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Managing Waste Through Managing People

Manfred Fehr

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1. Introduction

The status of the landfill

Municipal waste management policies to this date are constructed around the all important central facility: His Majesty The Landfill. Depending on the locally applied technology, there are all kinds of landfills. Some of them receive bio-waste and operate as anaerobic digesters, some collect the methane produced and burn it in flares, and others compress the methane to run gas or steam turbines. In recent times, in many parts of the world, bio-waste has to be treated in windrows before being tipped. In the developing world, a distinction is still made between open dumpsites, controlled landfills and sanitary landfills. Technical experience and local policies are dynamic. Both thrive on scientific accomplishments and are constantly on the move. In a developing country setting, the municipal administrator may be proud of having transformed his or her dumpsite into a landfill that receives all urban garbage without any methane capture. At the same point in time, the municipal administrator in an industrialized country is no longer allowed to tip bio-waste at his or her landfill and has to find next generation treatment or destinations for it. This author has even seen settings where methane capture facilities and steam turbines are being installed now at a landfill site, only to remove the methane originating from past deposits, because tipping of bio-waste has been legally banned.

Apart from the great variety of landfills, there is a great variety of urban waste compositions. Bio-waste represents approximately 30% of city garbage in the industrialized world, whereas it reaches the order of 70% in the developing world. It is easy to see the wide spread of challenges posed by the necessity of adequately "managing" this part of the garbage [1].

Landfill research has been concerned with correct location, construction and operation of the sites [2]. This is the essence of managing waste, because His Majesty is considered eternal.

Taking on the landfill

From simple concepts of material balances, which are the basic package of his chemical engineering background, this author has never been able to accept the existence of landfills as perpetual receivers of matter to the expense of natural resources. They represent a Parallel Planet, which swallows raw material without any return in sight. The battle against landfills finds its driving forces in this material balance upset, coupled with the rising opportunity cost of the huge Parallel Planet.

Inanimate matter does not listen or protest. "Managing" it is very easy. It goes to wherever the "manager" decides it should. It so happens that garbage does not exist in nature. It does not exist by its own will. It takes people to "produce" garbage. So this author set out on the road to "manage" people and induce them to stop producing garbage. If this were to succeed, landfills would become obsolete in the long run. All the scientific and administrative potential trapped in garbage collection and landfill operation would become available to the noble task of "managing" people in order to envisage a future with closed material cycles and without Parallel Planet. Of necessity, the research described here proceeded in Brazil: an emerging economy setting. Replication is thus essentially limited to similar settings inside and outside Brazil.

The top-down concept and its limitations

Governance strategies such as precise targeting for progressive landfill diversion of domestic waste are presently the single most urgent need of municipal administrators in emerging economies. General targets and directives are available from international organizations, but they need to be adapted and applied with local management talent.

The Zero Waste International Alliance (ZWIA) defines a zero waste goal as "to eliminate all discharges to land, water or air that are a threat to planetary health". It encourages the industrial sector to divert more than 90% of its waste from landfills or incinerators, and residential communities to establish benchmarks and timelines to reach 90% diversion within 15 years of adopting a plan [3].

At the turn of the century, the United Nations Organization introduced quantitative targets into global and local sanitation policies. The Millennium Goals of 2000 included environmental sustainability generally [4], and the documents originating from the Johannesburg Summit of 2002 referred to the advancement of sanitation services specifically [5]. The precise target of the Johannesburg Summit was and still is to reduce by one half the proportions of people excluded from sanitary services within a timeframe of 12 years, from 2003 to 2015.

Two unpleasant latent questions have so far eluded a satisfactory answer: When will complete domestic waste collection service become standard practice and when will all domestic waste be diverted from the landfills?

In this top-down environment, the directives are pushed along the pecking order from world summits to national governments and from there to regional and municipal

administrations. The latter are considered the end of the line, and results are expected to appear at this geographical entity. The main stakeholder in the waste movement chain is the producer, and not any of the cited government levels. In the case of domestic waste, it is the resident or the residential unit. In the case of school waste it is a particular school community. Neither of them is directly addressed by top-down policy directives and thus, they have remained relatively immune to those directives.

Present hierarchy of waste related policies

Table 1 summarizes the hierarchy for policy directives and decisions relative to urban waste.

Level 1	World Summits emit general and universal directives for the advancement of sanitation services
Level 2	National governments structure their pretensions to improve sanitary services in general and urban waste management in particular through legislation
Level 3	Local administrations are faced with the need for applying the national legislation within their geographical area of responsibility by way of detailing it and defining specific procedures of operation with precise timeframes
Level 4	The community at large is expected to obey the established local procedure, supported by private reverse logistics facilities

Table 1. Levels of waste management hierarchy (source: this research).

In past research [6], [7], this author has addressed levels 1 to 3 of the hierarchy and proposed methods to arrive at suitable timeframes for the evolution of urban waste management in cities. Those timeframes were derived from the 2002 World Summit directives and specific experiments with source separation in Brazil. To illustrate the type of approach, the result of that work is reproduced in Table 2.

Year	Target	% Tipped
2003	local diagnosis of waste movement	100
2015	the universe of residences not served by collection in 2003 has been halved	100
2027	all domestic waste is being collected (turning point)	100
2039	the local management threshold meaning the best achievable source separation result is reached, and all source separated waste is recycled	~33%
2051	the locally defined *zero waste* situation is reached	~0%

Table 2. General target schedule for reaching the stage of *zero waste* in municipalities of emerging economies (source [6]).

The treatment essentially follows the top-down order of directives, but derives its conclusions from experiments at the local level. The management threshold mentioned in Table 2 is the specific result of coaching people in source separation. In the experimental setting of a private initiative [6], it was shown that approximately 33% of domestic waste eluded source separation efforts and ended up in the landfill. The present chapter is

dedicated to describing the experimental methods used by the author to tackle this portion and to report on the results obtained. The challenge consisted of working at level 4 of Table 1 by producing precedents in sample communities for progressive landfill diversion of their waste.

The ZWIA (Zero Waste International Alliance) essentially works at level 3 as it attempts to convince city administrations and legislatures to enact the pertinent legal instruments for moving the city towards the final zero waste targets [3]. This author's team has produced material for this level as well. It took the form of a list of temporal and physical commitments by a city administration to reach the *zero waste* target within 15 years, and will be described shortly. Table 3 is anticipated here for illustration [7].

Year 1	Disseminate the program and the specific methods to be used among construction companies and health care institutions.
Year 2	Stimulate construction companies to anticipate the law and develop their treatment and recycling infrastructure. Initiate the collection of dry separated residue from residences by existing reverse logistics operators. Organize pilot units of decentralized composting and collect bio-waste from restaurants and pioneering apartment buildings.
Year 3	Establish voluntary drop-off points for large-volume trash items. Instruct medical establishments to separate their contaminated refuse.
Year 4	Pass the municipal law of solid waste. Irregular or clandestine deposits receive fines. Source separation becomes compulsory and is checked by municipal agents. Bio-waste is collected from residences in closed containers by operators of decentralized composting units.
Year 5	Existing reverse logistics operators absorb all separated dry material.
Year 6	The precarious rubble landfill is closed. Health care residues are collected and treated by private companies against payment.
Year 7	Centralized composting facilities are started by private operators
Year 8	All industries have their waste management programs.
Year 9	Recycled material begins to appear as raw material on the local market.
Year 10	Recycling industries establish themselves in the city.
Year 11	All producers of bio-waste have their management programs. The municipal landfill ceases to accept bio-waste.
Year 12	Barrels for collection of dry and clean packaging material are posted in the streets.
Year 13	Fines are applied to people who do not separate their waste.
Year 14	The municipal collection crews do no longer take away separated residues. They only take refuse, which does not fit the definitions of bio-waste or inert recyclables, to the correct destination to be defined by the city administration.
Year 15	There is no more waste to be tipped at the landfill.

Table 3. Municipal action plan of 15 years to reach a *zero waste* situation (source [7]).

Objectives for bottom-up warfare against the landfill

The following objectives were defined for the author's work on landfill reduction.

Devise methods that address the bottom of the waste movement hierarchy, namely the population at large.

Produce precedents in apartment buildings and schools to be replicated throughout the city in anticipation of municipal policies and laws.

Involve the complete existing reverse logistics chain from residents to wholesalers.

Discover the market forces in the chain and how they can be used to advantage by shrewd managers.

Rewrite waste management theory into people management theory by showing that source separation drives reverse logistics and not vice versa.

Describe and discuss the continuous learning path the research afforded for working with and managing the behavior of people.

Apply and expand the formerly developed theory of target scheduling at the municipal level. This means setting and obeying the timelines mentioned in Table 2.

For purposes of replication by interested communities, describe and discuss the specific infrastructure for waste collection developed in the apartment buildings and schools under study that has to form the transition point between families and reverse logistics operators.

2. Problem statement

The tale of garbage composition is an essential part of the success story.

Recently the author was asked to define *garbage* to lay people, i.e. lay people with respect to environmental management. They were all professionals of some field. So what is *garbage*? It does not exist in nature or on the market. It is produced by families right in the residences. The emphasis is on *produced*! How so? If you have a banana or a potato peel, this is not *garbage*. It is a food residue that can be composted and returned to the cropland. If you have a used sheet of writing paper or some pieces of cardboard, this is not *garbage* either. It is a cellulose residue that can be collected and returned to the paper machine. No *garbage* so far. Now, as soon as the families decide to mix the two items and to put them into a single bag to be thrown away, they *produce garbage* because then neither residue can be used again. *Garbage* then is not a byproduct of manufactured goods or agricultural produce. It is a product of human behavior.

