Evaluation of investments in recycling centres for construction and demolition wastes in Brazilian municipalities

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Accepted 22 September 2006

Abstract

There are very few construction and demolition (C&D) waste recycling centres in Brazil. To encourage the building and operation of new units, data were collected and analysed relating to C&D waste management and recycling in Brazil. Based on the results of this analysis, a conceptual model is presented for conducting viability studies of future C&D waste recycling centres.

Applying this model to verify the viability of private recycling centres, the results show that under current market conditions in Brazil, C&D waste recycling centres are not financially feasible based solely on revenue from the sale of processed products. Nevertheless, under the same market conditions, the recycling centres could be economically viable for public authorities depending on the particular circumstances of each municipality. The feasibility, however, depends on continuity and the production volume reached.

The conceptual model, the results of its applications and the discussions about the experiences of existing centres can strongly support public authorities and private initiatives in their decision-making about investments in Brazil and in other developing countries.

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1. Introduction

In 2000, according to IBGE (2000), 99.4% of Brazilian municipalities had some public collection of domestic waste, but only 33.1% of the municipalities had 100% of their housing units attended with public waste collection. A daily production of 150,000 t of solid waste represented approximately 0.90 kg per inhabitant. For the sake of comparison, Germany (in 2000) had a daily generation per capita of 0.90 kg, USA (in 2004), 2.0 kg and Canada (in 2004), 1.7 kg (Boranga, 2005; Calderoni, 2004).

In Brazil, 21.3% of the disposal of collected domestic waste was in waste dumps, without protection to prevent environmental impacts on the neighbourhood. Besides, only 5.5% of all collected domestic waste was sent to other destinations (such as composting plants, incineration and recycling plants). This means that 94.5% of collected domestic waste was sent to waste dumps or to landfill sites and just a part (5.5%) of the remainder was recycled (IBGE, 2000).

There is still no detailed information about the quantity of C&D (construction and demolition) waste produced in Brazil, but some large cities, such as São Paulo, Rio de Janeiro and Salvador, have specific estimates. In these three cities, the average C&D waste production was 0.49 kg per inhabitant/day, corresponding to around 31% of the total collected domestic waste (Nunes, 2004).

According to Ingalls (2000), C&D waste in the USA was between 15% and 30% of the collected waste disposed in landfill sites. It was estimated that in 1996, 136 million t of C&D waste (except for wastes from road and bridge construction and excavations) were produced daily in the USA, which represented approximately 1.27 kg per inhabitant. In the USA, 3500 C&D waste recycling centres processed between 20% and 30% of this produced C&D waste (EPA, 2000).

In EEA (2002) information is given about C&D waste recycling in some European countries. Denmark, Germany and Holland recycle more than 80% of the C&D waste pro-
ducéd; Finland, Ireland and Italy recycle between 30% and 50% and Luxembourg only 10%.

Among the 5507 Brazilian municipalities, only 11 (0.2%), besides the Federal District, have C&D waste recycling centres. Thirteen centres (of which seven are operating, one is restarting the operation and five have stopped operating) are stationary plants and recycle part of the C&D waste produced in local communities. It can, therefore, be concluded that a large part of the C&D waste produced in Brazil is not recycled.

Nonetheless, this situation is changing. Since the publication of CONAMA\textsuperscript{1} Resolution no. 307, dated 5th July 2002, all Brazilian municipalities are obliged to prepare and implement strategies for sustainable management of C&D waste (MMA, 2002). In the justifications for this resolution, mention was made of the feasibility of the production and use of C&D waste materials. However, there has been relatively little research in Brazil to prove the technical and economic viability of C&D waste recycling centres.

Results of economic viability analyses for C&D waste recycling facilities in the USA, India and Taiwan were quoted in some studies, but few details about the methodology used and data collection were presented (MACREDO, 2006; TIFAC, 2006; Huang et al., 2002). Kohler (1997) showed economic results of some German facilities, which incorporate a significant number of machines, in contrast to the simple C&D recycling facilities common in countries such as Brazil, India, Taiwan and Denmark (Nunes, 2004; TIFAC, 2006; Huang et al., 2002).

