The Informal Sector and Waste Paper Recovery in Bombay

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Abstract
Lack of raw materials is generally considered one of the main constraints to a comprehensive recycling industry in developing countries. This paper examines the possibilities for increasing waste recovery in the South. First a literature study provides a general introduction to the problems of solid waste management in developing country cities. Based on field surveys in the informal recovery sector and the literature on formal waste collection, a simulation model for the solid waste flows in Bombay is developed. Two policy options under varying degrees of public responsiveness are considered: the encouragement of the existing informal recovery sector and the introduction of a Western style recovery system. Extrapolations of four effects are provided for the period to 2010: formal and informal employment, environmental impact, public expenditure and income distribution. Results demonstrate that policy makers in developing country cities should be reluctant to introduce a Western style waste collection system. Promoting informal recovery does seem to be a cost effective and an environmentally optimal policy measure, although this does result in adverse consequences for income distribution.

Resumen
La falta de materia prima se considera como uno de los factores más importantes para la creación de una industria completa de reciclaje en el sur. Este trabajo examina las posibilidades que existen para incrementar la recuperacion de desechos reciclables en los países en vías de desarrollo, centrándose en Bombay, India. En primer lugar, un revision de la literatura sobre este tema servirá como introducción general a los problemas relacionados con los desechos sólidos y su recuperacion en las ciudades. Se desarrolla en este artículo un modelo que representa el movimiento de desechos sólidos en Bombay basado en estudios de campo en el sector informal de la recuperacion de basura, y en la literatura sobre la recuperacion en el sector formal. Se estudian aquí dos opciones de las prácticas a seguir, según las diversas actitudes del público: el fomento del ya establecido sector informal de recuperacion, y la introducción de un sistema de recuperacion de desechos al estilo de los que ya existen en los países de Occidente. Se presentan extrapolaciones de cuatro efectos distintos, cubriendo el período hasta el 2010: el empleo formal y informal, el impacto medioambiental, el gasto público, y la distribucion de ingresos. El fomento de la recuperacion informal parece ser la mas económica y una medida de política medioambiental óptima: los requisitos, en lo que se refiere a la inversión, son mínimos, y, a la vez, los gastos de los vertederos se ven reducidos; los efectos sobre el empleo también son positivos debido a la cantidad de mano de obra necesaria para el desempeño de la recuperacion informal de basura. Sin embargo, el impacto sobre la distribucion de ingresos es peor que en las políticas de reciclaje de Occidente.

Abrégé
On considère que l'absence de matières premières représente une des principales limitations imposées à une industrie globale du recyclage dans le Sud. Analysant le cas de Bombay, en Inde, ce document examine les possibilités d'accroissement de la récupération des déchets recyclables dans les pays en développement. À titre d'introduction générale aux problèmes que posent, dans les villes de ces pays, les déchets solides et leur récupération, les auteurs étudient la littérature existante à ce sujet. Sur la base d'enquêtes de terrain menées dans le secteur informel de la récupération et de la littérature traitant de la collecte formelle des déchets, un modèle simulant les flux des déchets solides dans Bombay est élaboré. Deux options politiques, formulées selon différents degrés de réaction du public, sont envisagées: encourager l'actuel secteur informel de récupération ou introduire un système de récupération de style occidental. Les extrapolations de leurs effets sur quatre domaines différents sont présentées pour la période allant jusqu'à 2010: effets sur l'emploi formel et informel, impacts sur l'environnement, conséquences en termes de dépenses publiques et effets sur la répartition des revenus. La promotion de la récupération informelle apparaît comme une mesure politique à la fois d'une plus grande efficacité-coût et optimale du point de vue de l'environnement: ses exigences en termes d'investissement sont minimales alors que le coût des décharges s'en trouve réduit; ses effets

sur l'emploi sont eux aussi favorables à cause du caractère fortement intensif en main d'œuvre de la récupération informelle des déchets. Cependant, son impact sur la répartition des revenus est pire que dans le cadre d'une politique de style occidental.

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Introduction

International trade and local recovery of waste paper seem to be two separate issues, yet both activities are closely linked through the price of waste paper. This implies that changes in the recovery of waste paper in one country can have a significant impact on the recovery of waste paper in another. A perfect example of this relationship was demonstrated in the late 1980s and early 1990s when the German government introduced various policy measures to increase the recovery of waste paper in Germany. From 1989 to 1993 collection in Germany increased by almost 50%. This sudden increase in supply resulted in a negative price for low grade waste paper on the international market (Hagen 1994). Many neighbouring countries encountered considerable problems in maintaining the local collection system and subsidies had to be provided to waste paper collectors to prevent bankruptcy.

The option to establish subsidies is not always available to developing countries governments who face tighter budgetary constraints; in addition, the recovery sector in developing countries is much more market-driven than in the North. The impact of price fluctuations can, therefore, be more severe in the South.

In this paper, waste recovery in developing countries will be described. In order to assess the possible impact of international price fluctuations on the local recovery of waste paper, a case study will be presented on the recovery sector in Bombay, India. As well as focusing on the economic effects, including developments in value added and public costs, the social impacts, such as employment and income distribution as well as the environmental effects, are also considered. Note that the impacts of the recycling process are ignored in this paper. Based on this assessment, recommendations may be made for improving the recovery sector in Bombay.

The paper is structured as follows. First, a general introduction to waste recovery and waste management in developing countries is described. A theoretical framework for the problem is then developed The issue is then narrowed down to waste paper in Bombay. The sources of waste paper and the actors involved in collecting the waste are described in the following section, followed by an assessment of the waste paper trade sector. A simulation model is developed in order to determine the overall economic, environmental and social impact for different scenarios of waste management. Finally, conclusions are drawn.

Solid Waste Management and Recycling in Developing Countries

Developing countries have been recovering and using recyclable materials from municipal solid waste for many years. Moreover, recycling activities in the South are expanding rapidly (Savage and Diaz 1995, Bennis *et al.* 1996). Two factors underlie this development. First, local industries have increasingly recognised the advantages of recycling, such as lower energy consumption and therefore they have increased demand for recyclable materials. Secondly, consumers and collectors have become more aware of the economic value of recyclable waste and therefore have improved separation techniques and expanded the supply of secondary materials. In this section, the last factor will be discussed and analysed. As literature on this subject is rather scarce, most conclusions are based on a survey undertaken for the waste paper collection sector in Bombay. First a literature overview on recyclable waste collection in developing countries is presented.

State-of-the-art of Solid Waste Management (SWM) in developing countries

According to the World Bank (1995), the share of population living in cities in developing countries rapidly increased from 28% in 1970 to 38% in 1993. Projections for future developments show that this tendency will continue at an even faster rate. This trend towards urbanisation coincides with economic development, leading to higher income and consumption levels. As a result, municipal solid waste will become a major problem for many cities in the South. The well-known waste management hierarchy which stems from SWM in industrialised countries - waste prevention, reuse, recycle, energy recovery, disposal - is also in force in developing countries (Schall 1995). However, though the order of the options is similar to the industrialised world, the configuration of these options differs. For example, waste prevention is particularly relevant for countries with high consumption levels. Unnecessary packaging materials or extravagant consumer behaviour is generally less common in developing countries, and therefore the possibilities to reduce waste production at the source are also less.

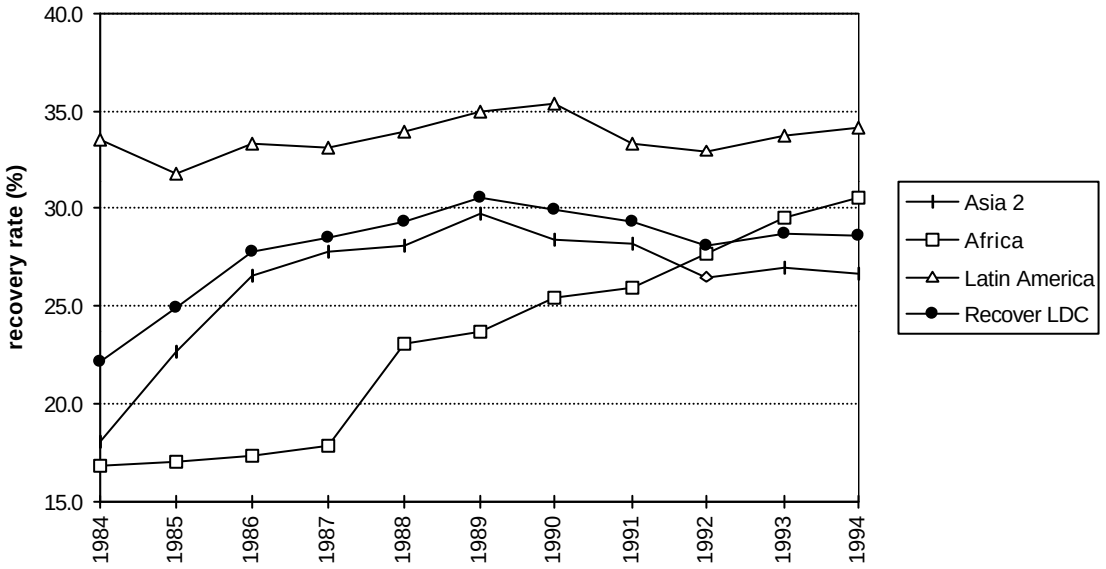
Disposal options in developing countries differ from the North. At present, up to 50% of municipal budgets in developing countries is spent on solid waste management. Yet, waste officials are not able to manage this problem efficiently. Due to the lack of funds, on average only 50% is collected in developing cities (Cointreau 1991). But even when budgets are adequate for collection, safe disposal remains a problem. Overall, inappropriate solid waste management leads to a number of societal problems, such as increased risk for epidemics, air-pollution caused by illegal waste burning and pollution of groundwater. The limited resources for SWM by the municipalities in developing countries increases the need for cost-effective options for urban solid waste management.

Most developing cities are serviced by an informal sector which exists in parallel with the formal waste collection authorities. This sector is mainly guided by market forces. The role of governments in recovering secondary materials is small. This informal sector is essential for the environment as well as the local economies in urban centres: first, by collecting waste materials the informal sector takes over a part of the burden of the municipalities. Second, since the waste

collection is labour intensive and involves no special skills or transaction costs, it provides a livelihood to many new immigrants and marginalised people in big cities in developing countries. Estimates show that these activities account for an estimated 1-2% of the workforce in large cities (Cointreau 1989). Waas and Diop (1991) estimate that in Dakar around 200,000 people are employed by the informal recycling sector. Third, informal collection avoids environmental costs and reduces capacity problems at dumpsites.

It is difficult to quantify the total contribution of the informal sector to urban waste management. The informal characteristic of this sector however, means there is a lack of official statistics on this economic activity. Quantification of the informal recovery sector is therefore rather scarce and uncertain. For Mexico, waste pickers are estimated to remove 10% of the municipal waste (Bartone 1991). In Bangalore (India), the informal sector is claimed to prevent 15% of the municipal waste going to the dumpsite (Baud and Schenk 1994). In Karachi, the informal sector reduces municipal waste collection by 10% (Ali *et al*. 1993). For specific materials, such as waste paper, more specific estimates can be derived. In figure 1, the slow increase of the recovery rate in developing countries is depicted. The African and Asia particularly, recovery rates have increased. However, the increase in Africa may also be the result of decreased consumption levels.

Figure 1. Waste paper recovery rates in developing countries (1984-1994)[1]



source: Pulp and Paper International (PPI) 1994

[1] The years 1993 and 1994 are projections based on the previous development.

[2] Japan and the Republic of Korea are excluded from "Asia"

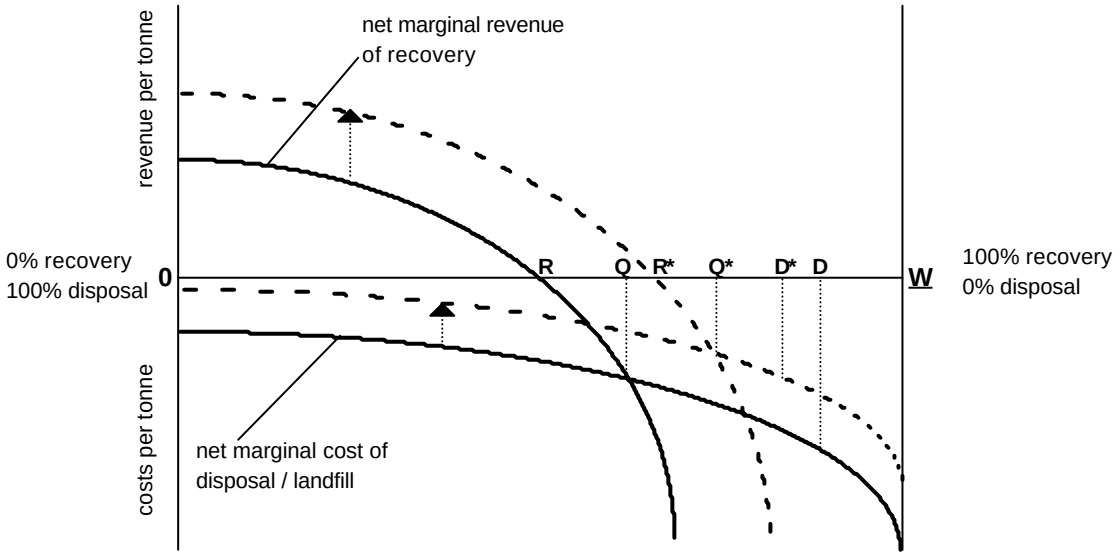
Theoretical framework for waste management and recycling

Three features are typical in the waste management situation in developing cities. First, the municipalities in developing countries have insufficient means to manage the growing burden of solid waste. Second, the informal sector plays an important role in recovering large quantities of solid waste at a zero cost to the public. Third, despite the efforts of the formal and informal sectors, significant quantities of waste remain uncollected. To illustrate the current waste

management situation in developing cities, a simplified illustration is presented in figure 2. Prices for each type of recovered material are assumed to remain constant. From this economic framework, the optimal waste management options (landfill and recovery) can be derived. On the vertical axis, direct costs and revenues are depicted of both options. The horizontal axis shows the quantities of the respectively recovered (recycled) waste and disposed (landfilled) waste. The total amount of generated waste **0W** remains constant.

