

Article

# Economic-Financial Analysis of Municipal Solid Waste Recycling in Brazil: a Case Study of a Recycling Cooperative

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## ABSTRACT

Economic development and the growth of industrialization have contributed to an increase in the generation of solid waste in urban areas. Municipal solid waste recycling cooperatives (MSWRCs) provide environmental benefits as well as better working and living conditions for waste pickers. This article analyzes the economic viability of a MSWRC in Brazil using economic-financial indicators, with data from September 2021. Economic viability was analyzed considering the net present value (NPV), annualized net present value (ANPV), internal rate of return (IRR), benefit-cost ratio (BCR) and discounted payback with a minimum attractiveness return rate (MARR) of 3% per year. Financial risk was evaluated using the Monte Carlo method, considering three scenarios for income and the remuneration of cooperative members. The base scenario (operating conditions prioritizing the remuneration of the members of the cooperative) places the future sustainability of the business at risk. Variations in the revenue from the sale of recyclable materials and in the remuneration of cooperative members exert a considerable influence on economic and financial indicators, representing a high risk of losses (between 23% and 26.6%). In conclusion, the future sustainability of MSWRCs depends on strategies for increasing revenue whether through the enterprises themselves or through public policies. The need for the better remuneration of cooperative members constitutes a challenge for management due to the need to make investments in the maintenance and growth of the production unit.

**Keywords:** economic viability; recycling; waste management; circular economy; sustainability.

## RESUMO

O desenvolvimento econômico e a crescente industrialização têm contribuído para o aumento da geração de resíduos sólidos em regiões urbanas. As Cooperativas de Centrais de Reciclagem (CCRs) de resíduos sólidos proporcionam benefícios ambientais, redução da pobreza e melhores condições de trabalho e vida aos catadores. Este artigo analisa a viabilidade econômica de uma CCR localizada no Brasil usando indicadores econômico-financeiros, com dados de setembro de 2021. A viabilidade econômica foi realizada considerando os indicadores Valor Presente Líquido (VPL), Valor Presente Líquido Anualizado (VPLA), Taxa Interna de Retorno (TIR), Relação Benefício/Custo (RBC) e Payback descontado, com Taxa Mínima de Atratividade (TMA) de 3% ao ano. O risco financeiro foi avaliado pelo método de Monte Carlo, considerando três cenários para a receita e a remuneração dos cooperados. O cenário base (condições operacionais priorizando a remuneração dos cooperados) coloca em risco a sustentabilidade futura do negócio. As variações na receita com a comercialização de materiais recicláveis e a variação da remuneração dos cooperados exercem elevada influência sobre os indicadores econômico-financeiros, representando elevado risco de prejuízos (entre 23% e 26,6%). Conclui-se que a sustentabilidade futura das CCRs depende de estratégias para aumentar a sua receita, quer seja pelos próprios empreendimentos ou pela promoção de políticas públicas. A necessidade de melhor remunerar os cooperados representa um desafio



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para a gestão, na medida em que se confronta com a necessidade de realizar investimentos em prol da manutenção e do crescimento da unidade produtiva.

**Palavras-chave:** viabilidade econômica; reciclagem; gestão de resíduos; economia circular; sustentabilidade.

## Introduction

Economic development and the growth of industrialization have contributed to an increase in the generation of solid waste in urban areas (Souza et al. 2012). According to the Solid Waste Overview issued by the Brazilian Association of Public Cleaning and Special Waste Companies (Abrelpe 2020), a considerable increase occurred in the amount of municipal solid waste generated in Brazil, going from 67 million tons per year in 2010 to 79 million tons per year in 2019.

Concerns with environmental protection and resource conservation in addition to the high economic potential have led several countries to implement formal systems for the collection and recycling of solid waste (Xu et al. 2017). Cudjoe et al. (2021) calculated that the recycling of solid waste in China avoided about 4765.9 billion kg of carbon dioxide emissions and 22.502 billion kg of methane emissions into the atmosphere in a 12-year period. Other studies have also shown that recycling contributes to a reduction in atmospheric emissions (Razzaq et al. 2021) and the contamination of humans and aquatic ecosystems by toxic products (Ferronato et al. 2021), avoids expenditures of energy and water in the manufacturing of new products, such as superabsorbent polymers (Somers et al. 2021), and reduces the amount of solid waste in cities (Gutberlet 2015).

Recycling is also one of the main components of a circular economy, along with reuse, restoration and remanufacturing (Petković et al. 2021). The objective of a circular economy is the elimination of waste and the continuous use of resources (Petković et al. 2021). Such a system can also contribute to social inclusion (Resnitzky et al. 2021). However, the circular economy needs to be implemented further to improve the efficiency of solid waste management in municipalities (Bui et al. 2022).