This study was carried out with the objective of compiling data relating to C&D waste management and recycling in Brazil. The data was then evaluated and a conceptual model for financial viability studies of C&D waste recycling centres proposed. The model was applied to determine the feasibility of private recycling centres in Brazil. In addition, the economic viability of existing recycling centres was examined, as well as the reasons for the successful and the unsuccessful experiences.

2. Viability analysis: concepts

The decision to set up a recycling centre should only be made if its economic and financial viability can be proven in a pre-project analysis that covers, among other aspects, the location of the plant, market studies, initial contacts with local public authorities to clarify possible requirements and consultations for the licensing of the facility (Kohler, 1997).

UNIDO (1987) presents a structural model for conducting viability studies of complex projects, involving large investments from various sources of financing. Simplifying this structure and adding the elements described by Kohler (1997), the essential stages in pre-viability studies of C&D waste recycling centres were identified, as follows:

- a. Market and competition analysis;
- b. Estimated generation of C&D waste;
- c. Estimated revenues and costs;
- d. Analysis of investments; and
- e. Breakeven point.

These elements form a conceptual model for viability studies for C&D waste recycling centres. Stages (a) and (b) depend on the geographic location of the centre. Since a location for the recycling centre project is not always specified when preliminary studies are being conducted, the viability study that has been carried out in this study only includes the other stages: estimated revenues and costs (a stage that is also influenced by location, but only partially), analysis of investments and breakeven point.

It should be emphasised that, once the region is chosen in which a certain centre will be constructed, it is essential that the first two stages be included in the viability studies, as well as the estimated revenues and costs, which depend on location (e.g., cost of land and transport and waste disposal costs).

3. Methodology

The data collection involved four activities. Initially, a bibliographic review was carried out. Then, a number of professionals from the sector were consulted (such as equipment and material suppliers, businessmen from the mining and recycling sectors and producer federations), who were qualified to provide essential data about C&D waste recycling. The data on the thirteen Brazilian C&D waste recycling centres were obtained through questionnaires sent to municipalities and visits to some of the municipalities and facilities. Most of the data were collected between January and November 2003.

This phase of the research showed that there are no large-scale private C&D waste recycling centres in Brazil. As a result, the remainder of the study was divided into two parts. One study, aimed at private enterprise, estimated the costs for future C&D waste recycling centres, one on a small scale and the other medium scale, with data collected in the market. The scenario technique with alternating hypotheses was used in this analysis, providing results through the Net Present Value method (NPV), which indicated under which conditions the facilities studied would be viable.

In a second study concerned with the public arena, actual data was used in the financial viability analysis. Input data was obtained from the management of existing recycling centres to compare costs and benefits.

4. Conceptual model: comparison between operating privately run and state run recycling centres

Economic and financial viability studies are usually conducted in the case of private recycling centres (not financed by the state). Public recycling centres, however, are often...

\textsuperscript{1} Brazilian Environmental Protection Agency.
built without an in-depth analysis of economic and financial viability. The decision-making criteria of public authorities (improvement of social living conditions, regional economic development, environmental protection, etc.) differ from the criteria used by private enterprises, which are essentially based on financial return (Motta and Caloba, 2002; UNIDO, 1987).

During the data collection of the existing public waste recycling centres, it was observed that all of them were built on municipal land. Therefore, there was no investment in the acquisition of the land for the recycling centres. It was also found that some equipment, such as loaders and dump trucks, were not considered investments because they were on loan from other municipal bodies or were leased.

In the viability study for private enterprise recycling centres, the investments in procurement of land and equipment must always be considered. In a study for public recycling centres, the investments in equipment should be taken into account, even when they are not always allocated to the centre.

Municipalities can consider in the viability analysis some benefits of recycling facilities, such as savings in C&D waste disposal and transport to landfills, and savings in material procurement.

