers and panels. This granulate is produced on its own account at a certain level of the internal price.

Fig. 1 Pressure drops in the DN25 valve using different structures
Source: [14].

The main and most important part of the investment plan is the identification of the necessary technology and its purchase price**.** The business plan counts with the extension of the existing operational site by a pressing machine. It is a technological facility made by the renowned company Salvadori (Fig. 2) under the trade name Metamorphosis II. The plan also considers the construction of the aluminium mould on the dimensional stability of the final product.

Fig. 2 Pressing machine
Source: [15].

Table 1 contains a list of planned acquired assets and the amount of the assumed levels of acquisition prices, which were obtained from the producers at the time of elaboration of the investment plan. The total amount of the investment is at the level of € 180,000 (including the need for working capital) and financed by foreign capital at an interest rate of 3% p.a.
The considered output product of the production process will be a noise reduction panel with dimensions of 1,000 × 500 × 60 mm after the extension of capacities (purchase of pressing machine + preparation of the aluminium mould) (Fig. 3, illustrative picture). This product could be used in the construction of noise reduction walls.

Table 1
List of the acquired assets – planned investment (I. stage)

Name of mechanism/technology	Acquisition price
Pressing machine Metamorphosis II (Salvadori)	150,000.00 €
Construction of aluminium mould for shaping perforations	10,000.00 €
TOTAL	160,000.00 €

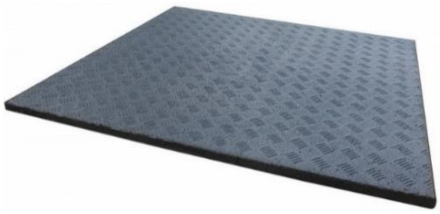

Fig. 3 Rubber-based noise reduction panel (illustrative picture)
Source: [16].

For the need of production capacity possibilities and also the calculation of sales prices, including the cost budget, it is necessary to identify the following issues. Based on the installed capacity of the machinery, which presents 40 m^2/day, the annual capacity of the pressed products of noise reduction panels is estimated at 14,000 m^2, at the continuous four-shift operation. A time fund of 350 days is considered 8,400 machine hours – MH). Such an operation requires the employment of 4 new employees at a gross salary of € 1,100/month (+ 35.2% employer contributions). Based on the assumed weight of the product 31 kg/m^2, with the considered ratio of the input raw material – 93% rubber granulate and 7% polyurethane binder, it is possible to determine the consumption of material inputs on an annual basis (434 tons of rubber granulate and 30,380 kg binder). Available evaluation methods were used to evaluate the investment plan, namely: Net Present Value, Profitability index, Internal Rate of Return and Payback Period. These generally known methodical procedures and their statements are presented in the works of Balaram [17], Cuthbert and Magni [18] and Mørch et al. [19]. The authors apply mainly two dynamic methods, based on the discounting: Net Present Value and Internal Rate of Return. Only some authors, for example Brealey and Myers, Fotr and Souček, use Profitability Index or Discounted Payback Period of project [20, 21]. The basic working hypothesis is the assumption that the presented concept for the production of rubber-based noise reduction walls will be cost-effective and the Discount Payback Period will be within six years.

RESULTS AND DISCUSSION

The basis of the cost-benefit calculation is the assumption of preliminary calculation of costs and product price. We have chosen the most frequently used margin calculation, while we applied the following rates within the individual items of direct and overhead costs:

– Energy rate per machine hour R_E/MH

$$R_E/MH = rated\ power\ of\ the\ machine \times Ø\%\ use\ of\ elec.capacity \times energy\ rate \quad (1)$$

$$R_E MH = 34\,kWh \cdot 0.9 \cdot 0.12\,€/kWh = 3.67\,€/MH$$

– Rate of calculation depreciation per machine hour R_D/MH

$$R_D/MH = \frac{acquisition\ price}{lifetime \times time\ fund\ of\ MH} \quad (2)$$

$$R_D/MH = \frac{160{,}000\ €}{6\ years \cdot 8{,}400\ MH} = 3.18\ €/MH$$

To calculate wage costs, the basis is the defined necessity of 4 new employees. The total wage costs of the company have been determined at the level of € 71,385.60/year. Based on the time schedule information of the pressing technology (8,400 hours/year), it is possible to calculate the wage cost rate:

– Wage cost rate per machine hour R_W/MH

$$\mathrm{R_W/MH} = \frac{wage\ cost}{time\ fund\ of\ MH} \quad (3)$$

$$\mathrm{R_W/MH} = \frac{71{,}385.60\ €}{8{,}400\ MH} = 8.50\ €/MH$$

The planned calculation has the following structure (Tab. 2) and it shows that the selling price shall be at the level of € 32.61 without VAT.