To encourage recycling and reduce problems related to the inadequate disposal of solid waste, the Brazilian National Solid Waste Policy established by Law No. 12305/10 encourages the creation and development of cooperatives and other forms of association among collectors of reusable and recyclable materials (Brasil 2010). In 2019, there were about 1,480 cooperatives or associations of waste pickers working in the selective collection of household solid waste in 1,438 Brazilian municipalities, totaling 31,500 members (Snis 2020).

A study by Yildiz-Geyhan, Altun-Çiftçioğlu and Kadirgan (2017) showed that formal systems, such as associations and cooperatives for solid waste collection, provide significantly better working and living conditions for waste pickers compared to informal systems. Machado et al. (2019) and Gutberlet (2021) also highlight the socio-environmental benefits of this activity, such as reductions in environmental contamination and poverty, social inclusion and the elevation of professional qualification levels.

The literature offers few studies on the economic viability of municipal solid waste recycling cooperatives. Some studies show that recycling is economically viable, such as in the production of polyols from rigid polyurethane foam waste, the internal rate of return (IRR) of which was 22.9% in one study (Kanchanapiya et al. 2021), and polystyrene recycling, with an IRR of 14% (Larrain et al. 2021). In other studies on structures similar to the operation of cooperatives, the economic viability of implementing a waste management center obtained an IRR of 57.60% (Pires et al. 2008).

However, Fidelis and Colmenero (2018) identified weaknesses in the operational activities of the recycling chain of seven Brazilian cooperatives and recommended maintaining and expanding public actions directed at members to improve the processes. Tirado-Soto and Zamberlan (2013), Dutra et al. (2018) and Gutberlet (2021) also recommended investments in infrastructure, governance and the training of cooperative members. Other weaknesses of MSWRCs are related to the problems of managing material and patrimonial assets and a lack of



specialization (Cardozo et al. 2015). The authors suggest the need to establish rational management methods, make small investments and simplify mechanisms for managing materials and assets.

Given this context, the aim of the present study was to analyze the economic viability of a MSWRC located in Brazil that operates in the recycling of municipal solid waste. The results can assist stakeholders in the planning, implementation and management of cooperatives to improve the efficiency and sustainability of such initiatives.

## 2. Material and methods

This is an applied study with a quantitative approach. The research intended to explore and explain the economic indicators of a cooperative, whose procedure is characterized as a case study. The base scenario of the present work was a cooperative that performs the recycling of municipal solid waste in the southern region of Brazil. Data were collected in September 2021 and further information was added during the development of the study, extending to February 2022, to complement the initial data whenever necessary.

### 2.1. Characteristics and structure of cooperative

The municipal solid waste recycling cooperative (MSWRC) has been in the recycling business for 19 years in the southern region of Brazil. Its history was marked by financial crises that led to the cessation and subsequent return to the activity. The MSWRC currently serves eleven municipalities and employs 65 individuals.

The MSWRC operates in a rented location with a physical space of approximately 10,000 m<sup>2</sup>. It has a constructed area of 2,878 m<sup>2</sup>, which includes sheds for storage, sorting and baling solid waste as well as a specific place for the office, cafeteria and other social activities.

The monetary value of the MSWRC represented by its fixed capital (Table 1) totaled US\$ 134,000. The highest unit value corresponded to the wheel loader, followed by the tipper, truck and conveyor belt for classifying waste. The residual value of the items (after 10 years) was estimated as 30% of the initial value, considering the depreciation rate, the useful life of each item (Brasil 2017) and the frequency of maintenance performed by the cooperative. The MSWRC also maintains a working capital in the company in the amount of US\$ 16,800 year<sup>-1</sup> for operations and maintenance of the structure.

**Table 1.** Monetary value (US\$) of fixed capital of recycling center cooperative.

Components	Initial value	Residual value (after 10 years)
Machines and equipment	68,600.00	20,580.00
Furniture and utensils	2,200.00	660.00
Trucks and vehicles	63,200.00	18,960.00
Total (US\$)	134,000.00	40,200.00

### 2.2. Production process and economic results

The recycling process begins with the receiving of approximately 300,000 kg day<sup>-1</sup> of municipal solid waste (organic and dry) from eleven municipalities located in the region where the MSWRC operates. The waste is collected via public urban cleaning and selective collection trucks in these municipalities and donated to the cooperative. After arrival, the waste is stored and then sent to two sorting conveyors, where the items are manually sorted, resulting in an average of 157,400 kg day<sup>-1</sup> of recyclable solid waste. After being separated, the different categories of recyclable materials are compressed and placed in an area for dispatch. Most buyers or



clients are local industries that use these materials to manufacture by-products. Figure 1 illustrates the stages of the solid waste screening process carried out by the MSWRC.