5. Results 1: Financial viability study for private enterprise recycling centres

5.1. Introduction

According to Peng et al. (1997), “the true success of a C&D recycling operation must be determined by establishing the scale of the operation to be implemented and its resulting economics”. The consultations of professionals in the sector in Brazil showed that private projects with less than 20 tonnes per hour (t/h) of C&D waste processing flow will probably not be financially viable, due to low productivity and low prices of the processed product. It was also found that a centre with a nominal processing capacity of about 50 t/h would have implementation and operational costs equivalent to those of a 100 t/h centre.

Therefore, it was concluded that two different recycling centre projects needed to be analysed: one on a small scale (20 t/h) and the other medium size (100 t/h). It was also assumed that, due to the lack of tradition in the use of processed products, as well as the lack of a C&D waste recycling project in the country, the viability of future private recycling centres will initially be somewhere between the two capacities above.

According to MACREDO (2006), for C&D waste recycling in the USA to be economically feasible, it has to be high-volume. In the American equipment market the major C&D debris processing facilities have daily capacities that range from less than 50 t to more than 2500 t.

The technology adopted in Brazil for the recycling of C&D waste is simple and labour intensive. In those projects, the required equipment processes only the mineral fractions and a magnetic component removes the metallic fraction. The other fractions, excluding the mineral and metallic ones, are previously removed by hand before the beginning of the crushing process. Table 1 shows the main stages in the recycling process of the Brazilian facilities, the main equipment used in this process and additional equipment.

Nunes (2004) presents the physical compositions of C&D wastes of three large Brazilian cities (São Paulo, Rio de Janeiro and Salvador) and one medium size city (São Carlos). Among these four cities, the sum of mineral fractions (compound of materials such as concrete, bricks and mortar) in the C&D waste was 96% on average (Salvador had the lowest value at 94%). Research on national averages for physical compositions are still not available, but as these cities use construction materials and building processes that are widespread in the urban areas of Brazil, a national average is probably close to the averages of the aforementioned cities. Of the Brazilian population, 81% live in urban areas (IBGE, 2000).

5.2. Estimate of costs

5.2.1. Fixed capital investment

The equipment used in C&D waste recycling centres requires substantial investment. Since the used equipment market, based on the mining sector, is strong in Brazil, this was taken into account in the analysis. Table 2 illustrates in a summarised form the fixed capital investments necessary for C&D waste recycling process and secondary operations.

Table 1
C&D waste recycling process and secondary operations*

<table>
<thead>
<tr>
<th>Stages</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>C&amp;D waste recycling process</td>
<td></td>
</tr>
<tr>
<td>Planning of granulometric profile</td>
<td>Computer, office and instruments</td>
</tr>
<tr>
<td>Reception of trucks and measurement of weight and volume</td>
<td>Scale (for production around 100 t/h) and instruments</td>
</tr>
<tr>
<td>Truck guided to unloading point</td>
<td>- Tools and mechanical excavator</td>
</tr>
<tr>
<td>Unloaded material inspected; unusable large-scale and contaminated material removed</td>
<td>Mechanical excavator, conveyer belt and vibrating belt feeder</td>
</tr>
<tr>
<td>Material sent to secondary separation line, where it is cleaned</td>
<td>Conveyer belt</td>
</tr>
<tr>
<td>Material sent to storage pile</td>
<td>Vibrating grid, conveyer belt, conical crusher and vibrating sieve</td>
</tr>
<tr>
<td>Material crushed and classified</td>
<td>Conveyer belt</td>
</tr>
<tr>
<td>Product sent to storage pile</td>
<td></td>
</tr>
<tr>
<td>Additional equipment</td>
<td></td>
</tr>
<tr>
<td>Crushing, transport and classification</td>
<td>Particle control pulverising system</td>
</tr>
<tr>
<td>Operation of wheeled equipment</td>
<td>Workshop, lubrication and fuel tank</td>
</tr>
<tr>
<td>Secondary operations</td>
<td></td>
</tr>
<tr>
<td>Handling of stock</td>
<td>Dump truck</td>
</tr>
<tr>
<td>Freight</td>
<td>Dump truck</td>
</tr>
</tbody>
</table>

* Basically for processing mineral and metal fractions.
for 20 t/h and 100 t/h recycling centres, according to production volumes and choice of new or used equipment.