Table 2
Planned product calculation

Calculation item	Note	Calculation unit – m^2
Material cost – rubber granulate	- own production or purchase	4.33 €
+ Material cost on binder	- purchase price 4 €/kg	8.68 €
+ Wage cost	- rate 8.50 €/MH	5.09 €
+ Energy cost	- rate 3.67 €/MH	2.20 €
+ Accounting depreciations	- rate 3.18 €/MH	1.90 €
= Total costs for production	-	22.20 €
+ Overhead costs of the company	- rate 146.36% from wage cost	7.45 €
= Total product costs	-	29.65 €
+ Profit calculation margin	- rate 10% from total cost	2.96 €
= Price without VAT		32.61 €

Based on the results of the financial-economic analysis (Table 3), we can state that:

– The Net Present Value (*NPV*) of the investment is higher than 0, i.e. the planned investment in the evaluated period of 6 years is repayable and at the same time shows a certain profit rate.
– Investment related to the purchase of production technology of the mould is profitable, as, during the economic lifetime of the project (*T* = 6 years), the return on initial investment is proven (*DPP* = 4 years, 3 months and 23 days).
– During the analysed period of 6 years, based on the calculated cash flow (*CF*), the level of the Profitability Index is assumed to be 1.38. The PI value is above level 1, which represents the success and profitability of the investment in the evaluated time.
– The Internal Rate of Return (*IRR*) is more than 23%, thus at a higher level than any alternative form of interest on invested capital and in particular with a level of appreciation that can fully cover the cost of the necessary foreign capital.
– The analysis of the turning point shows that the company should realize production in the amount of at least € 350,000/year so that it can cover the total costs, which are calculated within the capacity of 1 press. The utilization of production capacity at the turning point is at an estimated level of 75%, while the use of other presses available at the company would certainly create room for manoeuvre to reduce this level of critical capacity from the effect of fixed cost degression.

Table 3
Financial forecast – calculation of Cash Flow a Net Present Value

			2022	2023	2024	2025	2026	2027
1		Revenues	456,540.00	470,260.00	484,400.00	498,960.00	513,940.00	529,340.00
2	-	Costs (no depreciation and interests)	384,233.40	395,760.40	407,633.21	419,862.21	432,458.08	445,431.82
3	-	Depreciation	26,666.67	26,666.67	26,666.67	26,666.67	26,666.67	26,666.67
4	-	Interests	5,400.00	5,4040.00	4,680.00	4,320.00	3,960.00	3,600.00
5	=	Profit before tax	40,239.93	42,792.93	45,420.12	48,111.12	50,855.25	53,641.51
6	-	Income tax (21%)	8,450.39	8,986.51	9,538.22	10,103.34	10,679.60	11,264.72
7	=	Net profit	31,789.54	33,806.41	35,881.89	38,007.78	40,175.65	42,376.79
8	-	Reserve fund 5%	1,589.48	1,690.32	1,794.09	1,900.39	2,008.78	2,118.84
9	=	Disposable profit	30,200.07	32,116.09	34,087.80	36,107.40	38,166.87	40,257.95
10	+	Depreciation	26,666.67	26,666.67	26,666.67	26,666.67	26,666.67	26,666.67
11	=	CASH FLOW	56,866.74	58,782.76	60,754.47	62,774.07	64,833.54	66,924.62
12	-	Loan repayment	12,000.00	12,000.00	12,000.00	12,000.00	12,000.00	12,000.00
13	=	NET CASH FLOW	44,866.74	46,782.76	48,754.47	50,774.07	52,833.54	54,924.62
14		Discount (5%)	0.9532	0.9070	0.8638	0.8227	0.7835	0.7462
15	=	Present value of Cash Flow	42,766.97	42,431.97	42,114.11	41,771.82	41,395.08	40,984.75
Present value of Cash Flow total			251,464.70 €					
NPV (Present value of Cash Flow – Invested capit.)			69,359.70 €					
PI (Present value of Cash Flow/Invested capit.)			1.38					
IRR (in %)			23.85%					
DPP (period)			4 years 3 months 23 days					