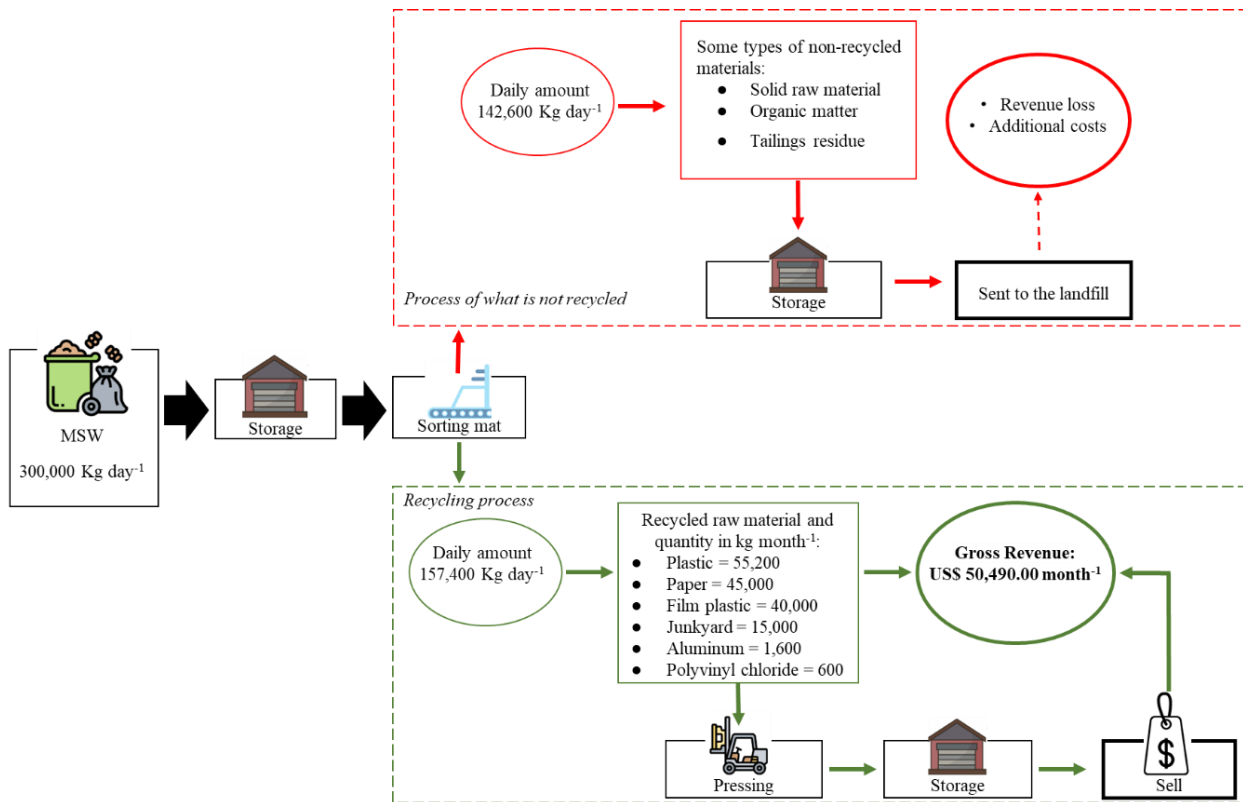


Fig. 1. Stages and quantity of screening process of municipal solid waste (MSW) received at MSWRC.

The financial income in the cooperative's cash flow comes from the sale of recyclable materials (Table 2), which is performed daily as soon as a sufficient volume is reached for transport via trucks. The manager of the cooperative investigates the market demand in order to sell the products at the highest possible price and carries out negotiations with buyers. Sales prices for recyclable materials are negotiated either "Free on Board" or "Cost, Insurance and Freight", depending on the agreement with each buyer.

The expenses of the MSWRC (Table 3) correspond to waste processing and shipping activities. Processing (sorting) is the step that requires more inputs and labor. Fuel costs occur in the sale of the sorted material to customers. The highest cash outflow regards the remuneration of the members. As a cooperative, there is equitable distribution of the financial surplus to all members. Seasonal hired labor (summer period) is remunerated by contract. The second largest expense is related to accounting (outsourced service), taxes and fees.