5.2.2. Operational Costs

Table 3 summarises the fixed and variable operational costs of 20 t/h and 100 t/h recycling centres. The fixed costs include costs for labour, energy, maintenance, depreciation, insurance, sales, consulting, interest and financing. The variable costs refer basically to costs of spare parts and fuel. This data gives the operational costs used in the financial analysis carried out in Section 5.3.

5.3. Investment analysis

5.3.1. The scenarios

The comparison methods between alternative investments can be grouped into static and dynamic methods. The dynamic methods differ from the static methods due to time factors in the inputs and outputs of the cash-flows by the use of interest rates. When properly used, the dynamic methods are one of the best tools for decision-making in Economic Engineering. The method used in the financial analysis of this research was the Net Present Value (NPV) that is one of the most frequently used dynamic methods. Besides the NPV, the scenario technique is also applied in the analysis. This technique allows, in a financial analysis, the estimate of favourable and unfavourable results under the considerations of the occurrence of different hypotheses (Alexander, 1997; Motta and Caloba, 2002).

Eight scenarios were used in the analysis, based on three hypotheses:

a. Nominal capacity: 20 t/h or 100 t/h;
b. Equipment: new or used;
c. Revenue from acceptance of C&D waste: yes or no.

Hypotheses (a) and (b) have already been discussed. Hypothesis (c) refers to charging of users (generators, transporters and public authorities), a so-called “gate fee”, for each tonne of waste delivered to the centre. In addition to the above three, another two hypotheses were included:
d. Is the cost of land included?
e. Are transport and waste disposal costs included?

In the simulated scenarios, the answers to (d) and (e) were taken to be negative, since the corresponding estimates depend on the location of the project, which is not defined in the viability study done in this research. It must be considered that when these costs are included, the overall costs of the project increase and the viability of the project is affected. So, the results obtained by the simulation of this research, which do not include all the possible costs, would be worse should all costs be considered.

When the scenario includes revenue from the acceptance of C&D waste, a financial simulation based on spreadsheets is used to estimate the lowest gate fee or price that can be charged per tonne (among the conditions of each scenario) to allow the project to be financially viable. This happens when the financial analysis results in a NPV of zero for the specific rate of return.

According to companies that produce finished products and employee federations from the area, the price of the processed C&D product is a direct function of the conventional product market. The hypothesis adopted in this research was that the price of the processed product should be at least 30% lower than the price of the conventional product. Since the average price of the product for use as base and sub-base materials for road building in Rio de Janeiro is currently US $4.00/t (not including taxes or freight) (SINDIBRITA, 2003), it is estimated that the price of the processed product should be around US $3.00/t (not including tax or freight).
The percentage of rejects in C&D waste processing is assumed to be 20%\(^3\). This percentage is not significant in the eight scenarios discussed here, since transport and other waste disposal costs associated with these rejects were not included. The production volume of the product was assumed to be 80% of the nominal equipment capacity, as usual in industrial projects.

5.3.2. Results of the analysis

Using an annual interest rate of 12%, after tax (the minimum value to be expected in the current Brazilian financial situation) the results for the eight scenarios mentioned in Section 5.3.1 are given in Table 4. The negative results of the even-numbered scenarios show that C&D waste recycling centres under current market conditions are not financially viable. Recycling centres fail to become financially viable solely through revenue from the sale of processed products. The results are more negative if the price of land and waste disposal costs are taken into account. For recycling centres to become viable under current conditions, other sources of funds are indispensable, such as revenue from the acceptance of C&D waste, tax benefits or other public subsidies.

Charging gate fees for the acceptance of C&D waste creates an additional option for revenue. Table 4 shows that in the scenarios that include the charge, the best results (lowest price paid per tonne to make the project viable) are those of scenarios 5 and 7, with prices of US $0.40/t if second-hand equipment is used and US $0.60/t if new equipment is employed, respectively, for 100 t/h recycling centres.