Once *garbage* is produced, what does it consist of? There is a surprising similarity in comparable countries. Since the author lives in the BRICS community (acronym for the emerging economies Brazil, Russia, India, China and South Africa), the pertinent data originate from a group of countries here referred to as BRICS et al. *Garbage*, i.e. raw waste,

has been analyzed in many of those countries. How much bio-waste has been found? China 72%, India 71%, Brazil 72%, Nigeria 72%, Nepal 71%. How many plastics? China 11%, India 9%, Brazil 11%, Nigeria 11%, Nepal 12%. In other words: comparable countries – comparable *garbage* – and consequently comparable needs for management [6]. Our world is not as vast and diversified as it may appear to the unsuspecting beholder! We are a global village after all. The apparent similarity may be misleading, though. Raw waste analysis is only the starting point of waste management. The ensuing competition poses to the cited countries the following challenge: Who will first succeed in transforming *garbage* composition into *residue* composition, i.e. raw waste composition into sorted waste composition? What can be recycled is clean *residue*, not raw waste or *garbage*.

Good management practices drive the composition around in a circle with a velocity that depends on local talent. *Garbage* composition opens and closes that circle as it is progressively transformed into residue composition. The secret of management here is to induce people to stop *producing garbage* and instead provide clean residues for recycle. The success may be represented by sequential points on the circle. Take the bio-waste as example. In the *garbage* there were 72% of it, but there was zero residue because *garbage* by definition is mixed matter. As soon as a community sets out on its learning curve and starts to keep its different residues separate, the percentage of bio-waste begins to grow and the *garbage* begins to diminish. This chapter will show separated biodegradable residue to reach 47% in medium size communities and 58% in small communities through sustained effort over long periods of time. The picture of the circle may be obvious now. As the effort proceeds, the bio-waste will eventually move around the circle and up to its limit of 72% of all waste and will thus be available for recycling. This closes the circle. Behavior management will have transformed 72% of biodegradable *garbage* into 72% of clean biodegradable residue for recycling. All other components will follow comparable evolutions, and the tale of *garbage* composition will become the tale of *residue* composition. The nomenclature is still somewhat precarious, but the basic idea of the composition tale is alive and invites for the big competition: Who will first succeed and become the champion of BRICS et al?

The problem may be stated as follows: Top-down directives essentially stagnate at level 3 of Table 1, mainly for lack of management talent at this level. Results have been unsatisfactory in emerging economies simply because level 4 of Table 1 has not been specifically targeted. The population at large has not been induced to modify its attitudes regarding waste, and this will not occur as long as His Majesty The Landfill remains the central piece of waste management strategies. City administrations of emerging economies will face the successive challenges listed in Table 2 over the next four decades. Up to the turning point, where all waste is being collected and tipped, the problem is mainly of technical nature. Raw waste production rate and composition will suffice to design, construct and operate His Majesty and all collection facilities. The demand on people reduces to the classical plastic bag procedure. They put all their garbage into a plastic bag and leave it at the curbside for collection. Picture 1 is provided to illustrate this procedure.

Picture 1. Classical plastic bag method of waste collection

As Table 2 predicts, this will continue until 2027 when top-down directives are expected to turn from tipping to recycling. From then on, the problem changes from managing waste into managing people. Level 4 of Table 1 will have to be specifically addressed. According to the theory of the management threshold mentioned earlier, sorted waste composition will become the all important parameter for setting recycling targets and developing the corresponding procedures. In order to prepare the approximation of levels 3 and 4 of Table 1 needed for successful planning, the research described here initiated the bottom-up direction of waste handling. The idea behind the method was to prepare people to accept and cope with the expected municipal legislation that eventually will make waste sorting at the source compulsory. The timeframe is sufficient for both sides to approach the meeting point. The municipal administration will develop and enact the bylaws, and the residents will practice source separation in anticipation of those bylaws, such that the transition will be rather swift.

3. Application area

As a bottom-up initiative, the research addressed people and their behavior in order to learn management lessons and acquire confidence in the types of results that can possibly be achieved. Apartment dwellers and school communities formed the testing ground. Additionally, existing reverse logistics facilities were included in the study because they are the link between residue producers and recycling industries. The reverse logistics chain provides the means of returning used material to the economy and consists of producers, retailers (recyclers) and wholesalers. The task comprised essentially two lines of action, namely teach residents and students to separate their waste and establish permanent relations with waste retailers in order to keep the separated material moving on to wholesalers.

4. Research course

The research followed its own learning curve by using experience gained in one step to tackle the next step. At the start, no experience was available and consequently, methods found in the literature were copied. They indicated the analysis of raw waste as essential starting point of waste management schemes. It soon became evident that raw waste composition is not a management tool because it cannot be reproduced upon separation at the source. As long as the waste is not separated at the source, reverse logistics has no raw material to work with and cannot grow. The most visible testimonies of this situation are the hydraulic bulk collection vehicles that circulate in the city, load all the waste bags left on the sidewalks and take them to the landfill. In the early stages of this research, the average domestic waste production in the cities studied (Araguari, Uberlândia and Ituiutaba) was measured to be approximately 630 grams per person per day [7], [8], but this number is dynamic. The data were obtained from the landfill operators and thus did not include waste dumped at illegal sites. In order to evaluate the potential for recycling, the research then turned to source separation. This is essentially a people game. Residents had to be coached over long periods of time in the task of separating their waste. This was done by providing oral and written instructions and following up with special visits. As soon as the first results of source separation appeared, reverse logistics entered the scene. This has been the rule of progress of the people game. Continuous contacts with reverse logistics operators have guaranteed that ever increasing quantities of source separated material are moved to appropriate destinations. The operators included informal recyclers and formal wholesalers. Progress of source separation also had to be accompanied by corresponding infrastructure improvements at the apartment building and school levels. The whole game is circular in nature, and this has been the most important experimental result. One action pushes the other, and the initiative may come from any action point in the circle. Source separation stimulates the infrastructure for collection, and suitable infrastructure attracts reverse logistics operators to move the material out. The system also works in the opposite direction. Improved infrastructure stimulates improved separation, and increased demand from reverse logistics pushes the infrastructure.

5. Method used

The strategy has been to experiment with small communities in order to test and approve the approach to "managing people". Pilot scale results are presented, and their extrapolation to the municipal level is outlined. This is a bottom-up procedure based on private initiatives that does not consume public funds.

The classical method of "managing waste" proceeds in the opposite direction. It relies on public funds to implement top-down models of desired waste movement. It starts at the wrong end of the reverse logistics chain, because it invests in recycler facilities without ever considering the residents who are the producers of the waste the recyclers are supposed to collect and recycle. This model has failed to produce any visible result of landfill diversion.

Consequently, this author has developed the theory according to which source separation drives reverse logistics, and not vice versa. Experience has shown that even a perfectly equipped recycler is unable to pick out any significant amount of useful items from mixed garbage. The people game then consists of coaching residents to provide separated residues for collection, instead of mixed garbage. This is the correct starting point for a management scheme because it focuses on the raw material producers of the reverse logistics chain. Separated residues possess an added value in the recycling market, and experience has taught this author that this added value is sufficient to create business opportunities not only for recyclers, but generally for all actors of the chain. There will be no need for social work to keep the residues moving along. Instead, the public administration can concentrate on regulating the market such that the landfill diversion reaches the desired level. Any amount of waste that enters reverse logistics and is recycled, immediately liberates funds from reduced landfill operating costs. Those funds can be redirected to managing people and to raising the added value of certain residues. The fundamental question a city administrator needs to answer in this game is this: How does the opportunity cost of tipping a certain residue compare with the expense required to divert it from the landfill?

The pilot experiments of managing people described here form the starting point of this type of consideration. They provide examples of producing raw material for reverse logistics at no cost to the public budget. The concept of replication refers to taking the message to more communities and teaching them to imitate the examples. A shrewd administrator will know how to proceed.

The basic strategy of the game has been to gradually reduce the degrees of freedom in the residue collection system. How can a resident of an apartment building be induced to deposit a certain residue in a certain container? The answer to this question will lead the way to an operational source separation system, but is not obvious from the start. This author has spent many years to partially reveal the secret. A definitive answer has not been found, but the fraction of success has moved from zero to approximately 0.67, meaning that fifteen years ago the apartment building under study did not divert anything from the landfill, and to-day it permanently diverts 67% of its waste.

The waste compositions studied and measured refer to total municipal waste in city A (Araguari), to unsorted household waste in cities A, B (Uberlândia) and C (Ituiutaba), to unsorted waste in apartment buildings and schools and to sorted waste in apartment buildings in city B. The total municipal waste composition in city A was obtained from the collection reports of city crews assigned to the task of collection and delivery to the landfill. The composition of unsorted household waste was experimentally determined by collecting waste left at the curbside in various town sections and in the town centers. This waste was spread out, sorted and weighed. Pictures 2 and 3 are provided to illustrate the method.