**Table 2.** Quantity and value obtained by category of commercialized waste.

Waste Category	Daily amount (kg)	Value (US\$ kg <sup>-1</sup> ) <sup>8</sup>	Monthly value (US\$)	Annual value (US\$)
Paper <sup>1</sup>	45,000	0.19	8,550.00	102,600.00
White HDPE <sup>2</sup>	12,000	0.72	8,640.00	103,680.00
Colored HDPE	8,000	0.72	5,760.00	69,120.00
Aluminum <sup>3</sup>	1,600	1.68	2,688.00	32,256.00
White PP <sup>4</sup>	7,500	0.40	3,000.00	36,000.00
Colored PP	7,500	0.30	2,250.00	27,000.00
Other <sup>7</sup> PP	200	0.20	40.00	480.00
White PET <sup>5</sup>	18,000	0.66	11,880.00	142,560.00
Green PET	2,000	0.60	1,200.00	14,400.00
Black film	36,000	0.11	3,960.00	47,520.00
Corrugated film	4,000	0.32	1,280.00	15,360.00
Scrap metal	15,000	0.07	1,050.00	12,600.00
PVC <sup>6</sup>	600	0.32	192.00	2,304.00
<b>Total</b>	<b>157,400</b>		<b>50,490.00</b>	<b>605,880.00</b>

Notes: 1) Corrugated, mixed and white paper, sold mixed (without separation). 2) HDPE = high-density polyethylene. 3) Average of 17 types of aluminum sold at different prices. 4) PP = polypropylene. 5) PET = polyethylene + terephthalate (thermoplastic material). 6) PVC = polyvinyl chloride. 7) Same as white PP, but sold separately due to lower value. 8) Prices from September 2021 considering exchange rate: US\$1.00 = R\$5.00.

**Table 3.** Cash outflows (monthly and annual US\$) for operation of recycling center cooperative.

Component	Value (US\$ month <sup>-1</sup> )	Value (US\$ year <sup>-1</sup> )
Remuneration of members	40,936.00	491,232.00
General administrative expenses	4,490.00	53,880.00
Rent	3,000.00	36,000.00
Inputs	800.00	9,600.00
General maintenance	400.00	4,800.00
Personal protective equipment	300.00	3,600.00
<b>Total</b>	<b>49,926.00</b>	<b>599,112.00</b>

Note: Exchange rate: US\$1.00 = R\$5.00.



### 2.3. Economic evaluation

The economic evaluation of the municipal solid waste recycling activity carried out by this cooperative was performed with the use of economic-financial viability indicators as well as sensitivity and risk analyses.

The first step consisted of the determination of cash flow for projects considering the model proposed by Casarotto Filho and Kopittke (2010). This is future cash flow with annual projections for a 10-year valuation period considering constant prices. A minimum attractiveness return rate (MARR) of 3.0% per year was used for all analyses, which corresponds to the actual interest rate of the Brazilian economy in the last 10 years. MARR is the opportunity cost of capital. In this work, all values originally obtained in Brazilian currency (R\$) were converted into US dollars (US\$) considering the exchange rate of US\$1.00 = R\$5.00.

The payback period of the invested capital (Payback), the net present value (NPV), annualized net present value (ANPV), internal rate of return (IRR) and the benefit-cost ratio (BCR) were the economic-financial viability indicators considered. Payback (Eq. 1) is the time in years ( $t$ ) necessary to recover the invested capital ( $I_0$ ) from future cash flows ( $CF_t$ ) discounted at the discount rate ( $k$ ), which represents MARR (Samanez 2009).

$$I_0 = \sum_{t=1}^n \frac{CF_t}{(1+k)^t} \quad \text{Eq. (1)}$$

The NPV (Eq. 2) is obtained by subtracting the cash flow for year zero ( $CF_0$ ), which corresponds to the initial investment ( $I_0$ ) of the venture, from the sum of future cash flows ( $CF_t$ ) discounted at the discount rate ( $k$ ) (Gitman 2010). An  $NPV > 0$  represents a net financial surplus after the remuneration of  $I_0$  at rate  $k$ , indicating that the project results in a higher rate of return than the MARR.  $NPV = 0$  represents the limit of acceptability, indicating that the project obtained a rate of return equal to rate  $k$  (i.e., MARR was reached).

$$NPV = \sum_{t=1}^n \frac{CF_t}{(1+k)^t} - CF_0 \quad \text{Eq. (2)}$$

The ANPV (Eq. 3) transforms the existing NPV into an equivalent annual value (Gitman 2010). ANPV is useful for analyzing projects that have different evaluation times. The result is interpreted identically to the NPV.