For the 20 t/h recycling centres in scenarios 1 and 3 to be viable, much higher prices are needed (US $2.52/t with second-hand equipment and US $2.89/t with new equipment) than in scenarios 5 and 7. This indicates that a greater production of the processed product facilitates the financial viability of the recycling centres.

These results prove the previously adopted premise: the financial viability of privately run recycling centres with processing capacities less than 20 t/h will probably be negative, due to low production and low prices of processed products. It was found that even 100 t/h recycling centres need to charge an acceptance price to have a positive cash flow.

5.4. Breakeven point

The breakeven point (BP) is the point at which total sales revenue and production costs are financially equal. In the case herein, the BP will be defined in terms of tonnes produced. Assuming that users (private or public) will pay the value fixed by the recycling centre, it is estimated that the BP in scenarios 1, 3, 5 and 7, will be reached at prices of US $1.67/t and US $3.33/t; recycling centres processing 20 t/h will not reach the BP at the price of US $1.67/t. Larger, 100 t/h recycling centres reach their BP around 110,000 t (production obtained from 65% of days worked per year\(^4\)). By charging US $3.33/t, 20 t/h recycling centres reach their BP with a production of 27,000 t (production obtained from 80% of days worked per year), while 100 t/h recycling centres reach their BP at 78,000 t (production obtained from 45% of days worked per year).

In India, a feasibility analysis has been carried out for a recycling plant to process 25,000 t/y for mineral fractions of the C&D waste. According to TIFAC (2006), “due to market preference of the customers to use natural aggregate, recycled aggregates have to be marketed at a discount to achieve sale of 25,000 t/y in 2/3 years time. The unit is viable but its operations highly sensitive to fluctuations in sale price of recycled aggregate and capacity utilisation of the plant”.

In Germany, because of such aspects as the high fixed capital investment and planning permits, C&D waste facilities can be economically viable only from a production of around 200,000 t/y (around 800 t/d) or more (Kohler, 1997).

6. Results 2: financial viability study for public recycling centres

6.1. General information about the recycling centres under study

Some of the recycling centres included in this study had ceased operations for some time (weeks, months or years) due to a variety of reasons, such as changes in municipal recycling policy, cuts in municipal budgets, theft, vandalism of facilities, or problems with local communities.

As can be seen from the age of equipment and time operating columns in Table 5, the recycling centres that have been operating continuously since their start-up are recycling centres E, H, I, K and M. The recycling centres that have been most idle are C, D, F and L. The ratio between age of equipment and time operating is 0.59, meaning that the equipment is halted for an average of 41% of the normal operating time.

Excluding the five recycling centres not in operation and the recycling centre that is restarting production operations, the ratio of (installed) capacity and (current) production for the seven active recycling centres is 0.55, meaning that the operating recycling centres only use an average of 55% of their installed capacity.

\(^3\) The mathematical average of the wastage found in ten of the recycling centres researched. The other three centres did not provide this figure (Nunes, 2004).

\(^4\) Considering 264 working days per year.
6.2. Estimate of costs and revenues

Despite sending questionnaires and visiting C&D waste recycling centres, not all data required for this research was obtained, especially cost-related data. In some cases the reason appears to be that because the centres were run by public authorities, cost control in the majority of recycling centres is not seen to be important.

In other centres, since the operation is outsourced, some contract managers were not willing to provide costs for commercial reasons. In addition, some of the data received from recycling centres was incomplete and contained errors. To deal with these problems, some information had to be estimated based on comparisons with other similarly sized recycling centres. The investment of costs and revenues consists of fixed capital investments, operational costs, and revenues and savings.

6.2.1. Fixed capital investment

When information was being collected during the first stage of this research, it was found that items such as loaders and dump trucks were not included in some of the fixed capital investments supplied by municipalities, since they were loaned from other municipal bodies or were leased. In order to standardise this information, the cheapest possible nominal purchase of used equipment was added to the fixed capital investments. The corrections were presented in Table 6. All recycling centres researched are located on municipal land. Therefore, investment in land procurement was not included.

