sustainability

MDPI

Article

Sensitivity Analysis as a Tool in Environmental Policy for Sustainability: The Case of Waste Recycling Projects in the Republic of Serbia

Ksenija Denčić-Mihajlov [1,*], Mladen Krstić [2] and Dejan Spasić [1,3]

[1] Faculty of Economics, University of Niš, Trg kralja Aleksandra Ujedinitelja 11, 18000 Niš, Serbia; dejan.spasic@eknfak.ni.ac.rs or dejan.spasic@ekof.bg.ac.rs
[2] Maksi-Co doo, Aleksinac 18220, Republic of Serbia; mlkrsta@gmail.com
[3] Faculty of Economics, University of Belgrade, Kamenička 6, 11000 Belgrade, Serbia
* Correspondence: ksenija.dencic-mihajlov@eknfak.ni.ac.rs; Tel.: +381-63-473-606

Received: 8 September 2020; Accepted: 24 September 2020; Published: date

Supplementary Materials

Table S1. Projected income statement for Financial CBA for End-of-Life Vehicles recycling center—Data used for calculation of CBA criteria.

No	Elements	n	n+1	n+2	n+3	n+4	n+5	n+6	n+7	n+8	n+9
I	Operating income	2,274,575.00	2,274,575.00	2,274,575.00	2,274,575.00	2,274,575.00	2,274,575.00	2,274,575.00	2,274,575.00	2,274,575.00	2,274,575.00
I 1.	Revenues from the sale of recycled raw materials	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00
I 2.	Revenue from the sale of used car parts	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00
I 3.	Revenue from recycling incentives	25,280.00	25,280.00	25,280.00	25,280.00	25,280.00	25,280.00	25,280.00	25,280.00	25,280.00	25,280.00
II	Costs of direct material	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00
III	Other business expenses	576,650.00	576,650.00	576,650.00	576,650.00	576,650.00	576,650.00	543,200.00	506,300.00	506,300.00	506,300.00
III 1.	Fuel, lubricant, gas and electricity costs	140,000.00	140,000.00	140,000.00	140,000.00	140,000.00	140,000.00	140,000.00	140,000.00	140,000.00	140,000.00
III 2.	Labor costs (gross)	154,800.00	154,800.00	154,800.00	154,800.00	154,800.00	154,800.00	154,800.00	154,800.00	154,800.00	154,800.00
III 3.	Depreciation costs	104,350.00	104,350.00	104,350.00	104,350.00	104,350.00	104,350.00	70,900.00	4000.00	4000.00	4000.00
III 4.	Transport, forwarding, and radiology costs	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00
III 5.	Costs of investment maintenance (fixed	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00	130,000.00	130,000.00	130,000.00

	assets)										
III 7.	Waste disposal costs	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00
IV	Operating profit EBIT	277,925.00	277,925.00	277,925.00	277,925.00	277,925.00	277,925.00	311,375.00	348,275.00	348,275.00	348,275.00
V	Financial expenses	21,000.00	18,900.00	16,800.00	14,700.00	12,600.00	10,500.00	8400.00	6300.00	4200.00	2100.00
VI	Income before taxes	256,925.00	259,025.00	261,125.00	263,225.00	265,325.00	267,425.00	302,975.00	341,975.00	344,075.00	346,175.00
VII	Tax (15%)	38,538.75	38,853.75	39,168.75	39,483.75	39,798.75	40,113.75	45,446.25	51,296.25	51,611.25	51,926.25
VIII	Net income	218,386.25	220,171.25	221,956.25	223,741.25	225,526.25	227,311.25	257,528.75	290,678.75	292,463.75	294,248.75
1.	Loan repayment	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00
2.	Accumulation	148,386.25	150,171.25	151,956.25	153,741.25	155,526.25	157,311.25	187,528.75	220,678.75	222,463.75	224,248.75

Table S2. Economic flow of the project End-of-Life Vehicles recycling center—Data used for calculation of CBA criteria.