$$ANPV = NPV \left[ \frac{k(1+k)^t}{(1+k)^t - 1} \right] \quad \text{Eq. (3)}$$

The IRR (Eq. 4) is the rate that cancels the NPV (SAMANEZ 2009). An  $IRR > k$  indicates that the project results in an  $I_0$  remuneration greater than the required MARR.  $IRR = k$  represents the limit of the acceptability of the project, indicating that the MARR has been reached.





$$IRR = \sum_{t=1}^t \frac{CF_t}{(1+k)^t} - CF_0 = 0 \quad \text{Eq. (4)}$$

The BCR (Eq. 5) is the division between the present value of the benefits ( $B_t$ ) and the present value of the costs ( $C_t$ ) of the project, together with the initial investment (Samanez 2009). A BCR index  $> 1$  indicates that the project results in an  $I_0$  remuneration greater than the required MARR. BCR = 1 represents the limit of acceptability. In this situation, the project results in equivalence (IRR = MARR and NPV = 0).

$$BCR = \sum_{t=0}^n \frac{B_t}{(1+k)^t} / \sum_{t=0}^n \frac{C_t}{(1+k)^t} \quad \text{Eq. (5)}$$

#### 2.4. Sensitivity and risk analyses

Sensitivity analysis enables identifying critical variables in the stages of projection and the identification of cash flows to evaluate a project by considering different hypotheses regarding the behavior of these variables (Samanez 2009). The variables that had the greatest impact on the results of the economic indicators were selected: revenues from the sale of recyclable materials and remuneration of cooperative members (Table 4). The value of annual revenues may change due to fluctuations in the sales price of recyclable materials (Gutberlet 2015) as well as fluctuations in the amount of material collected for recycling, which has seasonal or atypical variations, as in the case of the current COVID-19 pandemic (Forbes 2020). Two further scenarios were considered with a variation of  $\pm 20\%$  of revenue in relation to the base scenario.

Remuneration (amount of financial surplus distributed to the members of the cooperative) is a variable that depends on a managerial decision. In the present work, practically all of financial surplus was distributed to the members at the end of the year. Thus, two further scenarios were considered with a reduction of 15% and 30% in the remuneration of cooperative members compared to the base scenario.

For the risk assessment, which is the probability of NPV  $< 0$  (Gitman 2010), the scenarios proposed in Table 4 were simulated using the Monte Carlo Method with the aid of the @Risk 7.0.0 software (Palisade 2015). Triangular probability distribution was used for both variables, with 100,000 iterations to obtain the NPV.

**Table 4.** Scenarios for sensitivity and risk analyses.

Risk Variables	Unit	Distribution of probability	Minimum value	Base situation	Maximum value
Revenue (R)	US\$ year <sup>-1</sup>	Triangular	R1 581,644.80	R2 605,880.00	R3 630,115.20
Remuneration of cooperative members (RC)	US\$ year <sup>-1</sup>	Triangular	RC1 343,862.40	RC2 417,547.20	RC3 491,232.00

Note: Exchange rate: US\$1.00 = R\$5.00.



### 3. Results

Cash flow in the base scenario (R2 & RC2) is presented in Table 5. Year zero corresponds to the time at which the implementation and preparation for the start of the MSWRC activities takes place, the  $I_0$  and working capital values of which are the current condition of the cooperative studied. Years 1 to 9 had similar values and were therefore grouped. In Year 10, the residual  $I_0$  (30% of the initial value) and the full value of working capital were entered.

**Table 5.** Projected cash flow at constant prices (US\$) for recycling activity.

Description	Year 0	Years 1-9	Year 10
(-) Initial investment ( $I_0$ )	134,000.00		
(-) Working capital	16,800.00		
(+) Residual value of $I_0$			40,200.00
(+) Residual value of working capital			16,800.00
(+) Sale of recyclable materials		605,880.00	605,880.00
(-) Remuneration of members		491,232.00	491,232.00
(-) General administrative expenses		53,880.00	53,880.00
(-) Rent		36,000.00	36,000.00
(-) Inputs		9,600.00	9,600.00
(-) Operation & Maintenance		4,800.00	4,800.00
(-) Personal protective equipment		3,600.00	3,600.00
<b>(=) Free cash flow</b>	- 150,800.00	6,768.00	63,768.00

Source: Prepared by the authors, adapted from Casarotto Filho and Kopittke (2010).

Note: Exchange rate: US\$1.00 = R\$5.00.

The economic-financial viability indicators are presented in Table 6. In the base scenario (R2 & RC2), the MSWRC has indicators that characterize the unviability of the activity. A significant improvement in all viability indicators occurs with the increase in revenue (from R1 to R3). A similar effect also occurs when the remuneration of the members is reduced (from RC3 to RC1). The impact on the NPV of the activity resulting from variations in revenue and the remuneration of cooperative members is better visualized in Figure 2.