The investment average of US $12,500/t investment in installed capacity is obtained by dividing the totals of municipal fixed capital investments by the installed capacity in the recycling centres. This average is within the interval of values obtained for installed capacity in new projects (Table 3) of US $16,770/t (20 t/h capacity – new equipment) and US $8,170/t (100 t/h capacity – new equipment).

6.2.2. Total operational costs

Table 7 shows the total operational costs of production estimated for existing recycling centres. As can be seen in Table 3, according to quotations made in the market, the annual operating costs for 20 t/h recycling centres are US $189,467, compared to US $685,780 in the case of 100 t/h recycling centres (both using new equipment). These costs are above those found for the recycling centres under study. The reason for this may be that, despite the extra costs, these costs were still insufficient to represent actual operational costs of the recycling centres under study.

In addition, since they are functioning below their capacities, operating recycling centres have lower operational costs that those operating at full production. Furthermore, the historical data obtained for halted facilities could be out of date or under-reported.
An average unit cost of US $4.47/t is obtained for the thirteen recycling centres by dividing the total production costs, shown in Table 7, by the production capacity. However, dividing total production costs by actual production results in a real average unit cost of US $14.40/t. It can be seen that the average of real unit costs is approximately 225% higher than the average unit costs for a scenario involving the operation of recycling centres at full capacity. It also should be taken into account that for the production of C&D waste recycling centres to have outlets, the maximum price of the processed product must be around US $3.00/t (not including freight or taxes). The costs found are above this value.

6.2.3. Revenues and savings

According to Kartam et al., 2004, “the economics of recycling has to be viewed in relation to the cost of alternative waste management options such as landfilling and incineration. The cost of virgin raw materials ... is another important factor for the economic attractiveness of recycling”.

Concerning the revenues and possible savings for owners (municipal governments), the most significant are revenues from the sale of processed products, savings in C&D waste disposal, and transport and savings in procurement of material.

6.2.3.1. Revenues.

Only three C&D waste recycling centres sell processed products to private clients, although the quantities sold are tiny. Facility E sold around 1500 m³ of processed product between July 2002 and June 2003, at an average price of US $0.80/m³, including freight. Total revenues in those 12 mo were US $1200. In recycling centres H and I, processed products could be obtained for US $0.50/t (US $0.80/m³), not including freight. The total sales of these recycling centres were not available.

6.2.3.2. Savings in C&D waste disposal and transport to landfills.

Table 8 contains information on approximate distances from centres of municipalities, landfills and recycling centres. In some cases, the recycling centres are closer to the centres of municipalities than to landfills. This means that by directing C&D waste to these recycling centres, municipalities are saving on transport.

The table also contains landfill disposal costs in some of the municipalities under study. These costs vary from US $3.00/t to US $40.00/t. Adding transport costs⁶ and comparing them with production costs (average of US $14.40/t), it can be concluded that for some municipalities C&D waste processing can be advantageous based on the cost savings on transport and landfilling alone.