In the case of schools, the waste produced during the day was sorted and weighed by the students under the supervision of a research team. In the case of apartment buildings, the unsorted waste produced at the initial stage of the research was collected daily, spread out, sorted and weighed. Significant amounts of sorted waste became available only after several

Picture 2. Bio-waste sorting

Picture 3. Dry waste sorting

years of coaching. This waste already came from the apartments in divided form. Before weighing, the routine check by building employees moved any items from the wrong bin into the right bin.

6. Status

The zero waste tale for apartments is the happy end of the success story.

It used to be a dream. The Zero Waste International Alliance still calls it a vision. In the case described here for pioneering apartment dwellers, it has become a fact. No more collection and tipping. No more waste sitting on the sidewalk. It really sounds like to-morrow, but it is here to-day for anybody to see. The extrapolation may be restricted, but any determined community in a place with similar idiosyncrasy should be able to replicate the experience.

The point to be made here is this: A situation like the one described does not come about instantaneously through a single person's endeavor. It is a long-term management effort involving various stakeholders. It took fifteen years of team work to reach this fascinating point of a zero waste reality.

Moving on from apartments, a grade school was also chosen for the experiment. The average waste production in the school was measured to be 45 kg/day with the following composition: dry recyclable material 51%, biodegradable material 36% and refuse 13%. With 20 lecture days per month and 9 lecture months per year, this amounts to 8.1 tons/year. Considering that 2139 people frequent the school every day, the waste production reduced to 21 grams per person per day. This amount is an addition to the 630 grams per person per day of residential waste generation. It illustrates the fact that people produce waste in different locations during the day according to their activities. Inspiring extra-curricular

activities were proposed to the students that produced compost from bio-waste and delivered inert recyclable material to existing reverse logistics.

This type of practical environmental education in schools takes the message to students' families and thus multiplies the result of landfill diversion. Picture 4 is provided to illustrate compost production by students as practical environmental education activity.

Picture 4. Composting in schools

7. Results

Developing a zero waste project for city A (Araguari)

This particular study was built on the hypothesis that it is possible the reach a *zero waste* situation in a Brazilian city of 100,000 population within a timeframe of 15 years, given administrative dedication and a detailed plan of execution with reasonable progress deadlines. The municipality of A had committed itself to collaborate with data collection. The author's responsibility was to develop the plan and the deadlines for execution [7]

Data were collected on municipal waste and its handling procedure from the administration and through interviews of key stakeholders of the waste business. In all 27 municipal schools, information was collected on environmental education and on school waste handling procedures. The activities of recycler cooperatives operating with inert material in the city were studied. From the publications of ZWIA, existing international experience was extracted. The main operators of reverse logistics facilities were interviewed to collect data on quantity of material commercialized. The main operators were three recycler cooperatives that collect dry recyclable material in the streets. The local prison was operating a composting project where data on quantities were obtained. Information on quantities of material handled in street cleaning activities was secured from the municipal department of public works. All those data were used to construct the diagnosis of the present waste situation.

The author's team followed the movement of all waste in the city. They observed the collection of inert material by autonomous recyclers and by cooperatives. They observed the collection of mixed domestic waste by compression vehicles of the concessionaire. They followed the trail of health care residues and of construction and demolition debris. It became evident e.g. that the trucks used to collect mixed waste are inadequate for the task. They are useful in developed countries where 70% of domestic waste is low density dry material. In that case, the compression is effective in reducing the volume. In emerging countries, only 30% of domestic waste is inert and dry. The rest is bio-waste, which is very humid and by nature is already compact [1]. The compression vehicle does not reduce the volume, but expels leachate, which drops on the pavement and produces bad odors. The study also collected information from the literature on zero waste projects existing elsewhere [3]. Those sources supplied the information on the extensive timeframes necessary for implementation. Personal measurements and data supplied by the public works department allowed the construction of tables with quantities and composition of domestic waste. The fraction of domestic waste collected by recycler cooperatives and thus diverted from the landfill was determined by observation. They operate in large halls where they separate the collected material and prepare it for sale. Information on income and expenses of the public administration with waste management was collected from City Hall archives. The literature survey contributed ideas from cities that already have their *zero waste* projects in place.

The results of the study consist of the quantitative analysis of city waste and of the proposed 15-year management plan. The analysis of waste movement in the year 2007 is shown in Table 4.

Construction debris	172.6 t/d	68.1%
Domestic and commercial residues	54.0 t/d	21.3%
Street cleaning waste	13.6 t/d	5.4%
Health care residues	0.5 t/d	0.2%
Miscellaneous not collected items	12.7 t/d	5.0%
Total	253.4 t/d	100.0%

Table 4. Waste produced in city A in 2007 **(**t/d = tons per day, source: this research)

Collection covers 95% of demand. The remaining 5% of residences and establishments not covered compose the last item in Table 4.

Construction debris and health care residues are collected and taken to treatment and final destination by the producers. The collection of debris is carried out by three companies who use trucks and mobile recipients of five cubic meters each, and by approximately 1500 autonomous persons who use small pushcarts. The transportation fees are paid by rubble producers. The final destination is a precarious rubble landfill designated by the public administration where all rubble is deposited without treatment or reuse.

A company specialized in pasteurization and incineration of health care residues collects them from the various establishments or residences and treats them against payment. The biologically inert material is then tipped at the landfill.

All other waste is the responsibility of the public administration. It maintains a team of 48 operators who collect and tip domestic waste, and another team of 85 people who take care of street cleaning and park maintenance. The teams use three trucks with hydraulic compression chambers of 10-ton capacity each for domestic waste and one open truck of 14-ton capacity for street cleaning residues. Domestic waste has the characteristics shown in Table 5.

Bio-waste		50.3%
Recyclable dry material		
paper	13.3%	
metals	2.6%	
glass	4.4%	
plastics	12.4%	32.8%
Refuse		16.9%
Total		100%

Table 5. Composition of domestic and commercial waste (including restaurants) in 2007 (source: this research)

There were two recycler cooperatives with 29 members and 180 autonomous collectors in town, for a total of 209 persons in the business of collecting dry recyclable material. Among

them, they collected 10.6 t/d of material by visiting residences and by exploring the voluntary drop-off points in town. The 10.6 t/d represented 10.6 / (54.0*0.328) = 59.8% of dry recyclable material in domestic waste. This is a significant quantity. The sale of those components to the wholesale market can earn an average of BRL786.00/t (USD467.86/t). The value obeys the law of supply and demand and varies with time. The best prices encountered between 2007 and 2010 were those indicated in Table 6.

material	wholesale price BRL/t	
cardboard	450	
white paper	530	
ferrous metal	450	
aluminum	2200	
colorless glass	280	
colored glass	280	
rigid plastics	1000	
plastic film	1200	
PET	1200	
Tetrapak type	270	average 786

Table 6. Table 6 – Highest wholesale prices practiced in Brazil, years 2007 to 2010 BRL/t (local currency per metric ton, source: [9])

The 10.6 t/d earn an average of BRL8331.60/d (USD4959.29/d). When shared by the 209 people active in the sector, each one takes BRL39.86/d or BRL956.74/month (USD569.49/month). The conversion factors used here were: 1 month = 24 business days and 1 USD = 1.68 BRL.

As the legal minimum salary in Brazil in 2010 was BRL510.00/month, each recycler was able to earn 1.88 minimum salaries. This is only the starting point. With the action plan proposed hereafter and the consequent compulsory source separation, the collection will become easier and the earnings will grow.

From those data, the study developed the plan to divert from the landfill all waste produced in the city within a timeframe of 15 years. It established specific targets for each one of the 15 years with the respective responsibilities of the public administration who will put the plan into practice. Of the total amount of 253.4 t/d of waste produced in 2007, 12.7 t/d were not collected, 10.6 t/d were absorbed by the recyclers, and the remaining 230.1 t/d were tipped at the landfill. The challenge of the proposed plan consisted in extending the collection to 100% of demand and maintaining it there in spite of the constant demographic expansion.

The research produced the plan shown in Table 3, divided in stages of progress with the corresponding deadlines that still needs to be transformed into a municipal law to become effective. This is the standard procedure adopted by other cities in various countries, although the details vary. In the present case, the chain of events followed this order: oblige source separation using pioneering examples for illustration, take maximum advantage of existing reverse logistics, attract enterprises to process the raw material available in form of

source separated waste and apply fines for disrespect of the law. Fifteen years were foreseen for this operation to reach steady state.

In order to dimension the challenge, the waste production was extrapolated 15 years into the future. The existing annual demographic expansion rate of 1.4% was considered constant and taken to represent the increase in waste production. During this period of 15 years, the plan calls for elimination of the miscellaneous not collected items in Table 4 and the refuse in Table 5. As a consequence of complete collection service and compulsory source separation, those items will be distributed to the other entries in the tables.

Tables 7 and 8 show the prospect of waste production and composition at the end of the 15-year period. This result was derived from the premise of compulsory source separation, which is a consequence of managing people. The two tables refer to the waste that is separated at the source and does not need to be taken to the landfill. The collection crews will continue to collect any items that by inspection cannot be recycled. Although the tables show projected values, they can be used by the city administration to dimension diversion efforts over the years. The corresponding investment can be depreciated over the years against reduced collection and tipping costs.