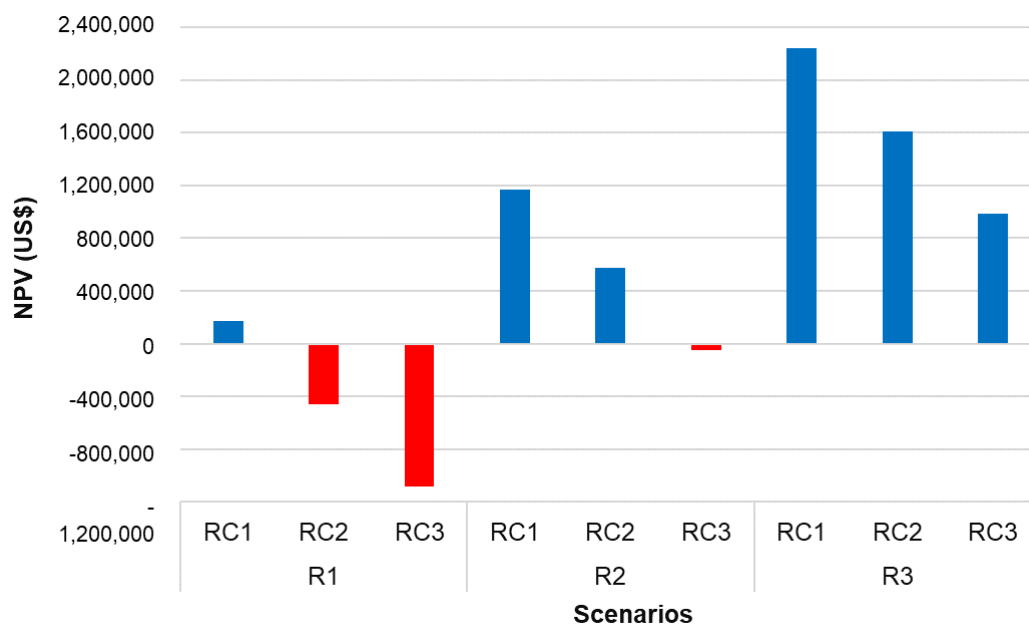
The indicators that consider the most likely revenue scenario (R2) demonstrate that the viability of the activity is significantly altered with the reduction in the amount destined for the remuneration of the members (from RC3 to RC1). Even a small adjustment in remuneration (from US\$ 491,232.00 to US\$ 485,293.76 per year), which corresponds to a reduction of only 1.21%, would make the MSWRC viable. In the lower revenue scenario (R1), the adjustment in the remuneration of the members would need to be greater, as viability was only found in the RC1 scenario. In the higher revenue condition (R3), all RC scenarios had high economic viability, enabling greater remuneration of the members.




**Table 6. Summary of main economic-financial indicators for scenarios evaluated.**

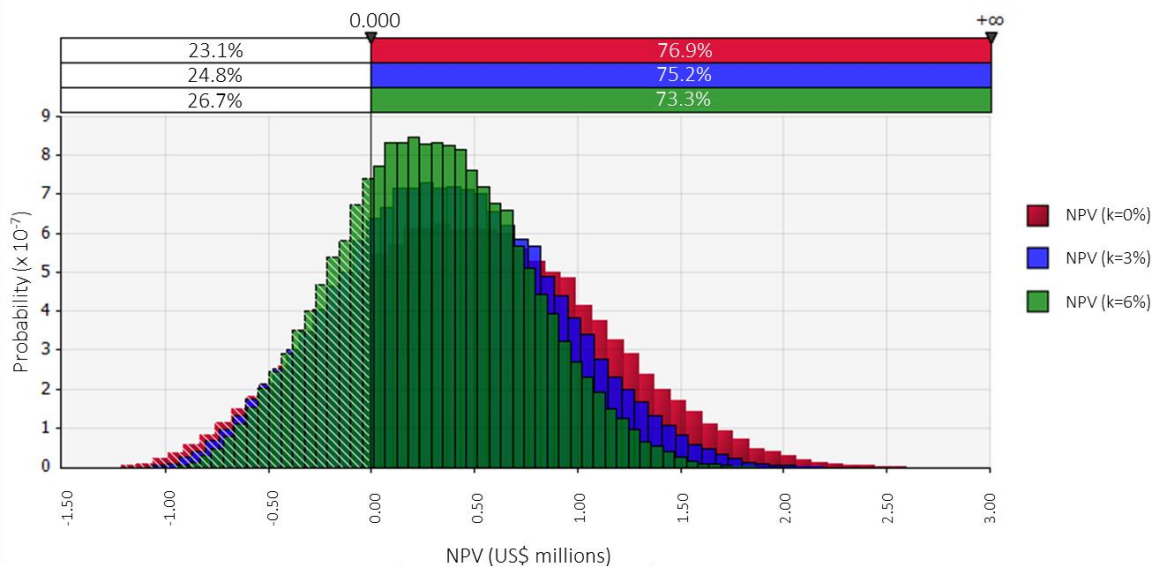
Scenarios	Discounted payback	NPV (US\$)	ANPV (US\$)	IRR (%)	CBR	
R1	RC1	5 years	172,782.49	20,255.38	19.4	1.04
	RC2	> 10 years	-455,763.80	-53,429.42		0.90
	RC3	> 10 years	-1,084,310.09	-127,114.22		0.79
R2	RC1	1 year	1,164,024.99	136,459.24	102.1	1.30
	RC2	2 years	577,892.06	67,746.58	52.9	1.12
	RC3	> 10 years	-506,54.23	-5,938.22	-2.4	0.99
R3	RC1	< 1 year	2,240,094.20	262,607.38	182.6	1.56
	RC2	< 1 year	1,611,547.91	188,922.58	133.7	1.35
	RC3	< 2 years	983,001.62	115,237.78	84.7	1.19