6.2.3.3. Savings on acquisition of materials.

Table 9 shows the annual savings that municipalities would obtain

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Table 5

General information about recycling centres

<table>
<thead>
<tr>
<th>Recycling centres</th>
<th>Commencement date</th>
<th>Age of equipment (Years)</th>
<th>Time operating (Years)</th>
<th>Capacity (t/h)</th>
<th>Capacity (t/day)b</th>
<th>Current production:Statusc</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1991</td>
<td>13</td>
<td>7</td>
<td>100</td>
<td>800</td>
<td>Halted</td>
</tr>
<tr>
<td>B</td>
<td>1996</td>
<td>8</td>
<td>6</td>
<td>40</td>
<td>320</td>
<td>Halted</td>
</tr>
<tr>
<td>C</td>
<td>1996</td>
<td>8</td>
<td>1</td>
<td>40</td>
<td>320</td>
<td>Halted</td>
</tr>
<tr>
<td>D</td>
<td>1997</td>
<td>7</td>
<td>1</td>
<td>15</td>
<td>120</td>
<td>Produces an average of 170 t/d⁵</td>
</tr>
<tr>
<td>E</td>
<td>2001</td>
<td>3</td>
<td>3</td>
<td>10</td>
<td>80</td>
<td>Produces an average of 10 t/d⁵</td>
</tr>
<tr>
<td>F</td>
<td>1999</td>
<td>5</td>
<td>0.25</td>
<td>15</td>
<td>120</td>
<td>Re-starting operations</td>
</tr>
<tr>
<td>G</td>
<td>2002</td>
<td>2</td>
<td>1</td>
<td>25</td>
<td>200</td>
<td>Produces an average of 30 t/d⁵</td>
</tr>
<tr>
<td>H</td>
<td>1995</td>
<td>9</td>
<td>9</td>
<td>40</td>
<td>320</td>
<td>Produces an average of 210 t/d⁵</td>
</tr>
<tr>
<td>I</td>
<td>1996</td>
<td>8</td>
<td>8</td>
<td>40</td>
<td>320</td>
<td>Produces an average of 210 t/d⁵</td>
</tr>
<tr>
<td>J</td>
<td>1994</td>
<td>10</td>
<td>n.a.</td>
<td>15</td>
<td>120</td>
<td>Halted</td>
</tr>
<tr>
<td>K</td>
<td>2001</td>
<td>3</td>
<td>3</td>
<td>40</td>
<td>320</td>
<td>Produces an average of 100 t/d⁵</td>
</tr>
<tr>
<td>L</td>
<td>2001</td>
<td>3</td>
<td>0</td>
<td>40</td>
<td>320</td>
<td>Halted</td>
</tr>
<tr>
<td>M</td>
<td>2000</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>64</td>
<td>Produces an average of 32 t/d⁵</td>
</tr>
</tbody>
</table>

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⁵ For recycling centres that are halted, the costs refer to the 12 mo before production was stopped.

⁶ Transport costs can be considered to be US $0.073/(m³ km) (SINDIBRITA, 2003).
through the acquisition of processed road building materials, assuming that the recycling centres were working at planned capacity. The average price of these products is US $4.00/t (not including taxes or freight). It should be noted that in eight of the thirteen recycling centres the possible savings from materials are higher than the operational costs. In the other five, the values are lower, although still significant.

6.2.3.4. Other savings and intangible benefits. Besides the savings and the revenues from C&D waste recycling centres that were estimated (either fully or partially), there are other benefits from these facilities, which are difficult to measure and quantify in financial terms, including (Nunes, 2004):

- motivation of local inhabitants to use the solutions offered for disposal of C&D waste, avoiding illegal disposal (such as cleaning and environmental restoration);
- less need for locations for C&D waste disposal, increasing the working life of inert and domestic waste landfills;
- reduction in environmental impact of extraction, transport and processing of natural resources; and
- improvement in municipal public image.

6.3. Investment analysis

Operating below their capacities, existing recycling centres are losing the opportunity of reducing production costs. In the case of halted recycling centres, there is bad use of public investment. The main reasons for this low utilisation are changes in municipal recycling policy, cuts in municipal budgets, low demand for C&D recycled products (weak sales and marketing strategies), maintenance failures, equipment theft, vandalism of facilities and problems with local communities.

For municipalities, the most significant revenues and savings from recycling centres are revenues from the sale of processed product, savings in procurement of materials and savings in C&D waste disposal and transport.

It was found that for some municipalities, C&D waste recycling can be advantageous, even in relation to savings on transport and landfilling only. Besides, in most of the analysed municipalities, possible savings from use of processed products are higher than the operational costs of the recycling facilities.

7. Comparison between results 1 and results 2

The case studies analyzed show that the majority of recycling centres in Brazil have been badly administered by public authorities (weak cost control, idle recycling
plants, and so on). This situation and its consequences on the performance of the facilities have to be taken into account by municipalities in future investment analyses.