The waste has three possible destinations: informal recovery for recycling, formal collection for landfilling, and, in the worst case, the waste will be left uncollected. These management options are expressed in the cost curves which depict the net marginal cost or benefits of each additional unit of waste for that particular management option. The net marginal cost curve for informal recovery starts above the horizontal axis because recycling initially generates net revenues. The marginal revenue decreases with increased collection because the remaining recyclable waste at the source becomes more scarce and the quality deteriorates. Relatively more effort is required to recover it. Recycling is cost-effective until the quantity **R**., which depicts the optimal quantity of recovered waste under free market conditions. Recovery of waste beyond R is not cost-effective. Recovery in developing countries will not exceed R because the informal sector is not compensated for the resulting additional costs.

Figure 2. Current and optimal recovery and disposal configuration



source: based on Bertolini 1994

The net marginal cost curve of disposal/landfill should be read from the right to the left. Waste collection starts at W and will move gradually towards the left as long as the municipal budget holds. This curve starts below the horizontal axes because formal collection does not generate net benefits. Therefore, this curve never intersects with the horizontal axes. As opposed to the net marginal curve of informal recovery, an increase in formal waste collection decreases its net marginal costs. These economies of scale are illustrated by the more than proportional decline of the marginal cost line, starting at the right hand side. Because municipalities in developing countries generally have insufficient budgets to collect all the disposed waste, formal waste

collection usually does not accomplish the desired quantity of WR. In figure 2 this is indicated by the amount WD which is the actual formal collection and landfill. This leaves an amount of RD as uncollected waste. Yet at R, the marginal costs of recovery are still lower than the marginal cost of disposal. Therefore, from the perspective of the municipality, it is still cheaper to recover waste instead of collecting it for landfilling. At the intersection of both marginal costs curves **Q**, recycling is no longer preferred above landfilling. Beyond Q disposing of waste is cheaper than recovery. This leaves a quantity of QW of waste to be disposed. A quantity of RD remains uncollected.

In industrialised countries where municipal budgets do not form a constraint, the most cost effective solution is to first increase the recovery for recycling purposes (from R to Q). Beyond Q, it is cheaper to collect the waste for disposal and thus follow the net marginal cost curve (DQ). For developing country, budgets are more limited which prevents the total formal collection of waste. Second, government involvement with the informal recovery sector is absent. Therefore, the municipality is not in a position to exploit the cheaper option of recovering RQ for recycling.

What is the most efficient solution to solving the problem of uncollected waste in developing cities, given the limited budget of municipalities and the limited involvement of governments with recycling? In the above theoretical framework, two options prevail. First, the waste collection of the municipality can be improved by increasing the efficiency of solid waste management. Official solid waste collection systems are often very inefficient: generally, second-hand vehicles are operated which are extremely polluting and not suitable for local conditions. As a result, maintenance costs are very high (Pearce and Turner 1994). Improvement to solid waste management will allow more waste to be collected for a similar SWM budget (shift D to D^*). This progress is depicted in figure 2 by a shift of the net marginal costs curve to the right.

The second option for reducing the uncollected solid waste is to encourage the recovery of recyclable waste by the informal sector. This can be achieved through the reduction or elimination of sales tax on local waste trade or through the promotion of waste separation at source. Another option which is often considered is the replacement of the informal sector by a Western style recovery system. Whether this alternative is feasible will be discussed in the coming sections. An improvement of the informal collection sector is depicted in figure 2 by a shift of the net marginal revenue curve to the right. This implies that the amount of recyclable waste collected cost-effectively will increase from R to R^*. In the new situation, the uncollected solid waste has decreased from RD to R^*D^*.

The Waste Paper Collection Sector in India

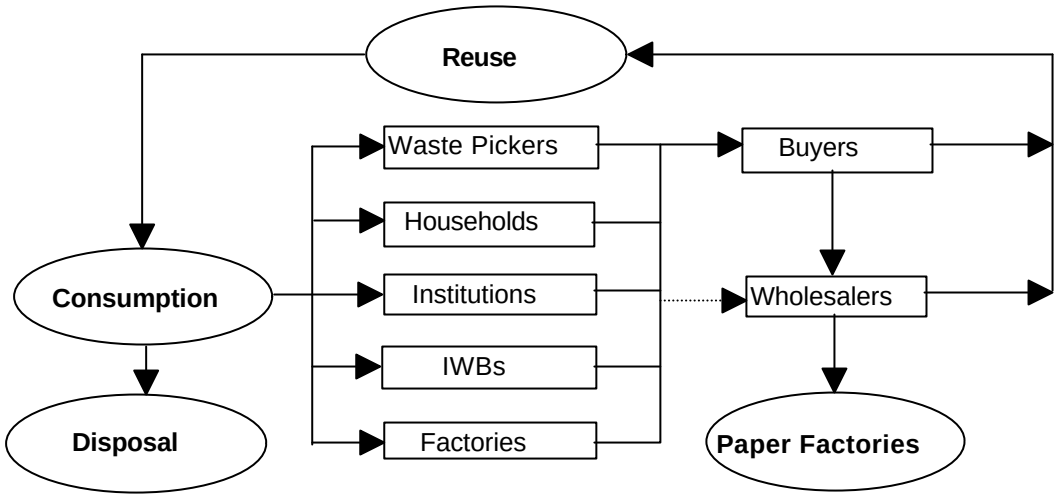
General Structure

In order to determine the economic, social and environmental impacts of different policies directed at the local collection of waste paper in India, it is necessary to understand the complex system of entrepreneurs and processes which are linked to this sector. Ignoring these complexities would lead to an underestimation of the social dimensions of the paper chain, because it is mainly the underprivileged who play an important role in this sector. The boundaries which will be considered in this partial life-cycle run from paper consumption to the disposal or recovery of paper products. Impacts from the actual utilisation of local waste paper are excluded. These upstream effects are considered in Beukering and Duraiappah (1996). The various routes of paper in the recovery sector are depicted by the flow-diagram in figure 3.

Processes

Unlike the processes which take place before consumption, the processes in this phase are extremely labour intensive and involve only a limited input of capital. The following processes will be considered. First, the *consumption* process is of major importance. Most studies on the paper cycle only look at the consumption of paper products which is either supplied by local manufacturers or by foreign producers. The fact that part of the consumption also involves re-use of waste paper without reprocessing taking place, is generally ignored. Yet, particularly in developing countries, re-use is an important alternative destination for waste paper and thereby may have a negative impact on the supply of secondary fibre to the recycling industry. Therefore, *re-use* is included in this study. This has two implications. First, the total level of consumption in this analysis will be higher than the formal level of consumption. The actual consumption will therefore be extended by a certain amount of re-used waste paper. Second, as re-use has a negative effect on the quality of the waste paper, it is assumed that paper which is re-used can no longer be available for recycling. This implies that the quantity of unrecoverable waste paper for disposal will increase if more waste paper is re-used.

Figure 3. Flow-diagram of the local paper consumption and post-consumer destinations of waste paper



note: IWBs =Itinerant Waste Buyers (see below)

After consumption part of the paper diverts from the cycle through either long term *storage* such as libraries, and through structural *losses* such as sewage. The waste paper can also be *burned* in order to reduce the disposal burden. The remaining paper is either *landfilled* at the dumpsite or it is *recovered* and supplied to the trade sector through different entrepreneurs. In the case of landfilling, the waste paper can still be recovered by entrepreneurs who operate at the dumpsites. Eventually, the trade sector will supply the waste to the paper industry or offer part of the merchandise for re-use to the consumers.

Entrepreneurs

The entrepreneurs who operate in this field can be broadly categorised into two groups: the formal and the informal sector. Generally, the Waste Management Department of the Municipal Corporation in cities in India are the only formal stakeholders in the post-consumption waste paper chain. The municipality is responsible for the collection, removal and disposal of garbage and sweepings from public roads, streets, foot-paths and lanes, and maintenance of dumping grounds (Hadker, 1995). Often, in developing countries, dumping or incineration is performed in an uncontrolled manner, resulting in high municipal costs. Recycling is rarely considered by the formal sector. The informal sector, which according to the International Labour Organisation (ILO) refers to those employers classified as own-account workers, unpaid family workers and those "not classifiable by status", collects and trades mostly unregistered waste materials (World Bank 1995). Various entrepreneurs play a role in the local supply of waste paper.

The main source of waste paper is *households*. They save their own waste paper which is either sold to the buyer or to the Itinerant Waste Buyer (IBW). As this mainly involves newspapers and magazines, the households are also the main source for re-use. In addition *institutions* and *factories* participate in the informal paper cycle. This group includes government departments, private companies and shops. Office boys or caretakers gather the waste paper which is generated in the offices, and they sell it off to IWBs or buyers. The

collection of waste paper is performed by either *waste pickers* or *IWBs*. The waste pickers, the majority of whom are unskilled migrants, roam the streets and dumpsites to collect any type of material which they can sell to the buyer. The *IWB* is also mobile, but instead of picking waste from bins or dumpsites, goes from door to door by bicycle to buy the waste from households or shops. Since his materials have not yet been mixed with disposable waste, the quality is much higher than the waste paper gathered by the waste pickers (Ali *et al*. 1993); this implies that the IWB is a major supplier of re-usable paper.

Finally, the waste enters the trade sector, which despite the fixed location may still be considered an informal activity because the traded materials are mainly unregistered and the labourers sorting out the waste belong to the non-wage employment. The *buyers'* main role in the paper cycle is to purchase from the above sources, sort out the waste, bundle it and sell it off to the wholesaler. The role of the *wholesaler* is to accumulate the purchased material until the quantity is sufficient for transportation to the recycling plant. The main difference between the wholesaler and the buyer is that the former is specialised in one specific type of material, whereas the buyer generally buys any type of waste which is offered. Also, the quantities dealt with by the wholesalers are much larger than the buyers' trade volumes. Occasionally, quantities are even sufficient for wholesalers to set up their own reprocessing factories.

A case study on the waste collection sector of Bombay

The collection of waste paper in India, mainly takes place in urban centres for obvious reasons: the amount of waste generated increases with increasing incomes and increasing population. Also the "throw-away" consumer behaviour is more manifest in cities. In addition, collection of waste is easier in cities as the population density is higher. Yet, this relation does not always hold. Traffic jams and high rise buildings can hamper the recovery and collection of waste. Also booming real estate prices makes it more difficult for waste traders to remain in the city areas. In this case study, Bombay was selected because it is representative of other megacities in developing countries. Since reliable information on local waste recovery in developing countries is lacking, several surveys were conducted in Bombay. A summary of the most important findings of these three surveys is given in the following sections. Information on the other stakeholders in the waste paper collection cycle is retrieved from literature or other surveys. The main objective of the surveys is to determine the relative contribution of the various entrepreneurs in the waste paper collection sector, and to analyse the performance of the entrepreneurs so that suggestions for improvement of the waste management in developing cities may be made. These data will be combined in the simulation model in a later section.

The Source and Collection of Waste Paper

The waste picker

Waste pickers contribute to solid waste management and to the supply of the recycling industry through the collection, sorting and selling of recyclable waste materials to buyers (Huisman 1994). The individuals operating as waste pickers originate from various groups, such as run-away children, migrant women or unemployed labourers. Research on waste pickers is rather scarce. In 1988, Gilhuis emphasised the role of waste pickers in Curitiba (Brazil). For Bogota (Colombia) it was estimated that 30,000-50,000 people earn from collecting recyclable waste (Hardoy *et al*. 1992). Huisman (1994) focused particularly on the position of female waste pickers in Bangalore (India). Furedy (1990, 1994) contributes by giving an overview of the social context of waste pickers in various Asian cities. The general conclusion of these studies is that waste pickers play a significant role in the management of waste in developing country cities.

A survey among waste pickers was conducted in order to facilitate quantification of their contribution. In other words, how much of the supply of waste to the recycling industry depends on waste pickers' activities and how much landfilling is avoided? In order to represent the variations in areas worked, 60 waste pickers were interviewed casually[1], in four types of areas: a dump site, a residential area, an industrial area, and a commercial area. Additionally, 7 group discussions[2] were held to enable the respondents to talk more freely about their activities and the social conditions. The outcome of these surveys will be used in the flow model which is explained in the coming sections. In addition, the possibilities for improving their performance are considered. For this reason, a qualitative assessment is made.

Profile of the waste picker

Of the total number of 60 waste pickers interviewed, 23 were male and 37 were female. Since respondents were selected at random, we can infer that the waste picking workforce is not equally divided between males and females. Since waste picking is a transitory occupation requiring no skills and resorted to by new immigrants to the city, it is seen as suitable for females and boys. This accounts for the bias in favour of females. Huisman (1994) confirms this finding.

