Economic efficiency of plastic recycling plant construction

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Abstract. Solving the problem of plastic pollution is a priority for all of mankind. A significant part of all plastic waste is recyclable and reusable. However, not every method of recycling and reusing plastic is cost-effective. The aim of the study is to justify the economic efficiency of the construction and operation of a plastic recycling plant in the city of Kazan (Russian Federation). When performing the calculations, the discounted method for efficiency assessment of investment projects was used. The method involves the calculation of several efficiency criteria: NPV, IRR, PBP, PI.

The study justifies the economic efficiency of the plant construction project based on the calculated indexes: NPV (net present value of the project) is 182 million rubles, IRR is 41.6%. As a result of risk modeling, it was found out that the greatest impact on the net present value of the project is made by an increase in the discount rate. Moreover, the project is highly resistant to a possible reduction in the price and volume of sales, growth in current and investment expenses. Putting the results into practice opens up potential for solving the complex task of saving natural resources, expanding the local raw material base for the production of building materials, and disposing waste having a long decomposition period, more specifically plastic waste.

Keywords: construction, plastic disposal, efficiency, NPV, project management.

1 Introduction
Plastic pollution is a global environmental problem. 1.6 million tons of waste are generated annually in the Republic of Tatarstan (Russian Federation), of which about 30% is plastic. Only 10% of plastic waste is recycled. The main method for this waste disposal is its storage at special landfills. Currently, the landfills of the Republic of Tatarstan are 80% full, which causes serious environmental, economic, social problems and is a danger to public health. Under the current conditions, the urgent task is the construction of a modern plant for PET bottles recycling in Kazan.

Works of many authors deal with the problem of biocontamination by plastic wastes and their recycling. For example, J. C. Prata notes the need for an integrated approach to the waste management system based on the plastics life cycle [1]. B. Carney Almroth and H. Eggert in their study consider the potential harmful effects of plastic on marine ecosystems and human health [2].

It is necessary to organize properly the collection of PET bottles and their disposal and to recycle the greatest possible volume of them. In almost all large cities of the world for separate collection of plastic containers there are special automatic machines for collecting bottles, which are then sent to the waste recycling plant. The economic and ecological efficiency of reverse vending machines is analyzed by J. Narendra Babu [3].

P. Treenate in the research studies the full life cycle of plastic bottles and concludes that their disposal through recycling is the best way to reduce the environmental impact of plastic compared to burning them [4]. N. A. Rorrer proposes to recycle plastic using biomonomers [5]. Another advanced technique for plastic recycling is described by S. Jaiswal, M. Salvador and D. Danso [6–8]. It consists in the use of microorganisms with a functionally specific gene that is able to decompose plastic.

A. S. Ashoor, M. Alzuhairi, A. F. Ahmad, A. R. Razali suggest using granules obtained from plastic bottles recycling as a modifying additive in asphalt mixes in pavement production [9–12]. This allows improving physical and technical properties of asphalt concrete and increasing the durability of roads.
Alternative uses of crushed recycled plastic are also suggested. For example, I. T. R. Yuliusman offers a method for producing absorbent carbon from PET plastic waste [13]. F. K. Alqahtani and A. Abed showed the possibility of using plastic granules as a concrete aggregate, which improves its thermal conductivity and strength properties [14, 15]. S. Agyeman recommends using cobblestones made from recycled PET bottles in places with non-heavy traffic, for example, for laying pedestrian walkways [16]. P. N. Mazenan conducted a study and concluded that sand aggregate in the manufacture of bricks can be replaced with recycled plastic [17]. According to A. K. Jassim, crushed polyethylene waste can be used to produce plastic cement, which is good for its technical characteristics [18]. Another material obtained from PET bottles is polystyrene, as shown by V. A. Szabó [19]. The study by M. K. J. E. Exconde showed that recycled polyethylene terephthalate is a good alternative material for 3D printer filaments [20]. In addition, the need to convert plastic into new materials, including construction, was presented in the work of P. O. Awoyera [21].