Municipal managers also need to evaluate whether it is economically more viable for public authorities to be the administrators of these recycling centres or to let them to be privately run. An option can also be public-private partnerships, where governments and private sector work together, which are becoming popular in Europe (UNECE, 2006).

The introduction of recycling incentives can benefit the financial viability of private recycling centres. The potential consumption of processed products by local and government markets has to be estimated, while municipalities can make contact and establish partnerships with neighbouring municipalities, state and federal governmental organisations and with the private sector. The technical and financial viability of actions must always be key decision criteria.

### Table 8

<table>
<thead>
<tr>
<th>Recycling centres</th>
<th>Approximate distances between Landfill disposal costs</th>
<th>Collection and transport costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Centre-recycling centre</td>
<td>Centre-landfill</td>
</tr>
<tr>
<td>A</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>B</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
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</tr>
<tr>
<td>D</td>
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<td>20.0</td>
</tr>
<tr>
<td>E</td>
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<td>40.0</td>
</tr>
<tr>
<td>F</td>
<td>6.0</td>
<td>10.0</td>
</tr>
<tr>
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<td>3.0</td>
<td>n.a.</td>
</tr>
<tr>
<td>H</td>
<td>10.0</td>
<td>12.0</td>
</tr>
<tr>
<td>I</td>
<td>15.0</td>
<td>12.0</td>
</tr>
<tr>
<td>J</td>
<td>10.0</td>
<td>8.0</td>
</tr>
<tr>
<td>K</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>L</td>
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<td>n.a.</td>
</tr>
<tr>
<td>M</td>
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</table>

* n.a.: information not available.

### Table 9

<table>
<thead>
<tr>
<th>Recycling centres</th>
<th>Installed capacity (t/h)</th>
<th>Annual estimated production of project (10^3 t/year)</th>
<th>Annual operational costs (10^3 US$)</th>
<th>Savings (10^3 US$)</th>
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<tr>
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</tr>
<tr>
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<td>25.3</td>
<td>176.3</td>
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<tr>
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<td>10</td>
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<td>136.3</td>
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<td>F</td>
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<td>25.3</td>
<td>144.9</td>
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8. Conclusions and recommendations

The CONAMA Resolution no. 307 obliges all Brazilian municipalities to prepare and implement strategies for the sustainable management of C&D waste. In the justifications for this resolution, mention was made of the economic feasibility of the production and use of C&D waste materials. However, there is little research in Brazil to confirm it.

This work was divided into two parts. One study, aimed at private enterprise, estimated the costs for future C&D waste recycling centres. In a second study, concerned with the public area, real data was used in the analysis of financial viability.

It could be concluded that the C&D waste recycling centres operating under current Brazilian market conditions are not financially viable for private enterprises. Revenue from the sale of the processed product alone is not enough to make these recycling centres viable. It is suggested that other sources of revenue be sought, such as charging for acceptance of C&D waste in recycling centres and the reduction in taxes and loans at lower rates than practised in the market.

C&D waste recycling centres can be economically viable for public authorities under current market conditions depending on the particular circumstances of each municipality (landfill disposal costs, transport costs from C&D waste to landfills and price of acquisition of natural products). The viability, however, also depends on continuity of operation and the production volume reached in the recycling centres.

The unsuccessful experiences of the public authorities with the administration of C&D waste recycling facilities must be considered by municipalities in their investment analysis. It should be evaluated whether it is more economically viable for public authorities to be the administrators of these recycling centres or to allow them to be privately run.

Please cite this article in press as: Nunes, K.R.A. et al., Evaluation of investments in recycling centres for construction ..., Waste Management (2006), doi:10.1016/j.wasman.2006.09.007
Since the use of recycled products is still not widespread in Brazil, investments in large-scale recycling centres with complex facilities will have more chances of failure compared to simpler ones.

The study was carried out in Brazil, but the proposed conceptual model for financial viability studies of future C&D waste recycling centres can be applied to other countries. The conclusions and perspectives that result from the analysis of the existing Brazilian centres can also strongly support public authorities and private enterprise in decisions about investments in Brazil and other countries.

References