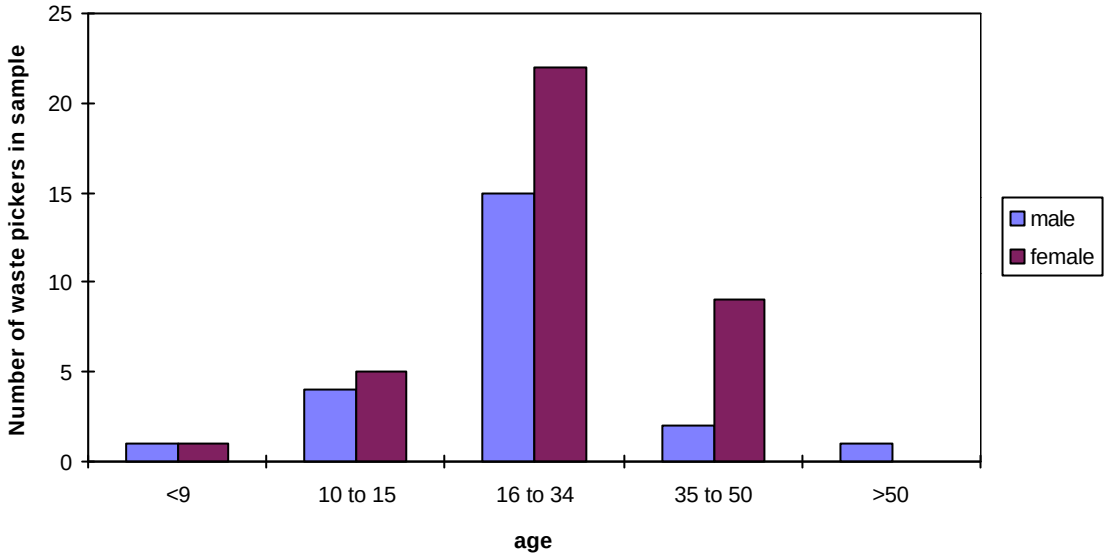
The frequency distribution in figure 4 shows that 60% of the respondents were 25 years old or younger. Of this young workforce almost 17% of the sample were children of 15 years or less. The drop-out rate from the workforce, particularly for males is pronounced after the age of 35. Again this outcome coincides with Huisman's study (1994) as well as NEERI (1995). An explanation for this phenomenon is that men find waste picking too inferior. Another reason could be that, although both boys and girls enter the trade at an early age, boys "graduate" into

[1] Casual selection implies that the interviewer operates in a specific area and randomly selects recognised waste pickers for an interview.

[2] The group discussions were held among waste pickers who were already interviewed and waste pickers who joined their friends.

other occupations, while women tend to stay on. Women perceive the advantages of bringing their children along with them and the freedom to decide upon their own hours of work.

Figure 4. Number of male & female waste pickers according to sex and age



Practically all the respondents were migrants. Almost 52% originated from Maharashstra State, of which Bombay is the State capital. 38% of the interviewed waste pickers came from Tamil Nadu. Half of the respondents were originally from rural areas, while only 7% came from other large cities. The illiteracy rate among the respondents was 75%. Only 10 waste pickers had had some kind of formal schooling, between Classes 4 and 9. Clearly, waste picking is a transitory occupation of new migrants who have little chance of finding other occupations. Another important finding was the dominance of Hindus in waste picking. Only one Muslim and one Buddhist worker were registered in the survey. However , Muslims were more prevalent in the buyers and the wholesalers surveys. This indicates that it is not necessarily the prescription of the Islamic religion which prevents Muslims from working with waste. A more likely explanation could be the stronger back-up of the underprivileged in the Muslim community, which makes resorting to waste picking unnecessary. Also the reluctance of Muslim women to go around in public places might be an additional explanation.

The social profile of the respondents was diverse. However, some patterns in social conditions were discernible A large majority of the waste pickers lived with their families and contributed to household income. It was observed that in waste picking families, young children accompanied their mothers from an early age. Only the male workers complained about police harassment. This particular vulnerability could also explain the lack of older male waste pickers. Common forms of harassment included extortion, verbal and physical abuse, false accusation in cases which occasionally led to imprisonment.

The female waste pickers did not complain of any harassment by the police. Although they did not confess to taking drugs, group discussions showed that a majority of the older male waste pickers and a few female waste pickers were addicted to drugs and alcohol. The women waste pickers complained about their husbands being addicted to alcohol. The common health

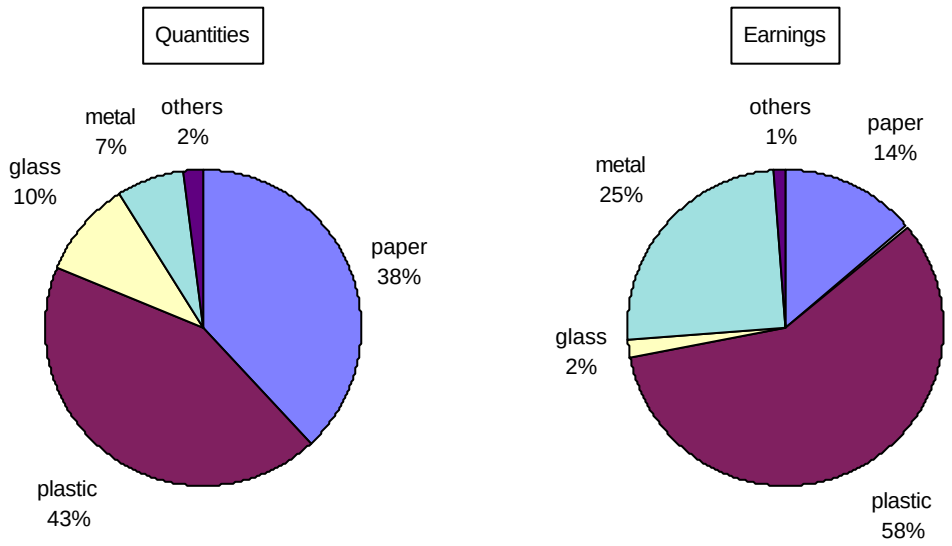
hazards that waste pickers faced were directly related to the unhealthy conditions in which they worked and the unhygienic and sometimes hazardous materials which they handled. Common ailments included viral infections, respiratory disorders, and skin infections. Cuts and wounds due to sharp objects in the waste handled were common.

Performance of the waste picker

All the respondents operated regularly in a particular territory. Trespassing into territories of others rarely occurred. A new arrival relied on a "senior" waste picker to whom he or she was attached for some time before operating individually. All the waste pickers said they sorted the materials before selling them. The sorting usually took place near the buyers' shop, just before the transaction.

The total average quantity of waste materials collected by the waste pickers per day was almost 13 kgs. The average composition of this bulk is depicted in figure 5. Clearly, paper and plastics form the major materials with respectively 38% and 43%. The category "others" mainly consists of wood and thermocol. The collected metals are tin, iron and aluminium. Within the category paper, brown kraft paper and duplex account for more than 70%. This is likely as the more expensive paper types are not disposed of in waste bins. It should be noted that the seasonal variation in waste paper collection by waste pickers is larger than for plastics because of the impact of the monsoons.

Figure 5. Compositions of quantity of waste and earnings by Waste Pickers



The average daily income of the waste picker in Bombay was Rs. 37. However, if the reported quantities are exposed to prevailing market prices of waste, their average income should be higher (Rs.57). This may be explained as either an underestimation of the respondents or as a general tendency of the waste buyers to pay less than the market prices. It was also found that male waste pickers (Rs.47) generally earned more than female waste pickers (Rs.28). Finally it should be noted that waste pickers also gathered materials which were not sold, but used for personal use such as firewood. This category is not included in the earnings assessment. Figure 5 also depicts the average contribution of the collected materials by waste pickers in terms of

earnings. Whereas paper was important in terms of volume, the earnings derived from paper were not significant. Because of the generally lower price of waste paper and low quality of the waste paper collected from the bins, paper only contributed 14% to the income of the waste picker. Plastic on the other hand contributed 58% of the total income. Typically, metals which only accounted for 7% of the collected materials in terms of volume, generated 25% of income. This explains the habit of waste pickers to burn waste at the dumpsites to recover the metals from the ashes.

Various correlation tests were performed in order to find variables which determined the income of the waste picker. In view of the unskilled nature of the work, it was expected that there would be a correlation between hours of work and earnings. However, the test rejected this notion. Also the correlation between age and earnings was negligible. Even the area of operation did not have an impact on the income levels. This suggests that waste picking is an activity which requires no particular skills and which is considered to be a survival strategy: waste pickers work until enough income is generated to buy the basic commodities. This is supported by the fact that only 7% of the waste pickers saved an appreciable amount of their incomes.

Almost 72% of the respondents reported seasonal variation in the quantity as well as the quality of waste collected. During the monsoons less waste was collected; moreover it was of a lower quality. Because lower quality means lower quantity, traders anticipated this slack period by stocking material and hence lower prices were apparent during the monsoons.

The respondents were also asked how they reacted to price changes. In the case of increased prices of waste materials, only one third of the waste pickers behaved predictably by maximising income. Most of the remaining waste pickers were not price-sensitive and collected uniform quantities. Only one respondent claimed to collect less with higher prices. More than 71% of the waste pickers had regular transactions with one buyer while 29% of the waste pickers sold materials to 2-3 buyers. This is a strong indication that there exists a large dependency on a particular buyer. The buyer attempts to enlarge his relatively small margin by keeping the prices as low as possible. In times of inflation, rising prices, poor weather and competition the waste pickers have to suffer the consequences of the decline in their income. The buyer binds them for longer periods of time through loans and other facilities.

Male respondents particularly considered waste picking as a temporary occupation. They preferred to switch to other manual labour such as construction work or street vending, if opportunities arose. The majority of the female workers preferred waste picking because of the independent nature of the work. Also, they claimed that waste picking was more rewarding. Coolies and construction workers earned respectively Rs.20 and Rs.25 per day (Huisman 1994). This difference in attitude between male and female is supported in part by the number of years the respondents had worked in waste picking. While males had an average experience of 7 years, females had 9 years experience.

Before the contribution of waste pickers to the SWM in Bombay and the supply to the paper cycle in India may be analysed by integrating the findings in the material flow model, several coefficients need to be defined. First, it is necessary to know how many waste pickers are

required to collect a specific quantity of waste paper. According to the survey, one waste picker collected approximately 1,400 kgs of waste paper per year if the negative impact of the monsoon is taken into account. This means that for the supply of 1,000 tonnes of waste paper derived from the street bins and the dumpsite, 714 waste pickers need to work for one year. The value added of this activity is completely determined by the weighted average of prices of the waste paper which is supplied by the waste picker. Because of the low quality of this waste paper, the average price is only Rs.1,610 per tonne. The contribution to the SWM in Bombay goes beyond the collection of waste paper - plastics, metals and other recyclable waste need to be taken into account in this respect. The findings showed that a waste picker collected approximately 4,000 kgs of waste per annum. It is assumed that the major share of this waste is collected from street bins.

One important social aspect of the survey was the number of children working in this type of activity. Child labour is a complex issue. Often, poor households have no choice but to send their children to work. Also, children who work in waste picking often have no families. The survey revealed that it is often boys who survive without families, while most girls accompanied their mothers and thereby supported the family income. Overall, 18% of the respondents were 15 years of age or younger.

A final estimation, required for the model is the number of waste pickers operating in Bombay. No official figures on the total numbers are known. Attempts to estimate numbers were performed in Bangalore (25,000 waste pickers from a population of 4.5 million) (Huisman 1994), and in Karachi (20,000 waste pickers from a population of 9 million) (Ali *et al*. 1993). This implies a ratio of one waste picker to between 200 and 450 citizens. Based on this ratio, Bombay would have about 25,000 to 50,000 waste pickers. However, the reliability of such an extrapolation is limited. Based on the surveys, it could be estimated that Bombay employs around 35,000 waste pickers. In terms of volume, 38% (13,300 waste pickers) of their efforts is concentrated on waste paper.

Other stakeholders in the supply and collection of waste

The remaining stakeholders of the group of suppliers to the waste trade sector will be described in this section. Given the diversity of this group, no survey was undertaken. Being the consumer of newly produced and re-usable paper and the only source of local waste paper, households, factories and institutions performed an equal role in the paper cycle in Bombay. Therefore, these stakeholders will be discussed simultaneously. IWBs, however, perform a different role and therefore they will be discussed separately.

Households, factories and institutions

The official per capita consumption of paper in India is 4 kg per year (Rao 1995). To obtain an idea of the volume of the waste paper flow in Bombay, this official figure must be adjusted. First, it does not provide a realistic representation of the true consumption in Bombay because it is the average per capita consumption of paper for India. The rural population, which still accounts for almost three quarters of the population, is predominantly illiterate (World Development Report 1995). Second, the amount of re-used paper is ignored in this estimate because the trade of waste paper for re-use is not registered. Finally, data on volume and composition of the waste in Bombay demonstrates that the per capita disposal of paper is at

least 13 kgs per year (Hadker 1995). This figure excludes the waste paper which is recovered for the purpose of re-use. On the basis of these facts, it is estimated that the average consumption of newly produced paper in Bombay is 18 kgs. Also, it is assumed that per capita re-use of waste paper for each Bombay citizen is approximately 2 kg. The total "informal" per capita consumption is therefore determined at 20 kg per year.

The post-consumption stage of paper in households and institutions can be divided into three categories. The first category is the paper that is diverted from the paper cycle for other reasons than disposal, such as sanitary paper and long term storage. Obviously, sanitary paper consumption is more important in the North than in the South. Therefore, sanitary losses are ignored in Bombay. Storage, on the other hand, is an important leak in the paper cycle. Given the conservative attitude towards disposing of books, magazines and reports, this ratio is significant in India. The second category includes the waste paper which is directly or indirectly supplied to the waste trade sector by households and institutions. From the buyers survey it was estimated that the buyer purchased approximately 50% of the traded materials from households, institutions, and factories. The IWB is fully dependent on households and institutions. The third category is the waste paper which, together with the other waste, is disposed in the street bins. Before this waste eventually ends up at the dumpsite, waste pickers will select out various valuable materials. This reduces the volume and changes the composition of the waste. Eventually 1.67 million tonnes of institutional and household waste paper were landfilled by the municipality in Bombay in 1992-93 (Hadker 1995). Given the average per capita waste generation of 0.5 kg per day which aggregates to 1.96 million tonnes for Bombay, and an approximation of 35,000 waste pickers in Bombay, it can be assumed that 8% of the post-consumer waste is recovered by waste pickers and 7% of the post-consumption waste is burned or remains uncollected. Although this figure is rather uncertain, more accurate estimates could not be derived from the available data.