No	Elements	n-2	n-1	n	n+1	n+2	n+3	n+4	n+5	n+6	n+7	n+8	n+9
I	Total cash-inflow	0	0	2,274,575	2,274,575	2,274,575	2,274,575	2,274,575	2,274,575	2,274,575	2,274,575	2,274,575	2,532,575
1.	Revenue			2,274,575	2,274,575	2,274,575	2,274,575	2,274,575	2,274,575	2,274,575	2,274,575	2,274,575	2,274,575
2.	Residual value of investments												258,000
II	Total cash-outflow	140,000	839,000	2,021,839	2,020,054	2,018,269	2,016,484	2,014,699	2,012,914	2,016,146	2,049,896	2,048,111	2,076,326
1.	Investment cost	140,000	818,000										
2	Operating cost			1,892,300	1,892,300	1,892,300	1,892,300	1,892,300	1,892,300	1,892,300	1,922,300	1,922,300	1,922,300
3	Annuity		21,000	91,000	88,900	86,800	84,700	82,600	80,500	78,400	76,300	74,200	72,100
4	Land clearing costs												30,000
5	Tax			38,539	38,854	39,169	39,484	39,799	40,114	45,446	51,296	51,611	51,926
III	Net cash-flow	−140,000	−839,000	252,736	254,521	256,306	258,091	259,876	261,661	258,429	224,679	226,464	456,249
	Net present value	1,168,750											

Table S3. Projected income statement for refrigerator recycling center—Data used for calculation of CBA criteria.

No	Elements	n	n+1	n+2	n+3	n+4	n+5	n+6	n+7	n+8	n+9
I	Operating income	3,464,172.00	3,464,172.00	3,464,172.00	3,464,172.00	3,464,172.00	3,464,172.00	3,464,172.00	3,464,172.00	3,464,172.00	3,464,172.00
I 1.	Revenues from the sale of recycled raw materials	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00
I 2.	Revenue from recycling incentives	2,441,837.00	2,441,837.00	2,441,837.00	2,441,837.00	2,441,837.00	2,441,837.00	2,441,837.00	2,441,837.00	2,441,837.00	2,441,837.00
II	Costs of direct material	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00
III	Other business expenses	1,359,950.00	1,359,950.00	1,359,950.00	1,359,950.00	1,359,950.00	1,359,950.00	1,247,500.00	1,042,600.00	1,042,600.00	1,042,600.00
III 1.	Fuel, lubricant, gas and electricity costs	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00

III 2.	Labor costs (gross)	309,600.00	309,600.00	309,600.00	309,600.00	309,600.00	309,600.00	309,600.00	309,600.00	309,600.00	309,600.00
III 3.	Depreciation costs	365,350.00	365,350.00	365,350.00	365,350.00	365,350.00	365,350.00	252,900.00	28,000.00	28,000.00	28,000.00
III 4.	Transportation costs	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00
III 5.	Gas costs-Nitrogen	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00
III 6.	Electricity costs	75,000.00	75,000.00	75,000.00	75,000.00	75,000.00	75,000.00	75,000.00	75,000.00	75,000.00	75,000.00
III 7.	Costs of investment maintenance (fixed assets)	110,000.00	110,000.00	110,000.00	110,000.00	110,000.00	110,000.00	110,000.00	130,000.00	130,000.00	130,000.00
III 8.	Freon disposal costs	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00
IV	Operating profit EBIT	409,307.00	409,307.00	409,307.00	409,307.00	409,307.00	409,307.00	521,757.00	726,657.00	726,657.00	726,657.00
V	Financial expenses	82,500.00	74,250.00	66,000.00	57,750.00	49,500.00	41,250.00	33,000.00	24,750.00	16,500.00	8,250.00
VI	Income before taxes	326,807.00	335,057.00	343,307.00	351,557.00	359,807.00	368,057.00	488,757.00	701,907.00	710,157.00	718,407.00
VII	Tax (15%)	49,021.05	50,258.55	51,496.05	52,733.55	53,971.05	55,208.55	73,313.55	105,286.05	106,523.55	107,761.05
VIII	Net income	277,785.95	284,798.45	291,810.95	298,823.45	305,835.95	312,848.45	415,443.45	596,620.95	603,633.45	610,645.95
1.	Loan repayment	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00
2.	Accumulation	2785.95	9798.45	16,810.95	23,823.45	30,835.95	37,848.45	140,443.45	321,620.95	328,633.45	335,645.95

Table S4. The economic flow of the project refrigerator recycling—Data used for calculation of CBA criteria.