Construction debris	223.8 t/d	71.7%
Domestic and commercial waste	70.0 t/d	22.4%
Street cleaning residues	17.6 t/d	5.6%
Health care residues	0.8 t/d	0.3%
Total	312.2 t/d	100%

The 5% of miscellaneous not collected items in Table 4 were distributed proportionately.
Example: $54.0*(1/0.95)*1.014^{15} = 70.0$ t/d.

Table 7. Projection of municipal waste production in 2022 (source: this research)

Biodegradable matter	42.4 t/d	60.5%
Dry recyclable material	27.6 t/d	39.5%
Total	70.0 t/d	100%

The 16.9% refuse in Table 5 were distributed proportionately.
Example: $50.3\% / [(100 – 16.9)/100] = 60.5\%$ and $70.0 * 0.605 = 42.4$ t/d

Table 8. Projection of composition of domestic and commercial waste in 2022 (source: this research)

Analyzing the existing reverse logistics chain in cities B (Uberlândia) and C (Ituiutaba)

The reverse logistics chains in those cities were studied by observing the actions and reactions of waste retailers and by maintaining contacts with several of them in order to discover the correct destinations for inert as well as biodegradable material.

Compulsory take-back systems are usually limited to specific items that are homogeneous and easily identifiable, such as batteries, tires, light bulbs or bottles. Residents simply take them back to the establishment where they bought them, and the items vanish from sight. The random logistics structure takes care of the large number of heterogeneous items in the

waste stream that have to be delivered to their respective recycling industries through unidentified channels. Personal initiative is at a premium here, and the price paid by the industry moves the market. In Northern countries, the city administration usually collects source-separated material, either from households or from voluntary-drop-off areas. In Southern countries, source separation is not yet seriously practiced, and the logistics is left to private initiatives [1], [8]. The people who sift through all the material that was not separated at the source are traditionally referred to as *waste pickers* or *recyclers*. This research has raised their social status and underlined their importance to the municipality by introducing the designation *retailers* in the reverse logistics chain. They collect items of their own choosing from the material left at the curbside by residents, accumulate them and sell them to the wholesalers in the chain who are the intermediaries that stock material bought from the retailers and sell it to the recycling industries. In the cities of emerging economies there usually are a limited number of wholesalers and an impressive number of retailers. The whole system is moved by the price structure of waste material components. The city administration does not intervene as long as no specific landfill diversion target exists.

The waste material retailers limit their attention to dry inert items that may be easily scavenged at the curbside, taken away and sold. This part of the residues is thus well taken care of by private initiatives, but its success depends on effective management models. The research team observed the retailers' activities and identified basic needs for improving the success of this operation. The first problem is source separation. In the absence of source separation, the retailers are obliged to tear apart bags or other containers left at the curbside in order to pick out recyclable items. As a result, landfill diversion is obtained at the cost of dirty sidewalks and personal friction between residents and waste retailers. Institutional waste producers even have the official collection vehicles come to their premises to take away all waste material. In this situation, cardboard e.g., with a market value of 0.27 USD per kg, is mixed with other items and tipped at the landfill. It is like burying money instead of putting it into circulation. The second problem is collection time. The municipal collection vehicles have established timetables for every section of town, and residents leave their unsorted material at the curbside approximately one hour prior to collection. This is the rush hour for retailers. Whatever they are unable to pick up during this hour is fatally taken to the landfill. As a result, landfill diversion is obtained at the cost of uncontrollable intense scavenging activities at the curbside during certain hours of the day, or in some cases at the cost of having material sit on sidewalks all day. The third problem is traffic congestion. Retailers collect their material with pushcarts, bicycles or horse carriages and move along slowly from residence to residence or from building to building. Inevitably, traffic slows down. As a result, landfill diversion is obtained at the cost of slower traffic and the corresponding state of tension of drivers. The management challenge of municipal administrations in this context may be summarized into source separation and traffic control, in order to avoid the stated problems related to landfill diversion.

Moving away from classical waste composition reporting by substance, the new concept of sorted-waste composition was established and quantified by experiment. The experiment consisted of the following steps. A sample community was chosen. Unsorted waste

composition was determined experimentally. Source-separation instructions were elaborated and passed on to the families of the community. Source-separation was monitored for eight months with regular analyses of the sorted material. Finally, sorted waste was analyzed and its composition established. This sorted-waste composition was used to establish landfill diversion targets as functions of time, possible to achieve with a modest educational effort.

The community was also used to observe and analyze the reverse logistics operators in the city. Source-separated material was put on display and the quantity of interested spontaneous takers was noted. This procedure was to answer the question whether reverse logistics drives source separation or vice versa. The question was answered by comparing the landfill diversion achieved with the established municipal practices to that achieved with source-separation in the sample community. Realistic landfill life spans were then calculated for various targeting options of recycling initiatives at the municipal level, and the results were evaluated against present Zero Waste initiatives throughout the World. Thus, the research provided the basis of landfill diversion targets as functions of time for the municipal administration.

The research also focused on the biodegradable portion of the waste stream that is presently simply taken to the landfill. It represents approximately 70% of all domestic waste material in Brazil [8]. In analogy to the compulsory take-back system mentioned earlier for specific inert product items, a pragmatic management model could require similar attitudes of food producers. The losses of fresh produce within the commercialization chain have been determined as 18% of turnover in the city, and household scraps amount to 45% of purchased food [10]. Those are experimental data. Environmental education may eventually reduce the amounts, but this would belong to another study. It would be reasonable to expect the farmers to take back those discards for reuse on the cropland. This is a tentative proposal of this research. It sounds futuristic, and the corresponding reverse logistics has to be developed. Even so, an effort has been made to take care of this large portion of waste in the municipal management model. Observations of bio-waste movement originating from restaurants and markets showed that the reuse procedure is already being practiced on a modest scale by strictly private initiative. It remains for the municipal administration to stimulate those initiatives in order to expand them to larger scales.

Two destinations other than the landfill were identified for bio-waste, namely animal feed and compost. Both applications only thrive on pure material, which in turn can only be obtained by source separation. Windrow composting of unsorted waste as applied in mechanical biological treatment stations reduces and neutralizes the mass to be tipped. The method has been tried in Brazil with the wrong objective to commercialize the compost, and has failed. It failed because a large human and financial effort was expanded to sort the collected mixed waste prior to composting, with no result [6]. The author chose to focus on a double-step source-separation in order to obtain pure biodegradable material for recycling, which would thus be diverted from the landfill. Tests of separating bio-waste were performed in sample communities with surprising results [8], [11]. Approximately 80% of

residents responded positively to the request for separation. Once the separation was accomplished, compost could be prepared on available premises within the community, and additionally, farmers appeared spontaneously to take the material away for use as animal feed. This was an unexpected result, but it stressed the importance of source-separation in the reverse logistics chain.

The alternative of decentralized composting was also experimented with in sample communities, which included households, service sector enterprises, schools and apartment buildings. The compost produced in all of those places was of excellent quality and found immediate application as soil conditioner in gardening. Open composting bins made of wood or bricks were used, as illustrated on Picture 4. Analyses of compost produced by this research at different locations are presented in Table 9 to illustrate the quality achieved. It is noteworthy that the compost produced in the condominium complex is much drier than that produced in the other communities. This is so because the composting operation had to be conducted close to the residences and any visual or odorous inconvenience had to be avoided. The quality did not suffer.

analysis	Condominium Complex CELT	Residences on Afonso Pena Street	Antonio Nunes de Carvalho School
pH	7.4	8.0	8.1
density	0.40	0.41	0.69
total humidity	8.3%	26.9%	32.4%
total organic matter	46.5%	40.4%	15.0%
total carbon	25.8%	22.4%	8.3%
organic carbon	22.0%	15.7%	7.1%
total mineral residue	44.4%	32.5%	52.9%
total nitrogen	1.2%	1.4%	0.5%
total phosphorus (P_2O_5)	0.6%	3.6%	0.4%
total potassium (K_2O)	2.3%	2.4%	1.5%
total calcium	1.0%	0.3%	1.0%
total magnesium	0.18%	0.3%	0.13%
total sulphur	0.18%	0.1%	0.13%
C / N ratio	20 / 1	16 / 1	17 / 1

Table 9. Analyses of compost prepared from bio-waste collected in three different communities by this research, 2004 - 2007.

With the successful inclusion of bio-waste into the reverse logistics chain, the landfill diversion of this material became viable.

The research moved on to identifying the existing informal reverse logistics operators, in order to determine the landfill diversion potential provided by them but not presently taken advantage of in the municipal waste management model.

The research provided the understanding of reverse logistics in the city, developed and demonstrated the importance of pragmatic sorted-waste composition reports, illustrated the

potential tasks of all stakeholders in the effort to reduce the size of the landfill, and developed ideas for solving the management problems inherent in reverse logistics. Apart from source-separation and traffic control, the study also explored unusual means of achieving diversion targets. They refer to promoting or subsidizing the reverse movement of certain waste items, such as multilayer packaging and glass in order to make them attractive to retailers and wholesalers. This idea has not been experimented with heretofore. No literature reports were found. It represents an original contribution to municipal waste management based on market forces.

The waste production rate in municipality C in 2004 stood at 194.3 tons per day with the following origins: builder's rubble 129.1, hospital trash 0.8, industrial 14.4, street cleaning 2, domestic 45 and tires 3 tons per day. This study was concerned exclusively with domestic waste. There were 28844 residential units in the city, with an average occupancy of 3.12 persons per residence. There were also 2985 commercial and 301 industrial establishments, apart from 192 public service points.