Notes: Discount rate ( $k$ ) = 3% per year; NPV= net present value; ANPV= annualized net present value; IRR= internal rate of return; CBR= benefit-cost ratio. Exchange rate: US\$1.00 = R\$5.00.



**Fig. 2.** Variation in net present value (NPV;  $k$  = 3% per year) according to income scenarios (R1, R2 and R3) and remuneration of cooperative members (RC1, RC2 and RC3).

Figure 3 shows the probability distribution of the risk analysis for the NPV developed with 100 thousand iterations considering scenarios of income (R) and remuneration of cooperative members (RC) at three levels of annual discount rate ( $k$  = 0%,  $k$  = 3% and  $k$  = 6%). The probability of the NPV being negative, which corresponds to the risk of the economic unviability of the activity, was 23.1% for  $k$  = 0%, 24.8% for  $k$  = 3% and 26.7% for  $k$  = 6% per year. The variation in risk was 3.6 percentage points, demonstrating that the discount rate  $k$  had little influence on the results.



**Fig. 3.** Net Present Value (NPV) probability distribution by risk analysis according to income scenarios (R1, R2 and R3) and remuneration of cooperative members (RC1, RC2 and RC3).

#### 4. Discussion

The results of this work using data from a municipal solid waste recycling cooperative (MSWRC) in southern Brazil as reference showed that the recycling of municipal solid waste can be economically viable depending on the amount destined for the remuneration of the members of the cooperative, which corresponds to the main cash outflow. Considering the base scenario of financial flows at the time of the research (scenarios R2 and RC2), the economic-financial indicators were highly sensitive to changes in the scenario, especially variations in the remuneration of the members.

The MSWRC prioritizes the distribution of financial surplus among its members, giving them greater remuneration for their work. The high remuneration of the members of the MSWRC studied (US\$ 491,232.00 year<sup>-1</sup>) is a positive factor, as it contributes to a reduction in poverty and favors social inclusion (Gutberlet 2021; Machado et al. 2019). This remuneration could be even higher, since revenues vary according to the quantities of waste processed and the prices practiced in the market. Some authors have shown an opposite situation to the case studied, with low remuneration of the cooperative members, whose monthly income was less than the Brazilian monthly minimum wage (Gutberlet 2015; Virgin et al. 2014), as well as systems with the unequal distribution of costs and benefits of recycling (Conke 2018), generating negative impacts with regards to worker turnover (Gutberlet 2015).

Prioritizing the remuneration of cooperative members is in conflict with the need to invest in capital to maintain and even grow the productive structure of the enterprise. Thus, there is a trade-off between the remuneration of cooperative members and investments in the company, which jeopardizes the survival of the MSWRC in the medium and long terms, revealing a management problem that also affects other Brazilian recycling cooperatives (Dutra et al. 2018; Fidelis & Colmenero 2018; Tirado-Soto & Zamberlan, 2013). The financial risk of the cooperative considering variations in revenue and the remuneration of members ranged from 23.0% to 26.6%, which is considered relatively high. In the analysis of the management of organic solid waste from a vegetable agro-industry located in Brazil, Gaspar et al. (2020) found zero risk for a discount rate of 6% per year and a 0.08% risk for a discount rate of 12%.