No	Elements	n-2	n-1	n	n+1	n+2	n+3	n+4	n+5	n+6	n+7	n+8	n+9
I	Total cash-inflow	0	0	3,464,172	3,464,172	3,464,172	3,464,172	3,464,172	3,464,172	3,464,172	3,464,172	3,464,172	4,550,172
1.	Revenue			3,464,172	3,464,172	3,464,172	3,464,172	3,464,172	3,464,172	3,464,172	3,464,172	3,464,172	3,464,172
2.	Residual value of investments												1,086,000
II	Total cash-outflow	650,000	2,973,500	3,096,036	3,089,024	3,082,011	3,074,999	3,067,986	3,060,974	3,070,829	3,114,551	3,107,539	3,130,526
1.	Investment cost	650,000	2,891,000										
2	Operating cost			2,689,515	2,689,515	2,689,515	2,689,515	2,689,515	2,689,515	2,689,515	2,709,515	2,709,515	2,709,515
3	Annuity		82,500	357,500	349,250	341,000	332,750	324,500	316,250	308,000	299,750	291,500	283,250
4	Land clearing costs												30,000
5	Tax			49,021	50,259	51,496	52,734	53,971	55,209	73,314	105,286	106,524	107,761
III	Net cash-flow	−650,000	−2,973,500	368,136	375,148	382,161	389,173	396,186	403,198	393,343	349,621	356,633	1,419,646
	Net present value	272,135											

Table S5. Projected income statement for End-of-Life Vehicles recycling center—Socio-economic CBA—Data used for calculation of CBA criteria.

No	Elements	n	n+1	n+2	n+3	n+4	n+5	n+6	n+7	n+8	n+9
I	Operating income	3,658,433.00	3,699,878.00	3,741,323.00	3,782,768.00	3,824,213.00	3,865,658.00	3,907,103.00	3,948,548.00	3,989,993.00	4,031,438.00
I 1.	Revenues from the sale of	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00	2,189,295.00

	recycled raw materials										
I 2.	Revenue from the sale of used car parts	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00	60,000.00
I 3.	Revenue from recycling incentives	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I 4.	Energy savings (reduced CO2 emissions) **	917,331.00	944,311.00	971,291.00	998,271.00	1,025,251.00	1,052,231.00	1,079,211.00	1,106,191.00	1,133,171.00	1,160,151.00
I 5.	CO2 emission savings *	491,807.00	506,272.00	520,737.00	535,202.00	549,667.00	564,132.00	578,597.00	593,062.00	607,527.00	621,992.00
II	Costs of direct material	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00	1,420,000.00
III	Other business expenses	980,019.00	980,019.00	980,019.00	980,019.00	980,019.00	980,019.00	946,569.00	909,669.00	909,669.00	909,669.00
III 1.	Fuel, lubricant, gas and electricity costs	82,085.00	82,085.00	82,085.00	82,085.00	82,085.00	82,085.00	82,085.00	82,085.00	82,085.00	82,085.00
III 2.	Labor costs (net)	616,084.00	616,084.00	616,084.00	616,084.00	616,084.00	616,084.00	616,084.00	616,084.00	616,084.00	616,084.00
III 3.	Depreciation costs	104,350.00	104,350.00	104,350.00	104,350.00	104,350.00	104,350.00	70,900.00	4000.00	4000.00	4000.00
III 4.	Transport, forwarding, and radiology costs	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00	76,000.00
III 5.	Costs of investment maintenance (fixed assets)	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00	100,000.00	130,000.00	130,000.00	130,000.00
III 7.	Waste disposal costs	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00	1500.00
IV	Operating profit EBIT	1,258,414.00	1,299,859.00	1,341,304.00	1,382,749.00	1,424,194.00	1,465,639.00	1,540,534.00	1,618,879.00	1,660,324.00	1,701,769.00
V	Financial expenses	35,000.00	31,500.00	28,000.00	24,500.00	21,000.00	17,500.00	14,000.00	10,500.00	7000.00	3500.00
VI	Income before taxes	1,223,414.00	1,268,359.00	1,313,304.00	1,358,249.00	1,403,194.00	1,448,139.00	1,526,534.00	1,608,379.00	1,653,324.00	1,698,269.00
VII	Tax (0%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VIII	Net income	1,223,414.00	1,268,359.00	1,313,304.00	1,358,249.00	1,403,194.00	1,448,139.00	1,526,534.00	1,608,379.00	1,653,324.00	1,698,269.00
1.	Loan repayment	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00
2.	Accumulation	1,153,414.00	1,198,359.00	1,243,304.00	1,288,249.00	1,333,194.00	1,378,139.00	1,456,534.00	1,538,379.00	1,583,324.00	1,628,269.00