In the reverse logistics chain, 29 establishments were identified that buy and sell inert recyclable material in the region. The number of informal collectors could not be determined exactly. An estimate was 220 families.

There existed a modest selective collection program run by the municipal administration through a waste retailer co-operative. This program relied on door-to-door collection and diverted from the landfill 20 tons/month or 0.67 tons/day of dry material items, composed of 59% paper and cardboard, 30% plastics of all kinds, 9% metals and 2% glass of all kinds. The landfill diversion thus achieved was only 1.5% (0.67/45) of domestic waste produced, and even so, there was fierce competition for this small source-separated portion by individual retailers. The remaining 98.5% of the waste, including all bio-waste, was tipped at the landfill, and the operating cost of waste collection and landfilling stood at USD14000 per month in 2004 when the research was initiated in this town. As the ratio of domestic to total tipped waste was 45/194.3 = 0.2316, the cost component pertaining to domestic waste was USD 3242.40 per month (14000 * 0.2316) or USD2.37 per ton (3242.40 USD/month / (45 t/day * 30.4 days/month)). Any recycling scheme would thus be credited with USD2.37 for every ton diverted from the landfill. This is a proactive way of waste management accounting.

The city administration worked with a collected waste density of 0.170 t/m^3, which when compacted in collection vehicles and on the landfill rose to 0.700, estimated the population growth rate at 1.65% per year and the per capita waste production rate at 0,500 kg per person per day (45000 kg/d) / (90000 persons). From those data, and excluding the modest recycling rate, the life span of the existing landfill was estimated to be 20 years and went from 2004 to 2024, for a total projected capacity of 387000 tons or 553000 m3. The domestic waste collection coverage was complete in the city, and 21 vehicles of different kinds were used in this service.

Landfill diversion as a target is not present in the directives of the last World Summit of Sustainable Development [5], but worldwide intellectual movements such as the Zero Waste

International Alliance [3] and the Global Anti-Incineration Alliance [12] work with total diversion targets within timeframes varying from 15 to 25 years depending on specific municipal contexts. The 20-year bulk tipping model encountered in the city under study was thus considered antiquated, and the research turned to finding ways of moving the city closer to worldwide targeting practices.

The basis for a reliable diversion target is a correct waste composition report. The traditional gravimetric composition list for the city was evaluated as stated in Table 10 for a sample community of apartment dwellers. This report results from the analysis by substance of original waste prior to any sorting. In previous research, the method was applied to other sample communities with results similar to those shown in Table 10 [8].

Very soon it was discovered that this way of reporting composition, albeit scientifically correct, was unsuited for reaching management decisions and setting landfill diversion targets. The reason? The fractions indicated in Table 10 are not necessarily pure material, and it remains unknown how much of each fraction could really be separated at the source and consequently, would be absorbed by the reverse logistics chain. In order to establish more reliable reports for targeting, the research developed the concept of *sorted-waste composition*.

The difference between pre-sorting and post-sorting compositions has been established for the first time in this research, and will be explained now.

A source separation program was implemented in sample communities, was supervised and accompanied for eight months. It was learned that source separation has to occur in two steps to be successful. The first step is the separation at the family level. The second step is a complementary separation at the community level, which corrects the errors or flaws that occurred at the family level. In practice, this implies for the case of apartment buildings, e.g., that the building administration runs the second step with its employees who collect the material from the families and pass it on to the retailers only after complementary screening. This is one more lesson learned from the practice of managing people instead of managing waste. Contrary to inanimate waste, people have emotions and are not perfect. Their behavior deviates from the manager's expectations. From this experience, it was possible to produce a new and more reliable composition report, this time for sorted material. Table 11 shows the result.

material	mass %
biodegradable matter	70
plastics of all kinds	13
paper and cardboard	12
glass	3
metals	2

Table 10. Unsorted household waste composition by substance (source: this research)

Upon comparing Table 11 to Table 10, it is apparent that not all bio-waste present in the raw waste was effectively sorted out in the source-separation program. In the particular case under study here, the theoretical amount of 70% shrank to the practical limit of 47%, even

with the two-step model. Where did the remainder go? It is hidden in the trash items of Table 11. The expression *educational trash* refers to the amount of material not sorted at the source. It contains bio-waste as well as inert matter in a state of mixture that makes sorting impossible. Here lies the fundamental argument of the composition paradigm: *Unsorted-material composition cannot be reproduced by normal source-separation due to human error and lack of dedication*. Families or house owners, even if instructed to do so, will not necessarily achieve perfect source separation. A realistic management model has to take this fact into account. Finally, the expression *administrative trash* refers to inert items that effectively are sorted out during the source-separation process, but nonetheless are unattractive to reverse logistics, mainly for reasons of pricing. They provide valuable input to a successful management model.

material	mass %
biodegradable matter	47
dry recyclable items	20
educational trash	29
administrative trash	4

Table 11. Sorted household waste composition by destination (source: this research)

The fallacy of the traditional waste composition report by substance can also be deduced from the information obtained at the retailer cooperative. Plastics in the city report of Table 10 represent 13 / 30 = 43.3% of dry waste. This fraction shrinks to 30% in the cooperative's recycling report, indicating that not all plastic material present in the waste stream was sorted at the source. The opposite is true for metals. The unsorted-waste report shows metals to account for 2 / 30 = 6.7% of dry waste (Table 10). In the cooperative's listing, metals occupy 9% of collected dry material, indicating that metals are easier to separate at the source than plastics and thus occupy a higher percentage level in the sorted-waste stream.

Figure 1 shows the material movement in a waste management model developed by this research based on double source-separation, on sorted-waste composition and on decentralized composting. The numbers in Figure 1 are taken directly from Table 11, except for the division of the bio-waste upon composting into bio-gas and compost, which is the result of the team's composting experiments. As the landfill diversion expectance increased from 1.5% to 67% in the new management model, the life span will be much longer than the 20 years originally predicted. The numbers shown in Figure 1 represent the best estimate of the immediate diversion potential in the city, which was not known prior to the execution of this research. It will form the basis of management actions. The challenge is to attain the potential within a stipulated timeframe, which in this case was set as 20 years.

What has been achieved so far? The bulk tipping model existing in 2004 was rejected because it was out of pace with modern waste management philosophies. Experimental sorted-waste composition was shown to indicate a diversion potential of 67% attainable through source-separation strategies. The timeframe of 20 years was fixed to reach this potential.

The challenge to put the model into practice required the study of the existing reverse logistics chain. The first question to be answered was whether the existing waste retailer community had sufficient capacity to face the required increase in inert items recycle. A condominium complex of 48 apartments was used to test the affirmative hypothesis. This experiment was carried out in combination with the sorted-waste composition study referred to earlier. As the source-separation program advanced until finally reaching the situation depicted in Table 11, the separated inert waste items became available for collection. The 220 families who comprise the retailer community randomly cover the whole city with their manual collection vehicles. Their collection efficiency is low because they depend on whatever they find displayed at the curb sides at the time they pass by. Planning is practically impossible. Several of the retailers who covered the street where the condominium complex is situated, were contacted. All of them expressed interest in passing by regularly and take away all inert items available. Those items included everything normally found in household waste and in this case separated from humid material, such as paper and cardboard, all types of plastics and metals, used clothing and wood. This lot has received the label "dry material" because it was and still is displayed in a completely dry state. The result achieved with this experiment was the proven fact that source-separation drives reverse logistics. The retailers to this day take away all dry components regardless of quantity. The arrangement with the selected retailers is to keep the material inside the building's premises for them to pass by during established hours of the day to take it away. There was no more need to have the material sit on the sidewalk. During the short period of loading, the retailers park their vehicles in front of the entrance to the building. Traffic flow is not affected. There is no expense to the city administration for this collection. The retailers take their lot to the wholesalers where it vanishes from sight. The city administration can concentrate its efforts and funds on the improvement of source separation, which according to Table 11 will drive reverse logistics to take care of 20% of all household waste. This experimentally established procedure is one more visible result of people management. Not only the apartment dwellers, but also the reverse logistics retailers had to be coached in order to behave as expected and close the circle of waste movement.

The reverse logistics for bio-waste is still incipient and needs to be developed. This is the other challenge for the administration in the 20-year period under consideration. Centralized and decentralized composting operations may be envisaged, and incentives need to be created for private operators to enter into this business. A collection infrastructure for bio-waste that uses appropriate vehicles without compacting accessories needs to be developed. The collection will attend those residential or institutional units who do not practice decentralized composting. The material will be taken to central composting stations to be processed by private operators. The city administration will provide the correct monetary incentives for this process by using the funds liberated by the reduced collection and tipping rates.