Finally, the question remains of how to increased household waste separation. There have been a number of studies by behavioural psychologists to examine the motivation of participants in recycling schemes and the effects of different kinds of incentives on the rate of participation. Urban citizens in the US were found to participate mainly for personal satisfaction associated with environmentally responsible behaviour. Yet, financial incentives such as direct charges for waste management services were also found to be necessary to motivate the less environmentally motivated citizens (Gandy 1994). Given cultural and economic dissimilarities, differences in motivation of citizens in developing and industrialised countries seem to be rational. A survey conducted among households in Bangalore revealed that the reasons for separating and selling waste were not purely economic (Furedy 1994). Most households replied that it was a tradition or habit. Nevertheless, 76% of the respondents also mentioned that "waste trading was important to their household, since the money they derived from selling the materials was useful". It should be taken into account that it is generally not the head of the household who takes care of the waste but the servant. For this group, the economic criteria are more important than for middle or higher class families who consume the paper. The may can be said for office-boys and caretakers working for institutions. It may be concluded that, although it is difficult to quantify, households and institutions make a significant contribution to the paper cycle in supplying waste paper

Although waste separation at the source is a tradition in most families and offices, efficiency can still be improved through environmental awareness campaigns. It should be realised, however, that overall economic development may also have counteractive effects on waste recovery. The danger exists that growing urbanisation will force the buyers to move from the residential centres to the industrial suburbs. As distances increase, the motivation of the households and institutions to separate and sell the waste diminishes. This trend may have a negative impact on the recovery rate (Furedy 1990).

IWBs

IWBs form an important part of the waste recycling system in Indian cities. They go around the city on bicycles or even on foot buying recyclable waste from houses, institutions, offices and other sources. The collected recyclable waste, mainly consisting of paper, plastic, glass bottles, and metal scrap, is purchased from households and institutions and sold to buyers. The IWBs are important for the paper cycle as they obtain waste at source before it is mixed, damaged or contaminated. Because the IWBs cover a different segment of the waste recovery sector, they are not in competition with waste pickers (Ali *et al*. 1996). Most of them are independent operators, while some are employees of the buyers on whom they are dependent for financial assistance. The IWB collects about 40 kgs of recyclable waste per day which generates a daily income of Rs.50-60 (Furedy 1994). Although the IWBs are common in most Indian cities, their presence in Bombay is minimal. Whereas their contribution to the supply of waste paper in Bangalore accounted for 19% (Beukering 1994), the field survey indicated a contribution of less than 4% by the IWBs in the Bombay waste paper supply. This can be explained by the fact that, due to the high rise housing in Bombay, it may be very difficult for the IWBs to access the residential and commercial areas and for door-to-door collection. Also the heavy traffic impedes the performance of the IWBs.

The municipality

The Solid Waste Management (SWM) in Bombay is undertaken by the Municipal Corporation of Greater Bombay (MCGB). The annual growth in waste generation in Bombay of 6.2% is almost four times as large as the population growth of 1.6%. Because of this exponential increase in solid waste, the total budget spent on SWM is simultaneously growing. At present 7% of the MCGBs budget is spent on SWM (Hadker 1995).

The solid waste department of MCGB employs 26,239 people. This implies that MCGB requires more than 9 employees to process 1,000 tonnes in a year. The total wage bill is around Rs.992 million, thus for labour only, SWM costs Rs.348 per tonne of garbage. Also transport is costly: assuming that about 780 trucks operate each day, covering a distance of 100 kms, the total daily consumption of diesel exceeds 2,600 litres. This alone costs around Rs.93 million per year. The overall budget of the SWM department in Bombay was Rs1,273 million in 1992-93, which means that the total costs of managing one tonne of garbage is Rs.447. Budgets of solid waste departments in developing cities rarely reflect full costs (Cointreau, 1996). One may consider this estimate to be slightly undervalued as the 170 hectares of land used for dumpsites in Bombay could be priced at Rs.1.5 billion (Hadker 1995). These opportunity costs are ignored. Also indirect costs such as related staff in other departments are not taken into account. As opposed to the entrepreneurs in the informal sector, the economic potential of solid waste is rarely exploited by municipalities. Obviously, the most valuable

materials have already been harvested before it waste reaches the dumpsite. Attempts in India to convert solid waste into compost have not been very successful until recently. Too often "Western technologies" are applied which are not suitable for Indian conditions (Baud & Schenk 1994). Although experiments are conducted to develop decentralised composting and energy recovery of solid waste, these new methods have not been applied on a large scale.

Table 1. Waste volume and composition for different stages in Bombay 1993 (in Kilo Tonnes, KT)

Material	disposed (bin)		recovered		burn/uncollected		collected MCGB	
	in KT	%	in KT	%	in KT	%	in KT	%
organics	1136	58	3	2	3	2	1130	68
dust	292	15	0	0	0	0	292	18
paper	197	10	61	38	51	38	85	5
plastic	210	11	69	43	57	43	83	5
glass	58	3	11	7	10	7	38	2
metal	41	2	16	10	13	10	12	1
others	27	1	0	0	0	0	27	2
Total	1961	100	160	100	134	100	1667	100

source: compiled from Ali et al.1993, NEERI 1994 and Hadker 1995

The volume and the composition of the waste changes during the process of collection and disposal. Waste pickers scour the street bins to extract valuable material. Table 1 demonstrates how much of each material is recovered from the bins in Bombay and how the composition alters accordingly. This change in volume and composition is an important element when evaluating environmental impacts, but also to verify the contribution of waste pickers to the solid waste management system. According to the table, it can be concluded that waste pickers play an important role in the further reduction of the post-consumption waste.

The waste which is eventually left will be either landfilled or burned. Waste burning is carried out both by the formal and informal sector. The main reason for the municipality to burn waste is to reduce the volume, particularly for the uncollected waste. Sometimes waste burning is also performed by waste pickers in order to select the metals which are left in the ashes. Obviously, this activity is very damaging to the environment. An air-pollution study in Manila indicated that refuse burning was the second major cause of health damage through air pollution (Larssen *et al.* 1996). Energy recovery does occur at a household level. Sometimes note books and magazines are used to heat traditional boilers. With continuous uncontrolled waste dumping and landfilling, the quality of the land deteriorates. As a result, underground water will become polluted through leaching of hazardous substances (Hadker 1995).

The Waste Paper Trade

The buyers

Buyers differ from the suppliers since they operate from a fixed location. They also trade all recyclable material. Their knowledge of materials and related prices is considerable. This knowledge ensures profitability since the margin between buying and selling price is generally low. In order to understand the performance of the buyer a survey was undertaken across 37 traders. As in the previous sections, the profile, the performance and the coefficients for the model are described.

Profile of the buyer

The majority of the buyers interviewed owned a compound of operations. 40 % of the respondents operated from rented units. The religious representation differed from the waste pickers survey: the composition of 65% Hindus, 19% Muslims and 13,5% Jains was more in line with the average distribution of the Indian population. The buyers were also better educated than the waste pickers: Of the 73% of the buyers that had some sort of education, 63% had enjoyed education until the primary level, 26% up to the secondary level, while 7% were educated up to undergraduate level. Half of the respondents entered the waste trading business because it was already a family activity. Compared to the wholesalers, buyers entered the cycle quite recently: 35% of the units started business after 1985 and 27% of the units were established between 1976 and 1985. The remainder of the units were set up before 1976.

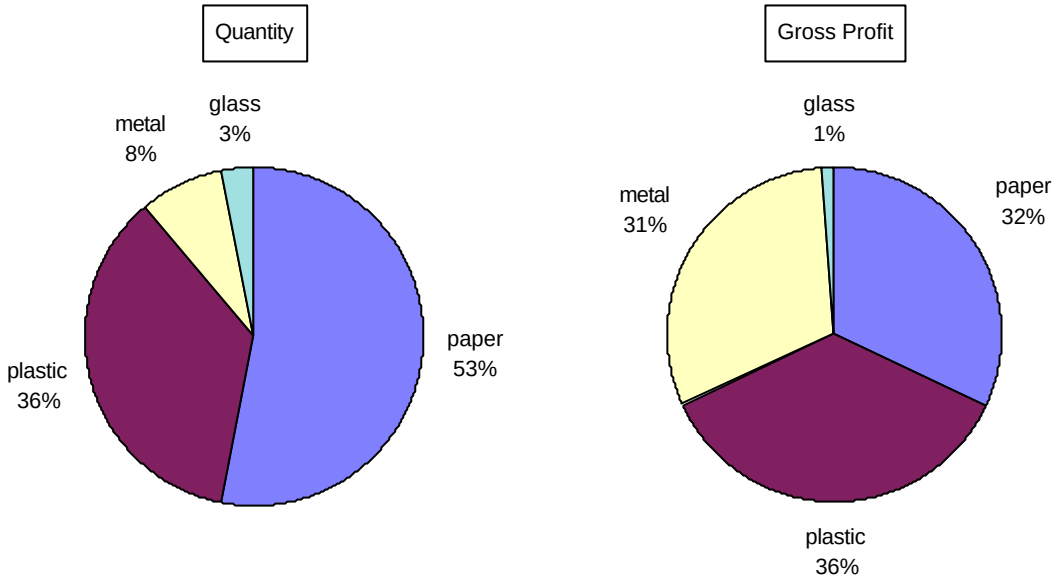
The most important suppliers of waste to the buyers were waste pickers (47%) and households (42%). Smaller amounts were supplied by itinerant waste buyers (4%), factories (4%) and institutions (3%). An essential difference between buyers and wholesalers was their locational preference. While most wholesalers were located in commercial or industrial areas, buyers preferred (68%) residential areas, probably to minimise the distance to their suppliers; 13 units were located randomly. The reasons given by the respondents for a certain location were proximity to residence, suppliers and customers, as well as good facilities and no interference from the government.

The scale of the area of operation was relatively small, consisting of 230 square feet (sq ft) on average with a range of between 50 and 1200 sq ft. This feature indicates that the average buyer dis not have much space to keep stocks. The average stock kept by a buyer was 1.34 tonnes per week. The majority of the buyers worked 9 to 12 hours a day and operated 6 days a week.

Performance of the buyer

The average buyer traded 39 tonnes of recyclable waste every month, with a slack period during the monsoons between June and September. The waste traded mainly consisted of paper, plastic, metal and glass. The composition in volume and value terms is illustrated in figure 6. Although waste paper is the most notable commodity in terms of volume (53%), in value terms plastic is more important. The seasonal impact is taken into account, as these are annual averages.

Figure 6. Composition of the quantity and gross profits of the buyer



The average total turnover of a buyer was about Rs.100.000 per month, with an average turnover of Rs.32,000 per month for waste paper. For paper, plastic and metal the gross profit per tonne was respectively Rs.1,390, Rs.1,767 and Rs.6,684. The average gross profit was Rs.22,500 per month of which Rs.7,290 gross was from paper. In order to determine the net profits, other costs are estimated. For employment costs, it was found that the average buyer unit employed 1.2 workers, excluding the owner. The average wage bill of a buyer unit, with an average wage of Rs.775 per month per employee, was Rs.900 per month. The average electricity bill and water bill only accounted for Rs.167 and Rs.27 per month respectively. Some entrepreneurs also indicated that they paid a certain amount of "hafta" - these are informal costs paid to the authorities to obtain permission to maintain a business. Only 5% of the respondents paid taxes. This cumulates to a limited amount of variable costs of about Rs.1,100 per month (excluding tax and hafta). Thus variable costs seem not to be very important for the performance of the buyer.

Price fluctuations of recyclable waste, on the other hand, had a major impact on the buyer's performance. It should be noted, however, that the cost of the property is not taken into account. Given the high land value in Bombay, this may have a considerable impact. Despite the relatively high gross profit rates, there was fierce competition between buyers: 86% of the buyers experienced the competition from other buyers as a major threat to their performance. The majority of the buyer units (62%) were located in areas with a high concentration of other buyer units. As a result, several buyers (18%) consulted other traders in order to fix prices and negotiate on territories.

To model of the collection sector in Bombay, several parameters need to be determined. In order to make a clear assessment of the total impact of the buyers of waste in Bombay, knowledge of the number of buyers operating in Bombay is crucial. Based on the average

quantity of waste paper traded by a buyer in the paper cycle and the total volume of waste paper traded, it was estimated that approximately 360 buyers operated in Bombay. It is assumed that buyers themselves do not supply to factories, but to wholesalers only.

The wholesalers

The distinctive features of the wholesalers were that they traded one type of waste, operated on a larger scale than buyers, and supplied directly to the paper mills. This section is based on data collected during a survey among 37 waste paper wholesalers.