The problem of the need for the collection and disposal of solid waste in the housing and utilities system of the Russian Federation was raised in the article by E.A. Dobroserdova, A.I. Romanova [22]. Y.V. Medyanik notes in her work the urgency for the Republic of Tatarstan (Russian Federation) of the problem of industrial by-products long-term storage at landfills and their further disposal [23].

The performed review allows us to conclude that the possibilities for the future use of recycled plastic materials are extensive. These raw materials will be in demand and will solve not only the environmental problem, but also expand the raw material base for obtaining building materials on its basis.

Thus, we set a goal to justify the effectiveness of the project for the construction of a plastic recycling plant for its final use in the production of asphalt concrete.

2 Methods

When performing the calculations, the algorithm including the following steps was used [24]:

1. input method for calculating the cost of construction, based on the calculation of resources at current prices and tariffs [25];
2. discounted method for efficiency assessment of investment projects:
   - net present value of the project
     \[
     NPV = \sum_{t=1}^{T} \frac{C_t}{(1 + d)^t} - \sum_{t=1}^{T} \frac{I_t}{(1 + d)^t} - I_0 \tag{1}
     \]
     - discounted payback period (PBP);
     - internal rate of return of the project:
     \[
     IRR = d1 + \frac{NPV_{(d1)} - NPV_{(d2)}}{NPV_{(d1)} - NPV_{(d2)}} \times (d2 - d1) > d; \tag{2}
     \]
     - profitability index of the discounted expenses:
     \[
     PI = \frac{\sum_{t=1}^{T} \frac{C_t}{(1 + d)^t}}{\sum_{t=1}^{T} \frac{I_t}{(1 + d)^t} + I_0} > 1 \tag{3}
     \]
     where \(d\) – is a discounting rate; \(C_t\) – is a cash flow in the period \(t\);
     \(I_t\) – expenses in the period \(t\);
     \(I_0\) – initial investment in the project.
3. sensitivity analysis of the resulting project efficiency indexes to a possible increase or decrease in the initial project parameters. There are following initial parameters: price and volume of sales of products, work and services; current expenses; investment expenses; discount rate. The resulting indexes are NPV, PBP, IRR, PI.
3 Results and Discussion
The investigation is concerned with a plastic recycling plant in the territory of Kazan (Russian Federation). The total area of the plant includes a workshop for plastic selection and sorting, a workshop for washing and cleaning containers, a workshop for crushing and granulating flakes and melting them to obtain the granulated material. The raw material for the granulated material manufacture will be plastic extracted from reverse vending machines.

The planned construction period is 2.2 years which was calculated using the software program “Adept: Construction Management” (Table 1).

| No. | Types of work                                    | Overall duration, days |
|-----|-------------------------------------------------|------------------------|
| 1   | Earthwork and foundations                       | 26                     |
| 2   | Framework, floor slabs, ventilation ducts, walls, windows | 480                   |
| 3   | Finishing works and floors                      | 93                     |
| 4   | Roofing                                         | 20                     |

Source: calculated by the authors

Calculations to justify the efficiency of construction were performed using the software program “Alt-Invest. Construction”. The planning time-frame is 6 years. When performing the calculations, the following expenses were taken into account: purchase of a land plot; equipment acquisition costs: optical sorting of PET bottles, a line for recycling PET bottles into granules with a capacity of 1000 kg of granules per hour; cost of construction of a factory building (Table 2).

| No. | Name                                                        | Cost, rubles       |
|-----|-------------------------------------------------------------|-------------------|
| 1   | Land plot                                                   | 50 000 000        |
| 2   | Estimated cost of construction of a factory building, rubles/sq.m. | 10 072            |
| 3   | Optical sorting of PET bottles                              | 4 200 000         |
| 4   | Line for recycling PET bottles into granules                | 37 000 000        |

Source: calculated by the authors

At the stage of plant operation, the following expenses were taken into account: the purchase of plastic, payment of salary to the employees, current expenses which are utility payments and management expenses, building insurance expenses. Key performance indicators are given in Table 3.