The test community of the aforementioned condominium complex was also used by this research to collect information on existing operators for bio-waste. Farmers from the

vicinity were contacted. They expressed interest in the source-separated material for use in their poultry and pig-raising activities. In fact, they covered various points in town where they collected food residues on a daily basis, mainly restaurants and fruit and vegetable stores. They all used motorized vehicles and barrels to move the material. It was only a question of calling upon one farmer at a time to regularly collect the source-separated bio-waste portion of the residues in the test community, which according to Table 11 amounted to 47% of waste produced. The scheme has been operational for several years now and is available for extrapolation or imitation. The precedent has been created without cost to the municipal administration, and as a consequence of people management.
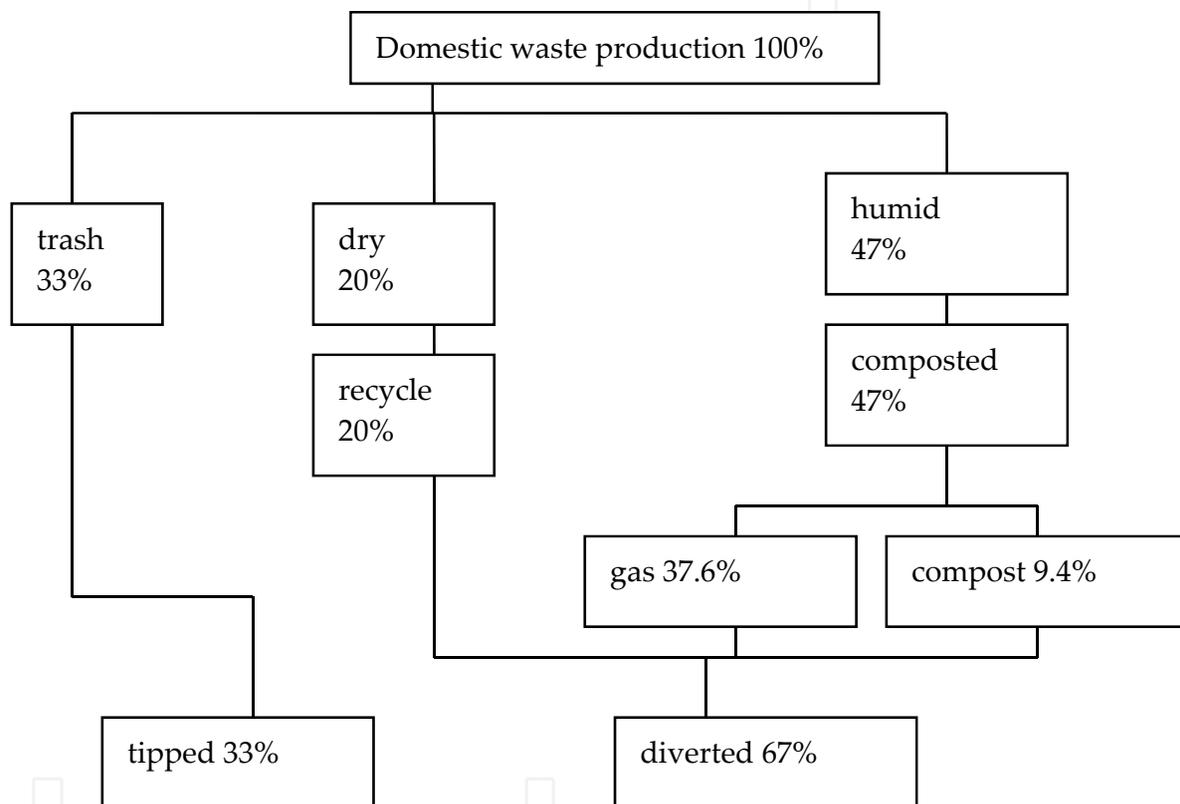

Figure 1. Material movement in the reverse logistics chain.
Management model developed by this research, based on sorted-waste composition.
Landfill diversion rates to be attained within 20 years.

The research also included composting tests. Experiments were carried out on the premises of the condominium complex, on the premises of the city water works and the electrical utility, and in the yards of several grade schools. All of these cases were successful in the sense that compost was prepared from food residues in a decentralized manner with excellent results. The composting operation according to the author's own research yields approximately 80% gas and 20% matured compost with 20% to 30% humidity. The reduction in volume is impressive, and the compost is immediately available for gardening. The experimental data of the decentralized composting operation have been published elsewhere [13].

In this respect, what remains to be done is to create centralized composting facilities in the city and stimulate their operation by private business. This challenge cannot be met by empirical research. It has to be included into the municipal waste management model.

The municipal model will include legal instruments that make source separation compulsory. The logistics for sorted dry material recycling is already in place. The private wholesalers and retailers will adapt their activities to improved source-separation. According to Table 11 and Figure 1 this will take care of 20% of domestic waste material at the end of the period considered. The municipal administration can concentrate its efforts on educational and legal measures to constantly improve source separation until reaching the target diversion of Figure 1. An example of tackling the 47% of bio-waste has been established by interaction with the farming community as illustrated. Additionally, the administration needs to solve the traffic problem created by reverse logistics. To start with, pertinent information has to be provided to the population on the strategic choices to be made. The unsustainable situation of leaving unsorted waste at the curb side to be indefinitely tipped at the landfill has to be confronted with the sustainable situation of presenting sorted material to reverse logistics retailers and exercising patience with temporary traffic slow-downs. A perfect management model is not available at this time. It needs to be constructed, and 20 years is ample time to do this.

What will be left to solve after the 20 years or after the 67% diversion mark? It will be the problem of educational and administrative trash as shown in Table 11. How to do this will depend on the creativity of the municipal administrators. As mentioned before, the most obvious route is to apply savings from reduced landfill operation costs to the creation of new reverse logistics channels for the items in question. What the tables do not show explicitly is the fact that a continuous effort is required to reach the target. If the tenure period of municipal administrations were four years, e.g., the waste management model would have to survive at least five successive administrations. This is the message the research described here conveys.

Developing an environmental management system in school A (EEJIS Public School, city B)

This part of the research confirmed the hypothesis that the concept of environmental management contained in the ISO 14001 norm can be applied in the context of public schools in Brazil. The work with people in this school went beyond waste handling procedures. It carried out an analysis of the school's physical interactions with the municipal infra-structure and indicated specific responsibilities of staff members in a possible environmental management system. The school's population consisted of 1924 students, 175 staff and 40 auxiliary personnel. The analysis of the school's impact on the physical city infrastructure identified water consumption as 3131 m^3/year, energy consumption as 46.1 Mwh/year, solid waste production as 8.1 tons/year, average noise level perceived by passers-by as 65 db, total school area as 6936.5 m^2, water permeable area as 2841 m^2 and impermeable area as 4095.5 m^2. The analysis evolved into the definition of permanent responsibilities of staff members to create a culture of constant improvements necessary for eventual ISO certification. This is an example of managing people to manage not only waste but to manage the environmental impact of a community.

Environmental impact analysis is a common management tool in enterprises of the production and service sectors. Its application in the public school context has not been reported upon, but environmental education practices exist in a variety of forms.

As early as 2004, the International Organization for Standardization (ISO) launched the Kid's ISO 14000 Program with the declared objectives to develop environmental awareness among children, to teach them to implement environmental management in homes and communities and to open them to the value of networking with young people in other schools [14]. The program was developed in Japan and has since spread to many other countries. By 2009 an estimated 210000 children worldwide had participated and achieved a 70000 ton reduction of CO_2 emissions. Reports from 2005 relate efforts to involve school children in Cambodia to protect the architectural, historical and cultural site of Angkor from deterioration by tourism [15].

The ISO 14001 certifiable norm itself details the procedure for any enterprise or community to implement an Environmental Management System (EMS) and apply for certification [16]. Thousands of enterprises worldwide have been certified. The importance of environmental education in the school context is described in [17], but the treatment remains general. No specific procedures for environmental impact analysis or possible certification are given.

The present study concerned itself with the novel idea of inducing a school community to seek certification as a pioneering experience in the Brazilian school universe. It went beyond simple environmental education by establishing and quantifying the impacts a school exerts on its neighborhood and on the municipal environment generally. This type of impact is not usually known to students. Its quantification is a first step toward creating environmental consciousness. From the analysis, proposals were elaborated for the school community as a whole to work towards reducing the impacts with specific physical and temporal targets in mind.

The implementation and continuous operation of an environmental management system is a long term effort that has to be supported by staff members. Students can at best contribute their temporary share during their period of school attendance. Consequently, the proposal defined the responsibilities in the ISO 14000 line of reasoning, namely assignments to specific parts of the community without identifying the persons who temporarily compose those parts. This translated into a management system where e.g. the reduction of energy consumption is the responsibility of the physics teachers and the management of waste is the responsibility of chemistry teachers and successive classes of grade 10 students. The inherent hypothesis stated that once those general responsibilities are routinely attended to with the corresponding result reporting, ISO 14001 certification may be envisaged.

The specific school chosen for the test was a public school in city B, which provides primary and secondary instruction from grades one to twelve. The idea that permeated the study was to create a precedent of an environmental impact analysis to be imitated elsewhere within the school universe.

The literature was searched for similar projects in institutions of higher learning and small businesses, but no precedent to the present study was found.

The analysis of the school's impact on the physical city infrastructure contemplated the topics of solid waste with respect to characteristics, quantity produced and destination, drinking water, storm water, energy consumption, soil available for rain water infiltration, existing vegetation on the premises, food consumption, traffic congestion related to student circulation and noise levels.

Data were collected by direct measurements, from school archives and personal observations. The purchasing files of the school administration yielded data on the consumption of food, light bulbs and plastic drinking cups. The solid waste produced was measured directly and analyzed according to possible destinations.

From the data collected, an environmental management system was proposed with temporal and physical targets as well as assignment of responsibilities. Specific programs were developed for improving the environmental impact derived from on-site vegetation, food quality, water consumption, solid waste production and energy consumption. The proposal also contained administrative infrastructure for continuous monitoring of those programs, a plan for obtaining the involvement of the total school community and for the preparation of monthly evaluations of progress.