Profile of the wholesalers

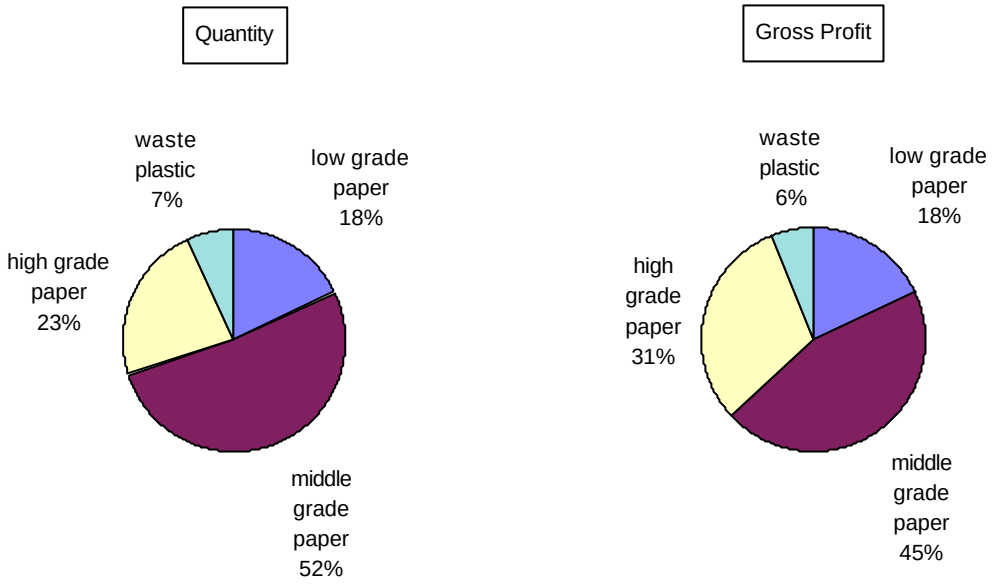
The majority of the respondents owned their company and the place of operation, while 35% operated from a rented location. This group comprised a relatively high representation of Muslims: 51 % Hindu, 43% Muslim and 3% Jain. The educational background of the wholesalers was generally higher than that of the buyers with 35 % enjoying primary level, 27 % secondary level, 14% undergraduate level and 3% graduated. The remaining 19% were exposed to some sort of informal education. More than half of the respondents entered the trade because it was traditionally practised by the family, while 32% claimed to have entered the waste trade for economic reasons. 11% of the wholesalers were former buyers and had expanded their businesses. The majority of the companies were established before 1985 (92%) of which 26% were established before 1965. There were not many recent entries to the sector.

The most important suppliers of waste to the wholesalers were buyers (39%), waste pickers (20%), factories (11%), institutions (23%), IWBs (5%) and households (2%). The location of the companies was generally (41%) in a commercial area, while industrial areas (24%), residential areas (24%) and mixed areas (11%) were less popular The reasons given by the respondents for these locations were the short distances to customers and suppliers, living in the area themselves and the existence of good facilities in the neighbourhood. Most of the wholesalers (78%) were located in an area where other wholesalers were active, including those specialising in plastics, glass and metals. The surface of the operating area varied from 50 to 400 sq. metres, with most wholesalers (62%) working from a surface area of less than 100 sq. metres.

Performance of the wholesalers

The average wholesaler had a monthly turnover of Rs.767,737. The monthly amount of waste traded by an average wholesaler was 382 tonnes, making the scale of a wholesaler unit much larger than the average buyer unit. The same applies to the gross profit which totalled Rs.170,076 a month, representing 22% of average turnover. Figure 7 illustrates the composition of the average waste paper wholesale trade. Most wholesalers traded in limited amounts of waste plastic. Middle grade waste paper constituted the major commodity for the wholesaler, the source for which was generally from households and institutions. The high grade paper, mainly comprised of white cuttings, originated from factories or printers. As can be seen from the distribution of gross profit this category provides larger profit margins. For example, the gross profit on white cuttings is Rs.3,025 per tonne while newspaper only generates a profit of Rs.850 per tonne for the wholesaler.

Figure 7. Composition of quantity and earnings of the waste paper wholesaler[1]



[1] - low grade waste paper includes kraft paper, mixed waste paper and corrugated paper;
- middle grade waste paper includes note books, , magazines and newspaper;
- high grade waste paper includes white cuttings, share forms, and office records.

As in the case of the buyers, the majority of the wholesalers claimed to experience a 'slack' period between June and September, when the monsoons influenced business. The majority of the units (65%) were open 7 days a week, while the remainder were active 5 or 6 days. In 3% of the units, employees worked up to 8 hours a day , in 68% 9 to 12 hours was the average working day, with longer hours in 19 % All these wholesaler activities provided work for an average of 7 employees per unit. The average salary of the employees in a wholesaler unit was approximately Rs.1,235 per month - higher than the wages in a buyers unit. The workers were paid on a monthly basis, again implying a more stable employer-employee relation than for the buyers. On average, the wage and electricity bill were respectively Rs.11,531 and Rs.386.

As opposed to the buyers, 86% of the wholesalers claimed to pay taxes which included sales tax and income tax. The percentage of sales tax varied from 4% to 6%, depending on the quantity traded, which would result in an average payment of Rs.52,885 per month. Hafta is also a common phenomenon in the wholesale trade. Wholesalers were generally well organised: more than 50% of the respondents had contracts with their suppliers in order to help prevent fluctuations.

Unfortunately the survey did not provide enough information to calculate the costs of transportation. The expectation is that transportation costs would cause a reduction in the profit margin of a few percentage points. The overall calculation (excluding transportation costs) leads to a net monthly profit of Rs.104,931, which corresponds with a profit margin of 14% on average.

In contrast to the buyers, competition was not mentioned as a trade constraint. Instead, power cuts, government interference and communication problems were cited as trade constraints by

the wholesalers. 16% of the wholesalers reported frequent contact with competitors for territory and price fixing. This suggests that there exists oligopolistic power among certain wholesalers. The total number of wholesalers can be estimated by dividing the total volume of waste paper traded by the average trade of a waste paper wholesaler. According to this approach Bombay appears to have around 67 wholesalers, implying a ratio of 7 buyers for every wholesalers. Estimates in Bangalore have revealed a slightly higher ratio (1:10) (Furedy 1994).

The Network Flow Model for the Waste Paper Supply in Bombay

To structure the waste paper flow of Bombay, a *simulation model* is developed. The main purpose of the model is to asses the current situation for economic, social and environmental characteristics and to analyse the impacts of changed circumstances or policy measures. Three main scenarios are presented: a baseline scenario, a scenario with the introduction of a Western recycling system, and a scenario in which the current informal system is improved. These scenarios are elaborated in the following sections. Crucial to the success of a particular management option is the willingness of the Bombay public to separate waste. Because this information is not available, a range (5) of exogenously determined public responses are simulated. Based on this exercise, it is possible to identify the optimal management measures under varying responses from the public. Including the baseline, 11 scenarios are assessed.

The time span of the analysis runs from 1993 to 2010. This period is sufficiently long to demonstrate the short and mid term effects of certain policy measures. Extension to the time horizon would be inappropriate because extensive societal changes would negate the underlying assumptions. The results of the analysis will first be presented of each individual year. Given the uncertainties regarding the data on the informal recovery sector and the performance of the formal waste management, the reliability of the model is limited. Relative price changes or technological developments are not taken into account. Therefore, the outcomes of this model should be solely interpreted as an illustration of the possible effects of the simulated policies.

Finally, the outputs of the simulation model will be evaluated by application of *multicriteria framework*. No attempt is made to internalise the intangible effects. Economic valuation of these effects lies beyond the scope of this study.

The simulation model

A graphic representation of the model and its boundaries is given in figure 3. Note that the industrial recycling process of waste paper is ignored in this model. The evaluation criteria of the simulation model respectively represent employment (y_e), environmental impact (y_i), income inequality (y_p) and public costs (y_y) within the waste paper cycle. These criteria are driven by the physical allocation of waste paper after consumption. The configuration of this allocation is specified by:

$$y_n = f_n(x) = f_n(x_s, x_b, x_l, x_u, x_i, x_w),\ n = e, i, p, y$$

The variable x is the vector of six types of physical allocations of waste paper: storage (x_s), burning (x_b), landfill (x_l), re-use (x_u), informal recycling (x_i) and Western-style recycling (x_w). In the simulation the waste paper allocations are constrained within:

$$A = \{x_s, x_b, x_l, x_u, x_i, x_w\}$$

where

$$\forall x \in A, x \in S = \{ 0 \quad x \quad X; x_s + x_b + x_l + x_u + x_i + x_w = X \}$$

A represents the constraint set for the number of scenarios which are simulated. *S* represents the constraint set of the waste paper cycle. These constraint sets are described in the coming sections. A specification of the model is presented in appendix 1. The four evaluation criteria provide a general understanding of the economic, social and environmental aspects of the waste paper recovery cycle.

Total employment: Employment is expressed in labour-years. The allocation of waste paper determines the composition of the actors involved in the waste paper recovery cycle. These actors include households, institutions, factories, waste pickers, IWBs, buyers, wholesalers, municipal disposal workers, and municipal recyclers; households, institutions and factories are excluded from the workforce because collection of waste paper forms a negligible part of their productive time. Because the model is limited to the waste paper cycle, the employees of the waste management department of the Bombay municipality (MCGB) are included only for the amount of waste paper which they collect. Similarly, waste pickers, buyers and wholesalers are included in the employment calculation for the part of their time they spend on the collection of waste paper. It should be kept in mind that the total group of people that depends on waste collection is much larger than the employment figure calculated in the model because the other waste flows are ignored. Formally the "employment" criteria is:

$$y_e = \sum_a e_{a,t} \qquad (1)$$

where $e_{a,t}$ denotes the number of persons employed in a certain type of work *a* in period *t*. A detailed description of the employment function is given in appendix 1.

Environmental impact: The environmental impact of the recovery sector derives from transport of collected or disposed waste paper, burning of waste paper and the landfilling of solid waste. Note that burning is different from incineration: it is only practised to reduce volume, no energy is recovered. As mentioned, the indirect effects of waste paper recovery such as savings on industrial energy and preventing deforestation, are excluded. To calculate the environmental impact, environmental indices are calculated based on the methodology presented in Weaver *et al*. (1995) (see appendix 2). First, the emissions generated by the processes in the waste paper recovery cycle are translated into six environmental problems (global warming, human toxicity, ecological toxicity, photochemical oxidation, acidification, nitrification and solid waste). Next, assuming equal importance of the six environmental problems, environmental indices are designed for each process. These indices on a per unit bases are presented in table 2. Consequently, for each scenario in the waste paper cycle an environmental score is generated. Formally, the environmental" criteria is:

$$y_i = \sum_j i_{j,t} \qquad (2)$$

where $i_{j,t}$ denotes the environmental impact of a process j in period t. A detailed description of the environmental function is given in appendix 1.

Table 2. Environmental indices for the processes in the waste paper recovery sector in Bombay

	unit	eco-index
transport by truck	per kg/km	0.0285
waste paper burning	per kg	10.7270
landfilling	per kg	7.6930

source: based on Virtanen and Nilsson 1993

Income inequality: In order to use the variable income distribution as a social indicator, the Gini-concentration ratio is calculated which is a numerical measure of overall income inequality (see appendix 5) (Gillis *et al*. 1987). The theoretical range of the Gini ratio is from zero (perfect equality) to one (perfect inequality). The group which is considered in this context excludes households and institutions. Included in the calculation of the Gini ratio is the group of people that loose their jobs. Formally the "income distribution" criteria is:

$$y_p = f(\gamma_t) \qquad (3)$$

where γ denotes the Gini-coefficient of a certain allocation of waste paper in period t. A detailed description of the income inequality function is given in appendix 1.

Public costs: Public costs for MCGB for the collection waste paper includes the wages of the civil servants, the costs of petrol and depreciation costs of the SWM equipment. In the case of the introduction of a Western waste paper collection system, the public costs will increase proportionally with the amount of collected waste paper by the municipality. Formally, the "public costs" criteria is:

$$y_y = \sum_j c_{j,t} \qquad (4)$$

where c_j denotes the public costs of a certain policy option j in period t. A detailed description of the public cost function is given in appendix 1.

Constraints

Consumption: Consumption is considered to grow with income and population. As explained, paper and paperboard consumption in Bombay is considered to be 20.4 kg per capita in the first period. The annual combined growth rate of population and income is estimated to be 5.91% (NEERI 1994). It is assumed that the sum of the post-consumption allocations (Σx_j) in period t is equal to the total consumption in Bombay over the period in Bombay. The definition function of the growth path of the total consumption and the sum of the post-consumption is:

$$X_t = 20.4 \cdot (1.0591)^t \qquad (5)$$

where X_t denotes the total consumption of paper in Bombay in period t.

Recovery: For reasons of long term storage, sanitary losses and technical limitations, the maximum recovery rate is 90% of the total consumption (Virtanen & Nilsson 1993).

$$(x_{u,t} + x_{r,t} + x_{w,t}) < 0.9\ X_t \qquad (6)$$

where $x_{u,t}$ denotes waste paper recovery for re-use, $x_{r,t}$ denotes informal waste paper recovery for recycling, and $x_{w,t}$ denoted formal recovery for recycling in period t.