Note: *[**1**]; **[**1**].

Table S6. The socio-economic flow of the project ELV recycling—Data used for calculation of CBA criteria.

No	Elements	n-2	n-1	n	n+1	n+2	n+3	n+4	n+5	n+6	n+7	n+8	n+9
I	Total cash-inflow	0	0	3,658,433	3,699,878	3,741,323	3,782,768	3,824,213	3,865,658	3,907,103	3,948,548	3,989,993	4,289,438
1.	Revenue			3,658,433	3,699,878	3,741,323	3,782,768	3,824,213	3,865,658	3,907,103	3,948,548	3,989,993	4,031,438
2.	Residual value of investments												258,000
II	Total cash-outflow	140,000	853,000	2,400,669	2,397,169	2,393,669	2,390,169	2,386,669	2,383,169	2,379,669	2,406,169	2,402,669	2,429,169
1.	Investment cost	140,000	818,000										
2	Operating cost			2,295,669	2,295,669	2,295,669	2,295,669	2,295,669	2,295,669	2,295,669	2,325,669	2,325,669	2,325,669

3	Annuity		35,000	105,000	101,500	98,000	94,500	91,000	87,500	84,000	80,500	77,000	73,500
4	Land clearing costs												30,000
5	Tax			0	0	0	0	0	0	0	0	0	0
III	Net cash-flow	−140,000	−853,000	1,257,764	1,302,709	1,347,654	1,392,599	1,437,544	1,482,489	1,527,434	1,542,379	1,587,324	1,860,269
	Net present value	9,266,787											

Table S7. Projected income statement for refrigerator recycling center—Socio-economic CBA—Data used for calculation of CBA criteria.

No	Elements	n	n+1	n+2	n+3	n+4	n+5	n+6	n+7	n+8	n+9
I	Operating income	6,044,687.00	6,192,404.00	6,340,121.00	6,487,838.00	6,635,555.00	6,783,272.00	6,930,989.00	7,078,706.00	7,226,423.00	7,374,140.00
I 1.	Revenues from the sale of recycled raw materials	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00	1,022,335.00
I 2.	Revenue from recycling incentives	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I 3.	Energy savings (reduced CO2 emissions) **	3,626,663.00	3,733,330.00	3,839,997.00	3,946,664.00	4,053,331.00	4,159,998.00	4,266,665.00	4,373,332.00	4,479,999.00	4,586,666.00
I 4.	CO2 emission savings *	1,395,689.00	1,436,739.00	1,477,789.00	1,518,839.00	1,559,889.00	1,600,939.00	1,641,989.00	1,683,039.00	1,724,089.00	1,765,139.00
II	Costs of direct material	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00	1,694,915.00
III	Other business expenses	2,227,128.00	2,227,128.00	2,227,128.00	2,227,128.00	2,227,128.00	2,227,128.00	2,114,678.00	1,909,778.00	1,909,778.00	1,909,778.00
III 1.	Fuel, lubricant, gas and electricity costs	58,635.00	58,635.00	58,635.00	58,635.00	58,635.00	58,635.00	58,635.00	58,635.00	58,635.00	58,635.00
III 2.	Labor costs (net)	1,223,768.00	1,223,768.00	1,223,768.00	1,223,768.00	1,223,768.00	1,223,768.00	1,223,768.00	1,223,768.00	1,223,768.00	1,223,768.00
III 3.	Depreciation costs	365,350.00	365,350.00	365,350.00	365,350.00	365,350.00	365,350.00	252,900.00	28,000.00	28,000.00	28,000.00
III 4.	Transportation costs	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00	300,000.00
III 5.	Gas costs-Nitrogen	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00
III 6.	Electricity costs	69,375.00	69,375.00	69,375.00	69,375.00	69,375.00	69,375.00	69,375.00	69,375.00	69,375.00	69,375.00
III 7.	Costs of investment maintenance (fixed assets)	110,000.00	110,000.00	110,000.00	110,000.00	110,000.00	110,000.00	110,000.00	130,000.00	130,000.00	130,000.00
III 8.	Freon disposal costs	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00	70,000.00
IV	Operating profit EBIT	2,122,644.00	2,270,361.00	2,418,078.00	2,565,795.00	2,713,512.00	2,861,229.00	3,121,396.00	3,474,013.00	3,621,730.00	3,769,447.00
V	Financial expenses	137,500.00	123,750.00	110,000.00	96,250.00	82,500.00	68,750.00	55,000.00	41,250.00	27,500.00	13,750.00
VI	Income before taxes	1,985,144.00	2,146,611.00	2,308,078.00	2,469,545.00	2,631,012.00	2,792,479.00	3,066,396.00	3,432,763.00	3,594,230.00	3,755,697.00
VII	Tax (0%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
VIII	Net income	1,985,144.00	2,146,611.00	2,308,078.00	2,469,545.00	2,631,012.00	2,792,479.00	3,066,396.00	3,432,763.00	3,594,230.00	3,755,697.00
1.	Loan repayment	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00	275,000.00
2.	Accumulation	1,710,144.00	1,871,611.00	2,033,078.00	2,194,545.00	2,356,012.00	2,517,479.00	2,791,396.00	3,157,763.00	3,319,230.00	3,480,697.00