Specific situation of solid waste

The average waste production in the school was measured to be 45 kg/day with the following composition: dry recyclable material 51%, biodegradable material 36% and refuse 13%. With 20 lecture days per month and 9 lecture months per year, this amounts to 8.1 tons/year. Considering that 2139 people frequent the school every day, the waste production reduced to 21 grams per person per day. This amount is an addition to the 630 grams per person per day of residential waste generation. It illustrates the fact that people produce waste in different locations during the day according to their activities.

A possible management system

In consequence of the impact analysis, the author's team proposed to the school administrators the participative development of an environmental management system (EMS) within approximately one year by assigning specific tasks to all segments of the school community with physical and temporal targets and demands for result reporting. The proposal indicated the formation of teams consisting of teachers and voluntary groups of students for carrying out each task. A sample task relating to waste management is listed below.

Task A: Solid waste management.

> Scope: establish waste production rates and best practice handling procedures for all waste and compare to production at home.
> Time line: one year.
> Responsible persons: chemistry teachers and 15 students.
> Progress indicator: reduction of percentage of waste taken to landfill

The impact analysis was a pioneering experiment in the Brazilian school context. It represented the starting point for devising the environmental management system. The proposal included the direct involvement of students and thus is expected to provide hands-on environmental education. The task of gardening will transmit notions on esthetics, ecology and utility of vegetation for mitigation of climate change. The task of solid waste management will raise questions on possible landfill diversion, and the idea of comparing generation per person in the school and in students' residences will take the message to the families. The same reasoning applies to water and energy management. Here students will be confronted for the first time with the need to check utility bills. The topic of rain water capture included in the proposal is an excellent engineering challenge to interested students. Topics of innovation and legal scriptures were included in order to provide breeding ground for social involvement of students as extracurricular activity. The topic on traffic congestion will be a challenge for prospective administrators to face, and that of noise levels within the school premises will involve considerations of social behavior. In all, the participation of students in the development of the management system can be an excellent stimulation for general environmental consciousness and personal involvement for many years to come. As students take the message home, they multiply and extrapolate the results of people management obtained in the school itself.

Experimenting with source separation in apartment building A (CELT Condominium, city B)

The evolution of domestic waste management practices in the urban residential condominium complex mentioned earlier is reported on here. A sustained effort over fourteen years has created a benchmark for landfill diversion by private initiative. The project was initiated in 1998 when the prevailing practice was to tip all waste at the landfill. In the presently attained situation, which is available for imitation elsewhere, 67% of all domestic waste produced in the complex is recycled without cost to the municipal administration. Instead of separating the inert recyclables, the effort was turned to separating the bio-waste. The management program derived from waste analyses and the work with people evolved into a two-stage source-separation procedure combined with the participation of handpicked reverse logistics operators. City crews now take to the landfill only 33% of all waste. Although this description is strictly valid only for Brazil, the story in itself might be of wider interest.

The condominium waste management project was created as a cooperation of the condominium administration with a graduate program of the local university. At the time (1998), the literature on urban waste management programs was still in its infancy. The industrialized countries already operated source-separation programs, but in Brazil only a few cities ran selective collection systems. The rule was mixed collection and tipping. Some municipalities had acquired sorting facilities for mixed waste, which at the time were considered modern. However, those facilities did not last because the cost-benefit relation was unfavorable. The cost of acquisition, installation and operation was high, the work environment of the employees was subhuman and the poor quality of the sorted material did not attract reverse logistics operators, i.e., operators of the commercial chain that returns

residues to the market. At the end of the nineties, those facilities were gradually closed by environmental government agencies, and a large vacuum was created in the municipal administrations related to financial and managerial aspects of domestic waste [8]. The municipalities that did not have acquired experience with selective collection returned to the old practice of tipping all waste collected.

It was at this moment of pessimism and desperation that the idea of the present project emerged. The author had traveled and inspected management programs in other parts of the world, but had concluded that these programs have very little geographic mobility. The literature shows reports on waste management from various countries. A literature review proceeding from Japan relates the general tendencies for urban waste and the differences in composition and management philosophies from one country to another [18]. A study from Tanzania relates the management philosophies tested in cities there and stressed the importance of popular participation in reverse logistics [19]. The first reports on source-separation efforts proceed from the U.S.A. [20], [21], [22], but did not dwell on the results possible with management of people. The present author visited facilities in Canada and Spain where biogas was captured from landfills and used for electric power generation. This strategy was later challenged by studies on the aggressive impacts of tipped biodegradable matter on soil and ground water [2]. Consequently, industrialized countries started to prohibit tipping of those solids at landfills, and the mechanical-biological pretreatment (MBP) facilities made their appearance and became common in Europe. The author visited them in Austria and Germany, and identified the major impediment to easy technology transfer: significant differences in waste composition. The present author's own research established the "70-30 rule", which states that in industrialized countries domestic waste roughly consists of 70% by weight inert items and 30% by weight bio-waste, and that in Third World countries the opposite is true [1]. The windrows in MBP facilities in Europe handle 30% of domestic waste. In Brazil they would have to handle 70%.

The present project anticipated in Brazil the surge of theories and technologies that, in the first decade of the present century, substantially modified the concept of the landfill, which ceased to be the main component of waste management programs.

The initial step was to produce an analysis of the solid waste situation in the city under study. In accordance with standard practice at the time, the team collected and analyzed several tons of domestic waste. As result, the composition data of Table 10 were obtained.

The following observations are in order. On dividing the quantity collected by official vehicles by the number of inhabitants, the domestic waste production rate was 630 grams per person per day. The relation between bio-waste and inert material in the waste stream according to the results of this study shown in Table 10 was 70 / 30, a piece of information not previously available in the city.

The next step was to refine the results in order to create more confidence in the numbers. Table 10 was constructed from analyses in various city districts. A specific analysis in condominium A resulted in the composition data of Table 12.

material	mass %
biodegradable matter	68
plastics of all kinds	10
paper and cardboard	9
glass	4
metals	2
textiles	3
others	4

Table 12. Unsorted household waste composition in condominium A (source: this research)

The next step was to confirm the new waste composition paradigm. Table 11 represents the best result obtained so far with source separation in residences and indicates the immediate landfill diversion target as 67% of domestic waste. This experimental result is considered a management tool. It provides a precise and realistic target. The timeframe for extrapolation and citywide application will depend on the administrative effort expanded.

In sequence, the destination problem was faced. The team studied the operation of reverse logistics in the city, which is completely informal. This was an additional opportunity to innovate.

The inclusion of reverse logistics in a waste management program had never been considered by the public administration. In the sense understood here, reverse logistics consists of all the operators of the commercial chain that return residues to the market. The main actors are wholesalers of inert material, and individual recyclers who in the new nomenclature are known by the name reverse logistics retailers. There are also cooperatives and operators dedicated to specific residue items like food scraps, or, in the new nomenclature, bio-waste.

At the beginning of the learning process, the research team would leave the source-separated residues at the curbside for anybody to take. Everything always disappeared, but as the passage of the retailers occurred at random, it also happened that the material stayed at the curbside until the municipal collection vehicle came along and took everything to the landfill. With this experience, the team identified the main shortcoming of the municipal waste management program. The activity of the retailers, who are the environmental force in the system, was not part of the program and was even obstructed by the physical impossibility of functioning. In fact, until this day the retailers have at their disposal approximately one hour per day for scavenging recyclable items in the whole city. This is the time period between the moment the residents display their waste at the curbside and the moment the municipal collection vehicle passes by to take everything to the landfill. Quite rapidly, the team succeeded in selecting the most reliable retailers and in establishing a durable partnership with them. This facilitated the job of both the retailers and the municipal collectors and guaranteed the correct destination for all separated items. The recyclable material had to be kept hidden from the municipal collection crew in order to allow for recycling by the retailers. The network of the residue producers (the families), the

intermediaries (the condominium administrators) and the receivers of sorted material (the retailers) was closed to the satisfaction of all concerned.

The learning process of this business occupied more than four years. The network of waste mobility was satisfactorily closed. In the last years since then, minor adjustments were still made to the procedure and to the underlying theory, and the system was pushed to the physical limit of recycling capacity.

How was the operational system pushed to the physical limit of recycling capacity?

Again using its own private initiative, the team started to attack the administrative trash. In 2005, the Brazilian National Environment Council passed Directive Number 358/2005, which made producers responsible for the correct destination of health care residues. Although medical establishments began to obey the Directive, residential units continued to place this type of residue into their garbage bins. The city administration simply does not have enough personnel to check on 160000 residences. The condominium administration wanted to set an example, and a contract was celebrated with a local company specialized in sterilizing health care residues. Various families in the condominium have persons under health care, small children or domestic animals that produce this type of residue. An additional container was put at their disposal to deposit their health care residues instead of mixing them with inert material. This type of residue represents up to four percent of total waste, and is collected weekly by the contractor. The condominium pays for collection and sterilization. The cost of this service is negotiated with the company and consists of a flat rate for the first 20 kg per month and an additional rate for every exceeding kg. The containers are supplied and regularly removed by the company. At present, the individual cost to each apartment comes to approximately 2% of the monthly administration charges.