Reuse: With growing income, reuse of waste paper declines. Quality demands of society increase so that, for instance, newspapers are no longer considered hygienic packaging material. Therefore, the share of waste paper which is diverted for reuse is assumed to halve over the period from 1993 to 2010. This implies the total volume of re-used waste paper ($x_{u,t}$) will grow proportionally less (1.67%) than the volume of paper consumption (5.91%) each year. This is denoted as:

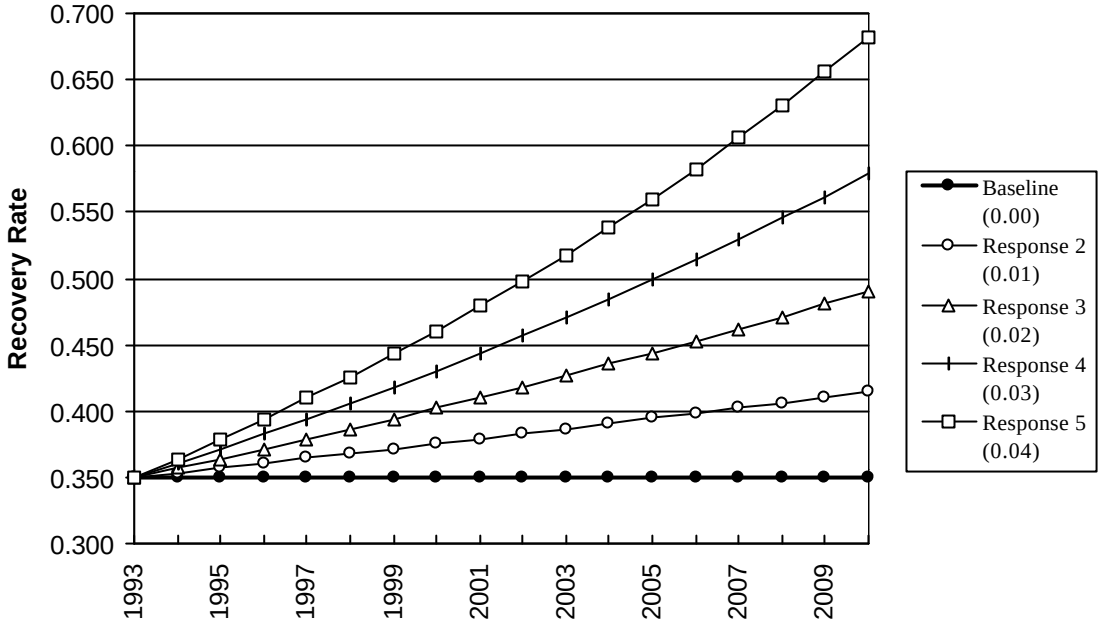
$$x_{u,t} = x_{u,t-1} * 1.0167 \qquad (7)$$

Responsiveness: A key feature in the analysis of the management alternatives is the effectiveness of a particular policy measure. Because an important instrument is the encouragement of consumers to separate the waste, success largely depends on societal response to recycling campaigns. A case study in Hong Kong demonstrated that despite a generally positive attitude in terms of willingness to improve recycling behaviour, in practise the success of a recycling campaign cannot be guaranteed (Chung and Poon 1994). Therefore, five different levels of responsiveness are exogenously defined to simulate the different degrees of success of the recycling campaigns. The responsiveness modifies the growth rate of the total waste paper recovery.

$$R_{R,t} = R_{R,t-1} \cdot (1 + á) \qquad (8)$$

where $R_{R,t}$ denotes the overall recovery rate, which is the sum of the reuse rate ($r_{u,t}$), the informal recycling rate ($r_{r,t}$) and the formal recycling rate ($r_{w,t}$) in period t. The á represents the response of society. A responsiveness parameter of á=0.05 implies that a particular management effort would lead to an annual growth of the recovery rate of 5%. Figure 8 illustrates the impact of the different degrees of responsiveness of the public to policy measures on the overall recovery rate.

Figure 8. Recovery rate developments with varying responses (1993-2010)



Policy measures and public costs: Ignoring the economies of scale, the standard municipal costs on labour, capital and fuel for collection of solid waste, are considered constant at Rs.998 per tonne (NEERI 1994). A Western waste paper collection system requires a significant starting investment to eg distribute waste paper containers and set up a special department for co-ordinating these activities. Therefore, an annual fixed costs component of Rs.146 million is assumed with an additional cost component of Rs.1,079 per tonne. The net costs will decrease with increasing success of the policy because the collected materials generate revenues as these are sold at market prices. It is assumed that for the first two years, government agencies are encouraged to comply with the new system. As a result the paper collected by the new system increases in the first two years to 10% of the total waste paper consumption. After this, the "Western" recovery rate will grow depending on the responsiveness of the public.

The annual fixed costs of the informal policy mainly comprises an intensive media campaign targeted at consumers and is estimated at Rs.20 million. Because the benefits of this policy will accrue to the informal sector, no direct income is generated for the public sector. Yet, the costs avoided for collecting disposed waste can create an indirect reduction of overall public costs. In a situation where the response of the public is absent, the public costs will increase with the budget spent on the public campaign. Sales tax payments of the waste paper traders are ignored as available data are unreliable.

Simulation results

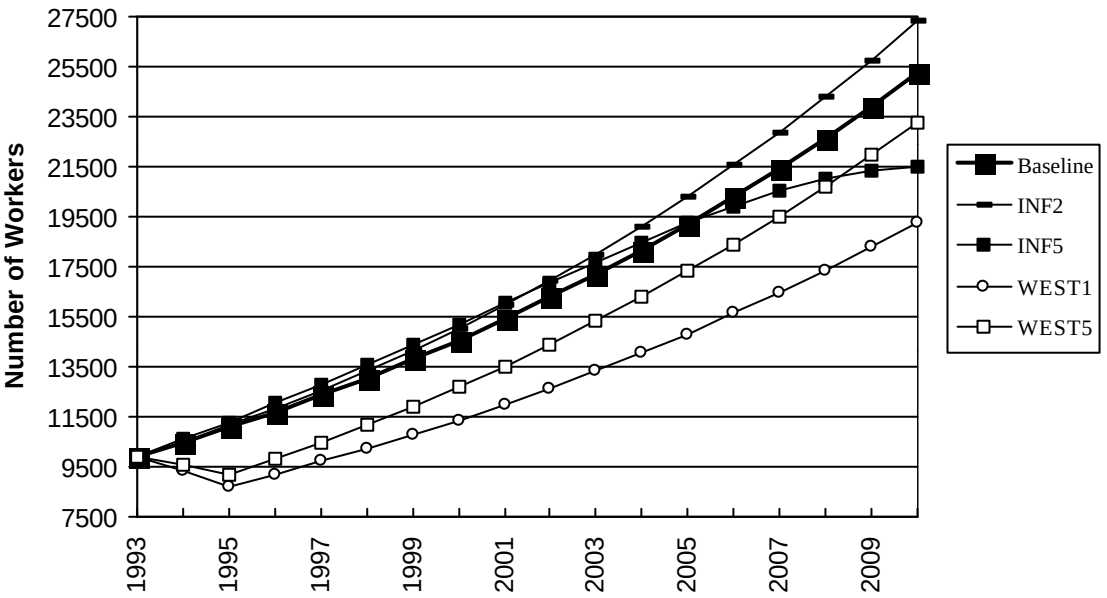
The simulation model is mainly for illustrative purposes. The coefficients in the model have been calculated from the field survey and therefore represent sample averages. Other coefficients are derived from literature or expert opinions and thus do not necessarily reflect population averages. Yet, as the field samples are drawn randomly and the applied literature is reliable, no systematic errors are expected. Therefore, it may be assumed that the model sufficiently meets the purpose of demonstrating the possible effects that derive from policies aimed at increasing

the recovery of waste paper in Bombay. These economic, social and environmental effects are discussed separately. The outcomes are presented graphically. For reasons of convenience, only those development paths are illustrated which generate a maximum or a minimum result. Unless presented otherwise, the baseline coincides with the "informal policy without public response" path (INF 1).

Employment

Figure 9 illustrates the outcomes of total employment in the local waste paper collection cycle in Bombay. One should realise that employment for overall waste collection is much larger. Not surprisingly, each development path eventually leads to higher levels of employment. This is the logical result of increasing levels of waste generation in Bombay. More people will get involved in the recovery or landfill of waste paper. Two interesting features arise. First, in the Western style scenario the level of employment drops immediately after the introduction of the new collection system. This is caused by the autonomous increase in waste paper supply by government agencies to the formal collection system which otherwise would have created employment in the informal sector. In the beginning labour intensity in the informal sector is higher than in the formal collection sector. In other words, in the short term crowding out of the informal sector will occur which will significantly reduce employment.

Figure 9. Total employment in the waste paper collection cycle (1993-2010)



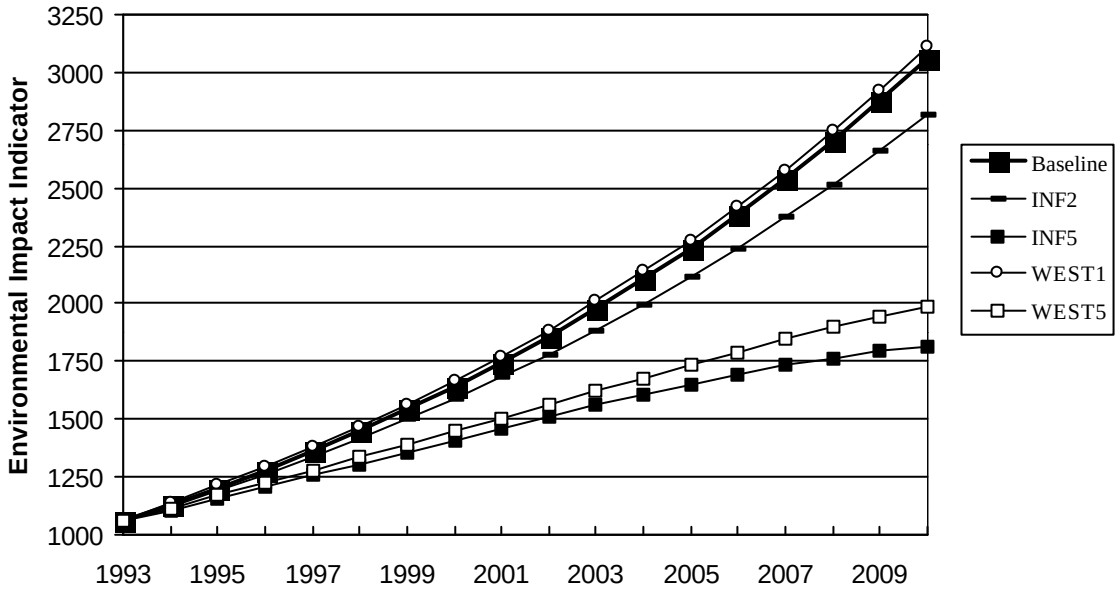
Second, it may be seen that in the long term it is not clear which policy option creates more employment; in the short run, the informal sector benefits most. More buyers and wholesalers, who in turn employ labourers, can operate in the waste paper market. In the longer term, however, this effect is offset by the fact that waste pickers and disposal workers will find less waste to collect because households and institutions start to separate their waste instead of disposing it. This effect can clearly be seen in the curve of the informal policy with maximum public response in figure 9. Relative employment will eventually decline because higher levels of separation result in less employment for the waste pickers and disposal workers. Efficiency improvement reduces employment in the collection sector. Therefore, employment is at its maximum in the scenario with informal policy measures and low public response. In appendix

4, the changes in the configuration of employment of respectively the baseline scenario, the informal scenario and Western style scenario with maximum public response, are presented for the period 1993-2010.

Environment

Figure 10 presents the environmental effects of the various scenarios in the paper collection cycle. Clearly, environmental quality decreases in time because more consumption leads to higher levels of waste generation. In turn the waste is collected and landfilled, which has additional negative environmental implications. This is demonstrated by the upward slopes of the development path, indicating increasing environmental impact over time. For the environment, the baseline scenario is almost the worst development path. In other words, a recovery policy is required to prevent environmental damage. Only in the case of a Western collection system and no response of the public does the environment deteriorate more than without policy measures. This is the result of the autonomous supply of waste paper by governmental agencies to formal recyclers which have a more fuel-intensive collection practise than the informal sector.

Figure 10 Environmental quality in the waste paper collection cycle with varying public responses (1993-2010)



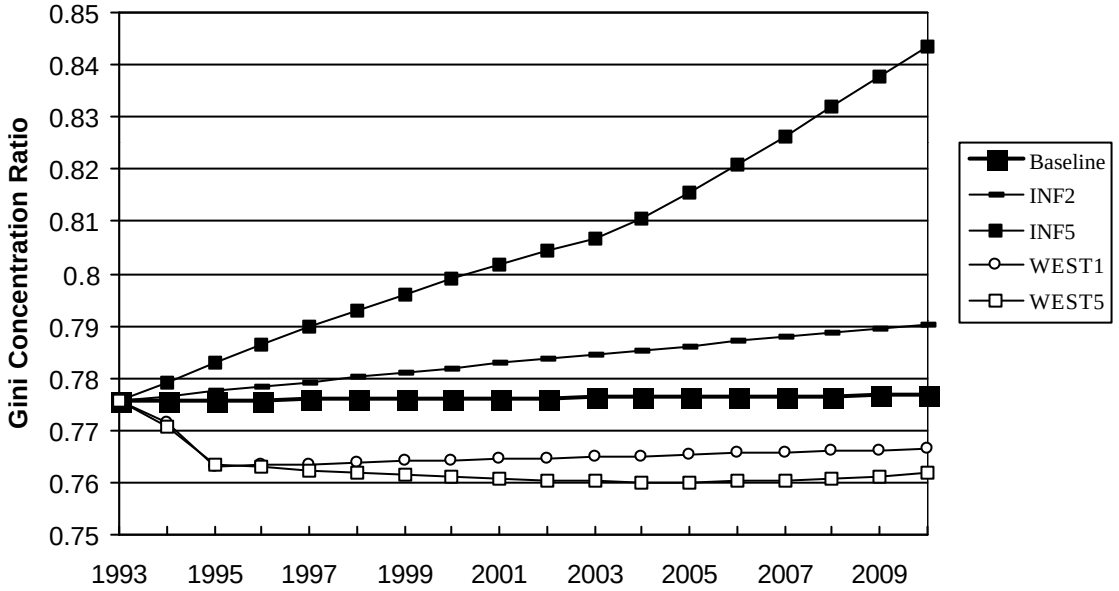
All the other scenarios are more desirable than the baseline scenario. In absolute figures, landfilling is considered the major environmental effect in the cycle (see appendix 3). Public response therefore plays an important role: the more paper is diverted from landfilling the better. On a per unit basis, waste paper burning is the worst practise in the cycle (see table 2). Note, however, that in this study waste paper burning is assumed to remain constant over time at a rate of 10% of the total waste paper generation. Interactions between policy measures and burning are thus ignored. Yet, even at this low rate, waste paper burning contributes significantly to environmental damage. Also transportation activities cause problems. In the Western style scenarios in particular, damage from transport is important. In appendix 3, the changes in the configuration of causes of environmental problems for the period 1993-2010 are illustrated for

respectively the baseline scenario, the informal scenario and Western style scenario with maximum public response.