Note: *[**2**]; **[**2**].

Table S8. The socio-economic flow of the project refrigerator recycling—Data used for calculation of CBA criteria.

No	Elements	n-2	n-1	n	n+1	n+2	n+3	n+4	n+5	n+6	n+7	n+8	n+9
I	Total cash-inflow	0	0	6,044,687	6,192,404	6,340,121	6,487,838	6,635,555	6,783,272	6,930,989	7,078,706	7,226,423	8,460,140
1.	Revenue			6,044,687	6,192,404	6,340,121	6,487,838	6,635,555	6,783,272	6,930,989	7,078,706	7,226,423	7,374,140
2.	Residual value of investments												1,086,000
II	Total cash-outflow	650,000	3,028,500	3,969,193	3,955,443	3,941,693	3,927,943	3,914,193	3,900,443	3,886,693	3,892,943	3,879,193	3,895,443
1.	Investment cost	650,000	2,891,000										
2.	Operating cost			3,556,693	3,556,693	3,556,693	3,556,693	3,556,693	3,556,693	3,556,693	3,576,693	3,576,693	3,576,693
3.	Annuity		137,500	412,500	398,750	385,000	371,250	357,500	343,750	330,000	316,250	302,500	288,750
4.	Land clearing costs												30,000
5.	Tax			0	0	0	0	0	0	0	0	0	0
III	Net cash-flow	−650,000	−3,028,500	2,075,494	2,236,961	2,398,428	2,559,895	2,721,362	2,882,829	3,044,296	3,185,763	3,347,230	4,564,697
	Net present value	16,358,967											

The sensitivity analysis performed in Tables 9 and 10 in this paper is a product of the application of Excel`s Goal Seek analysis to the data from Tables S1 to S8.

References

1. Cumbul Altaya, M.; Sivri, N.; Onat, B.; Sahin, U.; Zoraga, M.; Fatih Altay, H. Recycle of metals for end-of-life vehicles (ELVs) and relation to Kyoto protocol. *Renew. Sustain. Energy Rev.* **2011**, *15*, 2447–2451, doi:10.1016/j.rser.2011.02.017.
2. Foelster, A-S.; Andrew, S.; Kroeqer, L.; Bohr, P.; Dettmer T.; Boehme, S.; Herrmann, C. Electronic recycling as an energy efficiency measure—A Life Cycle Assesment (LCA) study on refrigerator recycling in Brazil. *J. Clean. Prod.* **2016**, *129*, 30–42, doi:10.1016/j.jclepro.2016.04.126.