CONCLUSIONS

Worn tires and their secondary recovery have a great potential for using the principles of the circular economy. The trend of secondary recycling is the production of pressed products from a mixture of granulate and binder. Advantage of such a mixture is the shape variability of the products, depending on the respective mould, as well as anti-slip surface, water permeability, frost resistance and simple application. These elements are predominantly applied for children playgrounds and traffic courts, sports surfaces or paving for garden and agri-segment. Bret and Lidmila and Lidmila et al. point out the utilisation of rubber granulate as sound-absorbing layer for noise reduction walls and shields [22, 23]. Unfortunately, this kind of filler for noise reduction walls hasn't been used in Slovakia so far. Bret states in his work that rubber presents excellent resistance against cyclic exposure to frost and also acts as a thermal insulator to some extent [24]. Its coefficient of thermal conductivity determined for the mixture GG 2/8 reached the level $\lambda = 0.11\ W \cdot m^{-1} \cdot K^{-1}$. Its insulating properties are therefore about 10 times higher than soil or sand, and only about 3-4 times lower than insulating materials such as polystyrene or mineral wool, other properties such as reducing noise reflection and absorption are ideal for the production of noise reduction panels. This is one of the reasons why the product noise reduction panel (dimensions 1,000 × 500 × 60 mm) was evaluated as an additional assortment, usable in the construction of noise reduction walls.

Based on the results of the economic calculation of the planned investment in the acquisition of new additional technology, extending the existing production capacity of pressed products, such an intention has the potential to increase the competitiveness of the company in the market, rise its added value and significantly increase its annual volume of sales. Nevertheless, before the production, it is very important to manage the process of necessary technical tests, obtain certificates and particularly, inform the designers of noise-reduction walls about the possibilities of this product and so support the potential of its use. We cannot compare our results with other results from available studies because this information is considered sensitive and unpublishable in practice. That is why we consider our work to be beneficial. However, it shall be understood in terms of presentation of the business plan concept, which, in case of changing input parameters (procurement prices, material inputs, energy, set production capacity, interest rates) will require recalculation of evaluated indicators.

The basic limitations of this paper include the fact that the concept business plan was applied in the conditions of the Slovak manufacturer (price of input materials, energy, labour costs and overheads) and therefore the results cannot be generalized for the wider global environment. It is about presentation of the original idea of replacing traditional noise reduction walls materials with a rubber-based input, which is looking for its application in recycling. The concept provides the basis for applying the presented methodology with a change in input data (amount and sources of investment, type of technology and change in input costs, sales prices, production capacities, etc.). The aim of further research direction will be the precise and targeted adaptation of input data, as well as research into the use of recycled tires in upgraded products with specification of the production of agglomerated boards.

The most significant opportunities include the extension of the product portfolio of the company, increase of production capacities and growth potential for the economic indicators. However, it is necessary to consider possible threats, mainly the lack of interest in the declared product by builders and designers due to preferring other filling materials for the noise reduction walls, as well as possible loss of production capacity because of the epidemiological situation or establishment of competitive operational sites.

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Marek Potkány
ORCID ID: 0000-0002-7477-6157
Technical University in Zvolen
Faculty of Wood Sciences and Technology
Department of Economics, Management and Business
ul. T.G. Masaryka 24, 960 01 Zvolen, Slovak Republic
e-mail: potkany@tuzvo.sk

Lucia Krajčírová
Technical University in Zvolen
Faculty of Wood Sciences and Technology
Department of Economics, Management and Business
ul. T.G. Masaryka 24, 960 01 Zvolen, Slovak Republic
e-mail: krajcirova@tuzvo.sk

Mária Osvaldová
Technical University in Zvolen
Faculty of Wood Sciences and Technology
Department of Economics, Management and Business
ul. T.G. Masaryka 24, 960 01 Zvolen, Slovak Republic
e-mail: osvaldovamaria@gmail.com