Income inequality

Figure 11 illustrates the developments in income distribution in the waste paper collection cycle with varying public responses for the period 1993 till 2010. The foregone income by the waste pickers who loose their jobs as a result of a particular policy are taken into account. Also the income of the formal recovery worker who enters the sector in a Western collection system is included in the analysis. The most unequal income distribution is noted by the value 0.843 and the most equal distribution has a value of 0.760.

Figure 11. Income inequality in the waste paper collection sector with varying public responses (1993-2010)



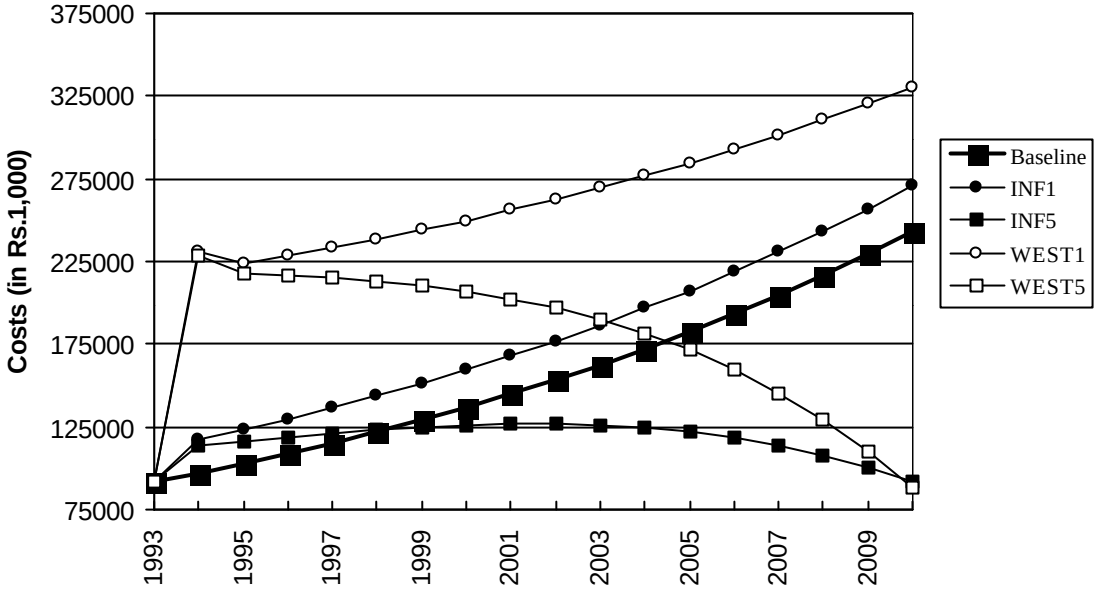
The informal policy scenarios are characterised by increasing inequality of income distribution. This is the caused by the relatively decreasing employment of the waste pickers while the wealthy traders become more important. For the Western style policy, income distribution moves in the opposite direction. The sudden decrease of these distribution curves is typical. This marks the entering in the labour market of the formal collection workers. Compared to the waste pickers, these workers are relatively well paid. Therefore the development path of the Western policy lies below the baseline scenario which indicates less income inequality. In appendix 5, an explanation is given for the Gini concentration ratio.

Public costs

Figure 12 illustrates the developments in public costs in the waste paper collection cycle with varying public responses for the period 1993 till 2010. The scenario with the least public costs is indicated by a score of Rs.7.6 million and the most costly situation implies public costs of Rs.32.6 million in 2010. The baseline scenario curve indicates that without policy, public costs will increase continuously in the future. These costs are caused by greater waste collection and landfilling efforts. Yet, a few scenarios lead to higher public costs than the baseline development. These cases are characterised by low public response. Although efforts are made to reduce the amount of disposed waste, no significant reduction is felt in terms of

landfilling. Nor does the Western collection system generate sufficient income from collected waste paper.

Figure 12. Public costs in the waste paper collection sector with varying public responses (1993-2010)



Another striking feature in figure 12 is the sudden increase in public costs with the introduction of a Western collection system in 1993/94. Obviously, the initial investment is much higher than for the informal policy where efforts are mainly focused on campaigns to encourage separation. A complex and voluminous infrastructure must be set up and maintained. The formal policy can therefore only be successful under conditions of maximum public response. This is illustrated by the curve "West 5" which reaches a public cost level of Rs.7.6 million in the year 2010. One should realise however that the informal policy reaches its break even point in a much earlier stage, under the condition of a public response parameter (á) exceeds zero. Thus, the net present value of the informal policy is higher than the formal policy, despite the fact that with maximum response the formal policy scores better in 2010. If the model accounts for the potential tax payments by the informal sector, this policy turns out to be more favourable than a Western collection system.

The evaluation model

The main purpose of the evaluation model is to select one alternative on the basis of its overall value score. This "weighed additive value function approach" involves several steps (Keeney 1992). First, the separate evaluation criteria need to be aggregated over time. Second, value functions are applied which associate a value between 0 and 1 with each criteria score in the range. The 0 and 1 values represent respectively the worst and best situations considered. This normalisation step facilitates comparison between the different discounted evaluation criteria. Finally, hypothetical weights are attached to combine the separate evaluation values into a single score. The outcome of this analysis is shown in table 3, and an explanation of this table is given below.

Table 3. Discounted scores of the separate and combined criteria

	Public Costs	Total Employment	Environmental effect	Income distribution	Average value*	Overall rank
Baseline	0.82	0.83	0.06	0.68	0.599	6
INF1	0.66	0.83	0.06	0.68	0.557	7
INF2	0.73	1.00	0.26	0.52	0.627	5
INF3	0.81	0.90	0.48	0.34	0.632	4
INF4	0.90	0.85	0.72	0.16	0.659	3
INF5	1.00	0.78	1.00	0.00	0.694	1
WEST1	0.00	0.05	0.00	0.92	0.243	11
WEST2	0.07	0.00	0.08	0.95	0.275	10
WEST3	0.22	0.23	0.39	0.99	0.457	9
WEST4	0.31	0.35	0.60	0.98	0.560	8
WEST5	0.45	0.45	0.86	1.00	0.688	2

* equal weighs for criteria

For the aggregation of the evaluation criteria over time different approaches are followed, ranging from discounting to simple summation. Because of its monetary nature it is legitimate to discount the public costs over the period 1993-2010. Using a 10% discount rate (Hadker *et al*. 1995), the lowest present value is reported for the scenario "Inf 5". In this scenario, the additional public investments for increasing recovery are limited while at the same time the avoided costs for the municipality are at a maximum as a result of the high recovery of waste by the public. Sensitivity analysis shows that the "public cost" ranking order is not very receptive for the discount rate selected. Only with a discount rate smaller than 2% "West 5" dominates the result of "Inf 1", because the former scenario generates significant revenues in the future. The conclusion for public costs criteria is therefore that the introduction of Western recycling system is by no means a costs saving solution. With the informal recovery policy, public cost reduction will already be achieved if the societal response leads to an annual recovery rate growth (α) of more than 1%. Such conditions are not ambiguous in most large cities in India.

For employment, the employment levels over the period are aggregated. From the ranking two conclusions can be drawn. First, it is clear that the Western policy generates much less employment than the informal policy. This is mainly caused by crowding out the informal sector. Yet, if the response of the public is positive formal employment will gradually increase because the labour intensity of Western recovery is higher than landfilling. As a result, in scenario "West 5" the level of employment eventually exceeds the level of scenario "Inf 5". For the informal policy an adverse relation between employment and response exists. The more successful the recycling campaign, the less employment is generated. More and more waste pickers will loose their employment as households start separating their waste and sell it directly to the informal traders. Recyclable materials become harder to find in the municipal waste. Typically, scenarios

"Inf 2, 3 and 4" score better averages than the baseline because the extra employment gained in waste trade exceeds the employment lost in landfilling and waste picking.

Environmental impact is ranked based on annual averages. The relationship between response and environmental impact is very strong. Regardless of the type of policy, higher public response leads to lower environmental impact. Therefore, formal and informal policies score alternately in the environmental impact criteria. The best score is registered for the informal policy because this scenario is less transport intensive than a Western style policy.

Income distribution is ranked on annual averages. Similar to the employment analysis, the response rate has an adverse impact on income distribution for respectively the formal and the informal policy. For the latter policy, a high response leads to higher income inequality because the income of the relatively wealthy traders will increase additionally. Note that the waste pickers become unemployed as a result of a successful campaign. The Western recycling policy generates more formal employment if the response is high, while at the same time the informal traders are by-passed. Therefore, scenario "West 5" scores best for income distribution.

In order to determine which scenario or policy alternative has the best overall score, the objectives of the decision maker are specified by attaching weights to each of the separate evaluation criteria (Beinaut 1996). These weights represent the relative importance of one criteria compared to the other. By incorporating weights, the utility function can be written as:

$$U(Y) = w_e\, U(Y_e) + w_i\, U(Y_i) + w_p\, U(Y_p) + w_y\, U(Y_y)$$

where weights are indicated by w_x, x = e, i, p, y, and are normalised to add up to 1. Generally, weights can be determined from opinion polls and/or expert judgements. This is beyond the scope of this project. Therefore, for illustrative purposes, a combined score is composed based on equal weights of the various evaluation criteria. The results are presented in the last two columns of table 3. Obviously, this illustration provides an inappropriate representation of the preferences of policy makers from Indian cities. In most cases, public costs will be a more important criteria than, for example, income distribution. Also employment may probably be considered more important than the environmental impact of the different scenarios. A survey among policy makers who make waste management decisions could reveal the correct weights. Nevertheless, the column "overall ranking" is helpful in demonstrating that there is not one particular policy which dominates the others. "West 5" owes its second rank to its beneficial income distribution and the environmental characteristics. However, in general the informal policy option scores better.

Therefore, policy makers in developing cities should be reluctant to introduce a Western collection system unless they are sure about a significant positive response of the public. The change that the public in developing countries is anxious to voluntarily separate their waste without financial compensation is probably small. Therefore, it seems to better to do nothing (baseline) than to initiate a Western recovery system. Promoting informal recovery does seem to be a cost-effective policy in most cases. Unfortunately, this is rarely performed in developing cities.

Conclusions

With growing urbanisation and increasing per capita consumption, waste is becoming an urgent social problem in many developing country cities. Given the composition of the disposed waste, the solution to this issue will mainly lie in the choice between recycling and landfilling. So far, developing country efforts for improvement have mainly focused on the latter. However, as is theoretically illustrated in previous sections , the potential for solving the waste problem through enhancing recovery activities certainly deserves more attention. The local governments can play an important role in this process by initiating appropriate recovery policies. In this paper, the question is addressed whether these activities should follow the Western approach of recycling or whether an alternative "informal" policy would be more appropriate. For this purpose, case study research was undertaken on waste paper collection in Bombay, taking into account both the formal and informal sector. Indirectly, this analysis can also be applied to the problem of crowding out the informal sector through an increase in imported waste paper. In this section, conclusions are drawn with regard to the economic, social and environmental dimensions of these research questions.

Recovery of recyclable waste in Bombay is an activity which at present is mainly performed by the informal sector, with minimal participation by government agencies. The largest group in the informal sector is the waste pickers. Partly as a result of increased attention of the media, this group is generally seen as the figure-head of recycling in developing countries. Therefore, one would think that what is good for the waste picker is also good for the recycling sector. This notion is not completely true. Waste pickers are dependent on the recyclable waste which is disposed of by households and institutions. Policies aimed at improving waste recovery at the source will therefore have a negative impact on the waste pickers' activities. This dependency implies a trade-off between social costs on the one hand and economic and environmental gains at the other. Waste pickers are dependent on inefficiencies of society. Yet advantages for society occur with improved recovery of waste. Increased unemployment among waste pickers may be compensated by the growth in the demand for labour from the expanding waste trading network and recycling industries. Another social advantage would be that waste pickers would not have to perform low status and unhealthy work , although obviously having no job is a worse alternative. The most important lesson from this distinctive relationship is that NGOs and policy makers should not restrict their views to the well-being and functioning of the waste pickers, but obviously not ignore their present role either.

Another important group is the generators of recyclable waste, such as households, institutions and factories. The earlier the separation of recyclable materials from the main waste stream occurs, the better. This will prevent unnecessary contamination and damaging of valuable secondary resources. Also, with separation at source, social benefits can be achieved as it is often the poorer servants and caretakers who gain from this process. Obviously this results in positive environmental impacts due to diminished *entropy* of resources, and less waste is landfilled or burned. In fact, source separation also facilitates a higher degree of re-use, which is certainly placed high in the waste management hierarchy, and helps to upgrade the low quality of waste paper for the paper industry. The main question is how separation at the source should be promoted and how the public would respond to such policies.

A link in the informal recovery sector which receives only limited attention is the buyers and the wholesalers of recyclable waste. This trade network forms a solid foundation for improving the recovery rate. Replacement of this informal network with a Western collection system may have devastating effects. Fortunately, examples of such government interventions are scarce. Still, some municipalities in developing cities seriously consider the incorporation of expensive source separation systems. Given current levels of poverty, such Western systems which depend heavily on "consumer volunteerism" are bound to fail. Nevertheless, the municipal attitudes towards the informal recycling are discouraging. "The municipal officers support the concept of recycling, but their plans are at the level of installing composting plants and generating energy from waste" (Ali *et al*. 1993).

The simulation and evaluation models which were developed for the waste paper collection sector in Bombay enabled the evaluation of the introduction of two types of policies: a Western collection system and an "informal" policy scenario. Also an explanation is provided for the development path without policy intervention. The wide range of public response to the policies illustrates the importance of this parameter which is generally not taken into account sufficiently in waste management policy decisions. In most scenarios, the "informal" policy of encouraging the public to separate their waste and market it personally to the informal network, appears to be the better option. The Western collection system can only be successful if *voluntarism* is large in developing cities. Given the relatively high level of poverty in most urban areas, it can be expected that would consumers prefer to sell their waste to the informal network instead of supplying it for free to the formal collectors. Other policy options such as securing waste prices, or subsidising the informal sector were not analysed because of the impossibility of enforcing such policies in an unregistered sector.