Another contact was made with a company that specialized in processing used light bulbs and broken glass, which amount to two percent of total waste. There is presently no legal obligation in the city to divert this material, and reverse logistics operators do not take it. Once again, the condominium wanted to set an example. The price of the broken glass contributes to the processing cost of the light bulbs. Volunteers in the condominium take care of the transportation. An extra two containers were provided for light bulbs and broken glass, respectively, and the residents were instructed how to use them. The containers are 100-liter plastic barrels, which the condominium acquired as part of the maintenance bill. The collaboration has been satisfactory. The extended period of learning had its virtues. The residents were confronted with new requests for sorting one-by-one, and not all at the same time. This fact explains the satisfactory cooperation. "Satisfactory" means that 80 to 85% of the families adhere to the sorting instructions. As they had never before been exposed to anything similar in terms of behavior, and as the number of families moving in and out of the building is quite high, this degree of collaboration is the maximum to be expected. The building employees complete the sorting task and thus compensate for the families at fault. This task is included in their work contract upon establishing their remuneration. The pails for bio-waste collection from the families and the barrels for curbside display of refuse are part of the condominium's maintenance bill. Accordingly, the project already progressed

beyond Table 11. The amount of "administrative trash" has already been reduced by 4% + 2% = 6%.

The proportion of waste presently diverted from the landfill arrived at (47 + 20) % = 67%, is steady and may be confirmed by inspection in the condominium at any time. The remaining 33% of waste is still displayed at the curbside to be taken to the landfill. The waste production in the condominium is on average 100 kg per day. The diversion is 67 kg per day. During the last ten years of operation, the team diverted from the landfill approximately

$$0.067 \text{ t/day} * 365 \text{ days/year} * 10 \text{ years} = 245 \text{ tons of waste.}$$

This is the visible result of people management and is available for replication.

Two more pictures are provided here to illustrate the source separation procedure. Picture 5 shows the basic three recipients used in pioneering apartments for waste disposal, namely one each for bio-waste, for dry recyclable material and for non-recyclable trash. Picture 6 shows the typical contents of the small bag that receives the trash.

Picture 5. Modern source-separation

The people game is a fascinating experience. Just to illustrate the interaction, the collection of batteries is evoked. The law obliges commercial establishments to receive used batteries

back for disposal, but people are always looking for the least effort solution. They would throw the used batteries into the refuse bag, which in the apartment receives non-recyclable items. One day, the administration took the initiative of providing a pail at the collection point in the building, especially for batteries. To the surprise of all concerned, that pail kept filling up with batteries at a rate o approximately two kg per month. With a very simple provision, the infrastructure stimulated source separation. This reaction has to be seen in its own context, of course. Had the people not been coached on source separation for a long time, they would not have responded to the provision of the new facility the way they did, which underlines the circular nature of the people game.
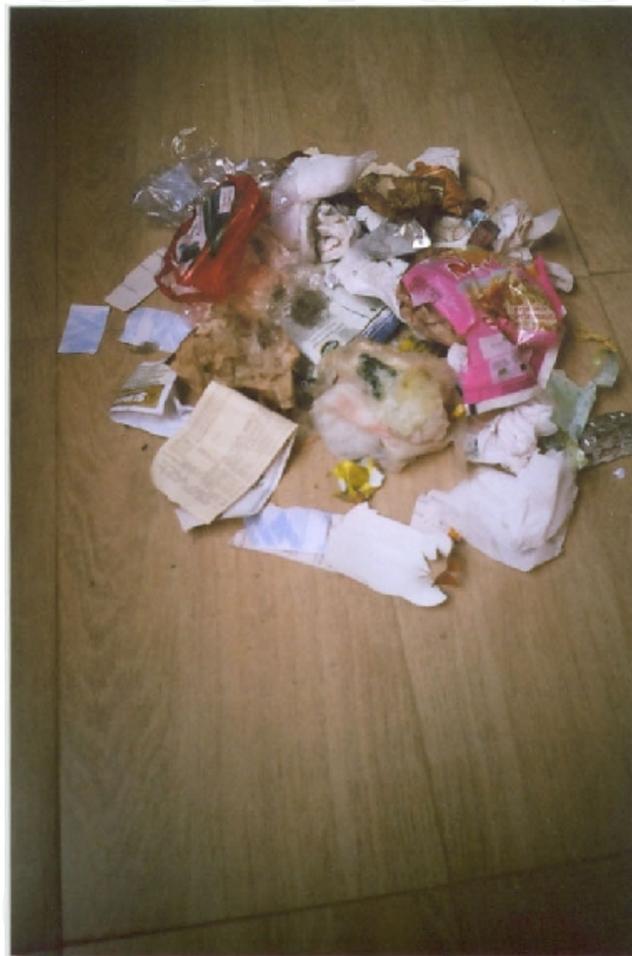
Picture 6. Trash to incineration

The interaction between reverse logistics, infrastructure and source separation

The following story pretends to close the report on managing waste through managing people. It optimistically summarizes the success of the people oriented waste administration effort in condominium A. It accounts for the logical cause-effect relations that have been able to lead the way to the surprising limit of zero landfilling.

It used to be a dream. The Zero Waste International Alliance still calls it a vision. In the present case it has become a fact. No more collection and tipping. No more waste sitting on

the sidewalk. It really sounds like to-morrow, but it is here to-day for anybody to see. To get the geography straight, this tale is happening in condominium complex CELT in city B with 650000 inhabitants situated in central Brazil. The extrapolation may be restricted, but any determined community in a place with idiosyncrasy similar to this one can replicate the experience.

The point to be made here is this: A situation like the one described does not come about instantaneously through a single person's endeavor. It is a long-term management effort involving various stakeholders, mainly the administrative team of the condominium. It took fourteen years to reach this fascinating point where a zero waste reality can be exhibited.

It started with the classical method of analyzing the waste. There are many forms of analyses for raw as much as for sorted waste. The sorted waste analysis is what matters because it indicates the possible destinations. The next step consisted of studying the existing reverse logistics stakeholders and facilities and of negotiating the waste movement with pertinent operators. This was followed by coaching families to sort their waste in the apartments. As this sorting is not perfect, the condominium employees came into the game to improve it. The source separated waste on average consisted of the items shown in Table 11. The administrative team provided the infrastructure for the waste movement and handed out spreadsheets to show the routing of all items. No miracles. Fourteen years of dedication.

The operational procedure now is such that on the whole, the condominium diverts approximately 67% of its waste from the landfill. This is the result of the overall sorting success of the families, but the present infrastructure allows for much more. So there are a few hardnosed families who have taken up the challenge of really using the infrastructure to its capacity, combined with a perfect sorting procedure at home, to show that "zero waste" can be achieved. Destinations other than the collection vehicle exist right now for all waste items from the condominium.

The point of the story is this: The internal operating procedure works its way down from the community administration to individual families or dwellers. The external scheme constantly negotiates deliveries and destinations with pertinent reverse logistics operators to keep the waste moving out. This is a permanent team effort.

Here is a sample of the pioneering families' present waste destinations. 58% is bio-waste or kitchen scraps that are delivered to a farmer for life stock breading. 30% is dry and clean packaging material like plastics, metals, glass, paper and cardboard. It is taken away by selected reverse logistics operators. 10% is health care or toilet residue taken away by a private company for treatment. This part is the only one with a price tag. The condominium budget covers the treatment. The remaining 2% is what is called refuse or trash. It does not fit into any of the preceding categories and is not attractive to reverse logistics. Examples are used napkins, plastized paper from packaged food, dirt from sweeping the floor, used filter paper from the coffee machine and the like. It is burned in industrial boilers or furnaces around town.

Pictures 7 and 8 are provided to illustrate how sorted waste is being offered to reverse logistics at the moment. The barrel seen in the background contains the 33% trash, which the city crew takes to the landfill. Upon comparing this situation to the starting point shown on Picture 1, the progress can be appreciated. It was slow, but it happened.

Picture 7. Sorted bio-waste ready for recycle

Picture 8. Sorted dry waste ready for recycle

Only a few families have so far reached this stage of perfect separation that eliminates the need for additional sorting by condominium employees and, above all, the need for collection by city crews. It is "zero waste" in the apartment, thanks to the condominium level infrastructure, and is the logical target for the rest of the families who are still hovering at 33% refuse. No utopia, only hard work.

Admittedly, the bio-waste still represents the biggest challenge, simply because existing reverse logistics operators are not prepared for handling it in the long run. Up to now, selected farmers have taken it away for life stock breading, as a result of continuous negotiations of the condominium administration with the farmers. The extrapolation of the scheme to a great number of condominium buildings will eventually require composting facilities to guarantee a secure and sustainable destination for this waste. This is the only point where the city administration may have to intervene. Incentives need to be created for private initiatives to run the composting facilities. It continues to be a people game, but its scope is beyond the reach of this research. Proposals are welcome.

8. Conclusions

In conclusion, the strategy has so far produced small scale examples on how to fight the landfills. "Zero waste" in apartments and schools has been shown to be achievable through the management of people, simply because waste obeys peoples' orders. Extrapolation of the examples to larger communities will form the challenge of the people game in the near future. This extrapolation will form the base of procedures by city administrations on implementing zero waste programs. His Majesty's days are counted.

Author details

Manfred Fehr
Institute of Geography, Federal University at Uberlândia, Uberlândia, Brazil

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