| No. | Name                                                        | Cost, rubles       |
|-----|-------------------------------------------------------------|-------------------|
| 1   | Purchase of PET bottles, per kg.                            | 13                |
| 2   | Salary costs (including insurance payments), per quarter.   | 2 258 335         |
| 3   | Utility payments and management expenses, per quarter.      | 8 790 120         |
| 4   | Factory building insurance, per quarter.                    | 409 897           |
| 5   | Plastic granules selling price, per kg.                      | 95                |

Source: calculated by the authors

Production output, which will amount to 960,000 kg of plastic granules per quarter, will begin immediately after the completion of construction, i.e. in 2.2 years. The recycled granules are planned to be sold at the price of 95 rubles per 1 kg. Ensuring the operation of the plant is assigned to the staff consisting of 32 people.

After calculating the required level of investment and planned income, the results of the project for the construction and operation of a plastic recycling plant were obtained (Table 4).
**Table 4. Efficiency indexes of full investment expenses**

| No. | Name                                      | Values                  |
|-----|-------------------------------------------|-------------------------|
| 1   | Annual discount rate                      | 18 %                    |
| 2   | Net present value (NPV)                   | 181,952,571 rubles      |
| 3   | Internal rate of return (IRR)             | 41.6 %                  |
| 4   | Profitability index of the discounted expenses (PI) | 1.79            |
| 5   | Discounted payback period (PBP)           | 4.13 years              |

Source: calculation tables from a software program “Alt-Invest. Construction” (calculated by the authors)

In the work project risks modeling was carried out including sensitivity analysis of NPV to a possible negative change of the initial indexes. Discount rate, price and volume of sales, current and investment expenses were chosen as initial indexes. The results of the risk modeling are shown in Table 5.

Thus, the project for the construction and operation of a plastic recycling plant is socially significant and cost-effective, since all efficiency indexes satisfy the requirements. Moreover, the greatest impact on the net present value of the project is made by an increase in the discount rate. According to other the initial indexes the project is highly stable.

**Table 5. Risk modeling**

| No. | Index name                                      | Values                  |
|-----|------------------------------------------------|-------------------------|
| 1   | Discount rate, %                                | 18 23 28 33 38 43      |
| 2   | NPV, million rubles                             | 182 127 83 47 18 -6    |
| 3   | Selling price, % from the planned amount        | 100 90 80 70 60 50     |
| 4   | NPV, million rubles                             | 182 127 73 18 -37 -92  |
| 5   | Volume of sales, % from the planned amount      | 100 90 80 70 60 50     |
| 6   | NPV, rubles                                     | 182 137 91 46 0,5 -45  |
| 7   | Current expenses, % from the planned amount     | 100 150 200 250 300 350|
| 8   | NPV, million rubles                             | 182 94 6 -82 -171 -269 |
| 9   | Investment expenses, % from the planned amount | 100 120 140 160 180 200|
| 10  | NPV, million rubles                             | 182 140 99 57 15 -27   |

Source: calculated by the authors

4 Conclusions

In the work, there was a review of various ways of recycling and reuse of plastic waste, in addition calculations were made to justify the economic efficiency of investments in the construction of a plant for its recycling. The results obtained allow making the following conclusions:

1. The project of a plastic waste recycling plant construction is a relevant solution to the environmental problem in the region, in addition, it is socially significant and cost-effective.
2. The production volume of the plant will amount to 960,000 kg of plastic granules per quarter, which will make it possible to obtain the income of 91.2 million rubles from the sale.
3. The discounted payback period of the project is 4.13 years. The internal rate of return is 41.6 %.
4. The proposed investment project is highly resistant to a possible reduction in the price and volume of sales, growth in current and investment expenses.
5. Plastic recycled into granule is supposed to be used in the road construction of the Republic of Tatarstan (Russian Federation), which will solve the complex problem of saving natural resources and recycling plastic waste in the production of building materials.
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