Another aspect that poses a financial risk for the MSWRC is the use of old machinery and vehicles, which results in high operating and maintenance costs in addition to low operational efficiency. The working capital (US\$ 16,800.00 year<sup>-1</sup>) is considered low, considering the size and volume of solid waste processed by the cooperative. The low financial investment in working capital, repairs and purchases of new machinery and equipment is a problem also reported for other recycling cooperatives (Santos et al. 2018; Tirado-Soto & Zamberlan, 2013). As a way of mitigating financial and management problems related to recycling cooperatives, Gutberlet (2015), Tirado-Soto and Zamberlan (2013) recommend the creation of cooperative networks that are capable of ensuring benefits in terms of raising financial resources, the creation of public policies and better mobilization among cooperative members.

The income of the MSWRC comes from the sale of recyclable materials in the regional market. For some of materials (HDPE, PP and PET), the MSWRC has established commercial transactions mediated by contracts (although verbal), which increase frequency, strengthen relationships of trust between agents and enhance reputations. Thus, the MSWRC seeks to diminish uncertainties in negotiations with buyers and minimize losses resulting from opportunistic actions (Williamson 1991). For other materials, sales take place via negotiations in the spot market. Other studies also mention the same sales strategy adopted by recycling cooperatives as well as the use of software, which enhances the recycling system through the scheduling of donations and determination of collection routes (Gutberlet 2015; Tirado-Soto & Zamberlan, 2013).

Another way of improving financial returns for recycling cooperatives regards the adequate separation of recyclable materials by the population. The MSWRC collects 300,000 kg of solid waste daily, about 53% of which (160,000 kg day<sup>-1</sup>) is recyclable material that can be sold. Thus, environmental education actions and public policies aimed at the proper separation of solid waste on the part of the population would improve the financial return of MSWRCs, contribute to increasing the lifespan of sanitary landfills where non-recycled waste is directed (Gutberlet 2015) and would reduce expenses in the production of new products (Somers et al. 2021).

Zikali et al. (2022) reported that US\$ 45,000 month<sup>-1</sup> of potential income from recyclable materials are lost due to the improper handling of solid waste in Dangamvura, Zimbabwe. Proper separation contributes to reductions in environmental impact and disposal costs (Alam & Qiao 2020; Fraifeld et al. 2021; Mersoni & Reichert 2017). Thus, environmental education is fundamental to the process (Gu et al. 2022).

Developing actions on the local level and projects that include waste management programs that enhance environmental awareness and encourage engagement on the part of society has been shown to be effective at reducing problems related to improper waste disposal (Cárcamo & Peñabaena-Niebles 2022; Moustairas et al. 2022; Yusuf & Fajri 2022). Furthermore, government support is essential to the promotion of continuous improvements in the structural organization of MSWRCs and the management of municipal solid waste (Navarrete-Hernandez & Navarrete-Hernandez 2018; Zhang et al. 2021). The National Solid Waste Policy in Brazil has contributed to the promotion and inclusion of MSWRCs in municipal solid waste management. However, some issues should be considered regarding the unique situation of each municipality and greater guidance for measures of gradual evolution, in addition to stimulating joint actions among municipalities (Grisa & Capanema 2018).

Formal or informal waste pickers perform fundamental work that benefits the environment and society and therefore require measures for better working and living conditions (Gouveia 2012). In the case studied, the municipalities could contribute to the promotion of environmental education actions to improve selective collection in addition to investments in equipment that can help MSWRCs achieve greater recycling and improve the quality of life of workers.



## 5. Conclusion

The analysis of the economic-financial indicators of the MSWRC evaluated in this study revealed that the project can be economically viable depending on the amount of value destined to the remuneration of the members of the cooperative, which is the main cash outflow. The MSWRC enables higher remuneration to the members by dividing the financial surplus among them. However, such prioritization is in conflict with the need to invest in the production structure, placing the survival of the MSWRC at risk in the medium and long terms.

There are also aspects that pose financial risk to the MSWRC, such as the high costs of operating and maintaining used machines and vehicles as well as the small amount invested in working capital compared to the size of the cooperative. Alternatives, such as the creation of cooperative networks, could contribute to the management and capture of financial resources. Such conclusions serve as support for managerial decision making regarding the use and distribution of the financial resources of MSWRCs to ensure future sustainability.

The results of this study can assist researchers and other professionals in all sectors of the economy – whether on the local, national or global level – to develop strategies aimed at improving the performance of MSWRCs. Considering the scarcity of studies on the subject, there is a need for more research on the economic viability of this activity as well as better government incentives for the training of managers of MSWRCs and the promotion of environmental education to raise awareness in the population.

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