Finally, the effects of increased importation of recyclable ` on the informal waste collection sector are assessed. The disadvantage of a market driven sector is the vulnerability to price fluctuations. Most local waste traders have sufficient margins in their trade to survive a recession. The most vulnerable groups in the informal sector are the waste pickers and the IWB who operate at subsistence level. Given the importance of these actors in the current system, a decrease in the price of waste might lead to significant damage in the recovery rate of recyclable waste. Not only can this result in a shortage of raw materials for the recycling industry, it also increases the solid waste burden in developing cities. This is another argument for improving the current system and reducing its vulnerability to price fluctuations. Encouraging consumers to sell their waste directly to the informal waste sector is a way of achieving this. Consumers will not be as sensitive to price fluctuations as waste pickers because their total livelihoods do not depend on it. The main issue, however, is whether waste imports will have an effect on the price of local waste. This question is addressed in Ramaswamy *et al*. 1996.

This paper focused predominantly on policies which directly address recovery of recyclable waste in developing countries. It is concluded that local governments can improve this process provided their policies build on the existing trade-networks and take into account the prevailing market forces. Only than can recovery rates increase which subsequently reduce landfill costs. Yet, besides policies which directly focus at the supply of recyclable waste, indirect policies stimulating local demand for secondary materials can be regarded as important tools. These demand policies, such as providing financial incentives to industries to use more recyclables or

designing government procurement specification to allow recyclable content, can have similar positive effects on recovery rates as direct supply-oriented policies.

Appendix 1

SET OF EQUATIONS

I. The Basic Model

$X_t = \sum_j x_{j,t}$ — j = s, b, l, u, w, r

$X_t = X_{t-1}(1 + \mu)$ — $X_1 = 204{,}000$; $\mu = 0.0591$

$r_{j,t} = x_{j,t} / X_t$

$r_{s,t} + r_{b,t} + r_{l,t} = R_{L,t}$

$r_{u,t} + r_{r,t} + r_{w,t} = R_{R,t}$ — determines $r_{r,t}$

$R_{L,t} + R_{R,t} = 1$

$R_{R,t} = R_{R,t-1}(1 + \acute{a})$ — $R_{R,1} = 0.35$; for á see below

$r_{s,t} = 0.1$

$r_{b,t} = 0.1$

$r_{u,t} = r_{u,t-1}(1 + \hat{o})$ — $r_{u,t} = 0.10$; ô = -0.04

$r_{w,t} = r_{w,t}(1 + \acute{a})$ — for $t > 2$, $r_{w,1} = 0.05$; $r_{w,2} = 0.10$

II. Employment

$E_t = E_{f,t} + E_{inf,t}$

$E_{f,t} = e_{l,t} + e_{w,t}$

$E_{inf,t} = e_{wp,t} + e_{iwb,t} + e_{be,t} + e_{we,t} + e_{bu,t} + e_{wh,t}$

$e_{a,t} = q_{a,t} / \mathring{a}_a$ — a = l, w, wp, iwb, bu, wh

$e_{e,t} = 1.2\, e_{bu,t} + 7.3\, e_{wh,t}$ — e = be, we

$q_{l,t} = x_{l,t}$

$q_{w,t} = x_{w,t}$

$q_{wp,t} = s^z_{wp,t}(x_{u,t} + x_{r,t})$ — $s^z_{wp,1} = 0.41$

$q_{iwb,t} = s^z_{iwb,t}(x_{u,t} + x_{r,t})$ — $s^z_{iwb,1} = 0.03$

$q_{rest,t} = s^z_{rest,t}(x_{u,t} + x_{r,t})$ — $s^z_{rest,1} = 0.56$

$q_{bu,t} = s^x_{bu,t}(q_{wp,t} + q_{iwb,t} + q_{rest,t})$ — $s^x_{bu,1} = 0.24$

$q_{wh,t} = s^x_{wh,t}(q_{wp,t} + q_{iwb,t} + q_{rest,t})$ — $s^x_{wh,1} = 0.76$

$s^z_{wp,t} + s^z_{iwb,t} + s^z_{rest,t} = 1$

$s^x_{bu,t} + s^x_{wh,t} = 1$

$s^i_{a,t} = s^i_{a,t-1}(1 + \eta_a)$ — a = l,w,wp,iwb,bu,wh,rest; for η_a see below

III. Environment

$I_t = i_{b,t} + i_{l,t} + i_{tr,t}$

$i_{b,t} = \phi_b \cdot x_{b,t}$

$i_{l,t} = \phi_l \cdot x_{l,t}$

$i_{tr,t} = \phi_t (x_{u,t} \cdot d_{u,t} + x_{r,t} \cdot d_{r,t} + x_{w,t} \cdot d_{w,t} + x_{l,t} \cdot d_{l,t})$ — $d_{u,1}=15$; $d_{r,1}=50$; $d_{w,1}=75$; $d_{l,1}=20$

$d_{j,t} = {}_{dj,t-1}(1 + \beta)$ — j = u,r,w,l; $\beta = 0.021$

IV. Public Costs

$C_t = c_{l,t} + c_{inf,t} + c_{f,t}$

$c_{l,t} = 998\, x_{l,t}$

$c_{inf,t} = c_{inf,t-1}(1 + \grave{U})$ — $c_{inf,1} = 20{,}000$; $\grave{U} = 0.02$

$c_{f,t} = 145{,}669 - 1080\ x_{w,t}$

V. Income Distribution

$\gamma_t = \int A / \int (A+B)$ for A and B see below

$\int A = \int (A+B) - \int B$

$$\int B = \sum_{a=1}^{9} e_{a,t} \{ \sum_{b=1}^{a-1} y_{b,t} + 0.5 \cdot y_{a,t} \}$$ a = eu,wp,iwb,we,l,w,bu,wu

b = eu,wp,iwb,we,l,w,bu,wu

$$\int (A+B) = 0.5 \cdot \{ \sum_{a=1}^{9} e_{a,t} \cdot \sum_{a=1}^{9} y_{a,t} \}$$ a = eu,wp,iwb,we,l,w,bu,wu

$y_{a,t} = e_{a,t} \cdot w_a$ a = eu,wp,iwb,we,l,w,bu,wu

Table 4. Parameters values for different scenarios

	Base-line	Informal Policy					Formal Policy				
		Inf1	Inf2	Inf3	Inf4	Inf5	West1	West2	West3	West4	West5
α^*	0.00	0.00	0.01	0.02	0.03	0.04	0.00	0.01	0.02	0.03	0.04
η_{wp}^{**}	0.00000	0.00000	-0.00140	-0.02190	-0.03760	0.05270	-0.00750	-0.00750	-0.00750	-0.00750	-0.00750
η_{iwb}^{*}	0.00000	0.00000	0.01000	0.01750	0.02500	0.03000	0.00000	0.00000	0.00000	0.00000	0.00000
η_{rest}^{**}	0.00000	0.00000	0.01000	0.01750	0.02500	0.03000	0.00500	0.00500	0.00500	0.00500	0.00500
η_{bu}^{**}	-0.00580	-0.00580	0.00000	0.00530	0.01020	0.01470	-0.01230	-0.01960	-0.02790	-0.03770	-0.04950
η_{wh}^{**}	0.00173	0.00173	0.00000	-0.00178	-0.00359	-0.00546	0.00343	0.00510	0.00673	0.00833	0.00991

* α is the annual growth rate of the overall recovery rate

** η_a is the annual growth rate of the share of actor a in the supply or trade of waste paper

SYMBOL DEFINITIONS

Meaning of Variables

X_t		total paper consumption
$R_{j,t}$	j = R,L	process categories
$r_{j,t}$	j=s,b,l,u,w,r	process rates
$x_{j,t}$	j=s,b,l,u,w,r	process quantities
E_t		total employment
$E_{j,t}$	j=inf,f	employment per worker group
$e_{a,t}$	a=l,w,wp,iwb,be,we,bu,wh	employment per sub-worker group
$q_{a,t}$	a=l,w,wp,iwb,be,we,bu,wh	quantity of waste paper per sub-worker group
$å_a$	a=l,w,wp,iwb,be,we,bu,wh	productivity per worker in sub-worker group
$s^s_{a,t}$	a=l,w,wp,iwb,bu,wh; s=z,x	share of sub-worker group in worker process s
I_t		total environmental impact
$i_{j,t}$	j=b,l,tr	environmental impact of processes
$d_{j,t}$	j=u,r,w,l	distance of related to process
C_t		total public costs
$c_{j,t}$	j=r,inf,f	public cost of policies
γ_t		Gini coefficient

$y_{a,t}$	a=ue,l,w,wp,iwb,be,we,bu,wh	income of work group
$y_{b,t}$	b=ue,l,w,wp,iwb,be,we,bu,wh	income of work group
$e_{a,t}$	a=ue,l,w,wp,iwb,be,we,bu,wh	labour years of work group
w_a	a=ue,l,w,wp,iwb,be,we,bu,wh	wages of the actors in the work group

Meaning of Indices

	t:	time
Categories (R)	L:	"diverted from cycle"
	R:	recovered
Processes (x,r)	s:	storage
	b:	burning
	l:	landfilling
	u:	re-use
	w:	formal "Western" recycling
	r:	informal recycling
Worker group (E)	f:	formal
	inf:	informal
Sub-worker group (e)	l:	landfill
	w:	formal recovery
	wp:	waste pickers
	iwb:	itinerant waste buyers
	bu:	buyers
	wh:	wholesalers
	rest:	households, institutions, factories
Worker process (s)	z:	source separation
	x:	waste paper trade
Process activity (i)	b:	burning
	tr:	transport
	l:	landfilling
Policy (c)	l:	regular landfilling
	inf:	promote informal recovery
	f:	promote formal recovery
Income actors (y,e)	ue:	unemployed workers
	wp:	waste pickers
	be:	employees of the buyers
	iwb:	itinerant waste buyers
	we:	employees of the wholesalers
	l:	landfill
	w:	formal recovery
	bu:	buyers
	wh:	wholesalers

Appendix 2

Environmental Indices

The environmental impact of each process is expressed by an index. The following steps should be followed:

The first step is to build an *eco-balance* for each relevant process (e.g., transport, burning, landfilling) based upon an inventory of environmentally-relevant inputs (e.g., energy) and outputs (e.g., air emissions, solid waste). The fuel use in landfilling comes from the bulldozer operations. Table 5 depicts the inputs/outputs, related to the relevant processes linked to 1 tonne of waste paper.

Table 5. Eco-Balances

Transport by Diesel Truck in India (per km/ton waste paper)					
Input	unit		Output	Unit	
Energy	MJ	1.3379	Particles	kg	0.001259
			CO_2	kg	0.116476
			CO	kg	0.000626
			HC	kg	0.000313
			NOx	kg	0.001566
Fuel oil (light)	*kg*	*0.03148*	SO_2	kg	0.001259

Burning Waste Paper (per ton waste paper)					
Input	unit		Output	Unit	
Waste paper	kg	1,000	Solid Waste	kg	55.87609
			CO_2	kg	939.624
			CO	kg	1.39999
			VOC	kg	0.299334
			NOx	kg	1.500028
			SO_2	kg	1.300009

Landfilling of Waste Paper in India (per ton waste paper)					
Input	unit		Output	Unit	
Waste paper	kg	1,000	Particles	kg	0.0012592
Energy	MJ	1.3379	CO_2	kg	142.35658
			CH_4	kg	51.767331
			NOx	kg	0.00156613
			HC	kg	0.00031323
			SO_2	kg	1.300009
			CO	kg	0.00062645
			VOC	kg	0.299334
			Organic matter	kg	751.22513

Fuel oil (light)	*kg*	*0.03148*	Solid Waste	kg	55.87609

source: compiled from Weaver et al. 1995, Virtanen and Nilsson 1993

The second step is to prepare an *eco-profile* from the *eco-balances*. The significance of the different inputs and outputs depends upon their contribution to environmental damage. There are seven environmental problems which are relevant to the pulp and paper industry: global warming, photochemical oxidation, acidification, nutrification, and solid waste. The Centre of Environmental Studies in Leiden provides a scoring matrix which indicates the relative contribution of different emissions to each of these environmental problems (CML, 1992). This provides the basis for deriving an *effect-score* for each process in respect to each problem. Effect scores are normalized over global levels of emissions (Guinee, 1995) to provide an eco-profile for the process. The normalisation process converts the emissions into relative contributions to environmental problems by dividing the effect scores by the total extent of the relevant effect scores for a certain area and a certain period of time. The total extent of the relevant effect scores are applied on a global scale and are derived from Weaver *et al*. 1995.

The third step is to assign weights to the different kinds of problems to reflect their differing importance to society. Weaver *et al.* attach equal weights to the various problems. Whether the same weights should be applied for the Bombay waste paper cycle is not clear. From the perspective of the municipality, the weight for climate change is probably lower than for instance solid waste. Yet, from a national perspective this weight configuration is likely to be different. Since all processes are described in unit terms (e.g., per tonne of product), the *environmental index* is also a unit-based index. The metric is dimensionless and consistent so that the index can be used to develop an environmental objective function. The results of the eco-profile and normalization are given in table 6 for the various environmental problems.

Table 6. Eco-profiles and indices

Environmental impacts normalised with world score for KT*(1.0 E-9)	Global Warming	Human Tox.	Ecological Tox.	Photochemical Oxydation	Acidification	Nutrification	Solid Waste	**Average env. index**
	3.80E+13	5.80E+11	1.10E+14	3.70E+11	2.90E+11	7.50E+10	1.60E+12	**(equal weights)**
Transport	0.00307	0.00906	0.00000	0.17679	0.00812	0.00271	0.00000	**0.02850**
Burning	24.72696	4.73586	0.00000	0.00000	8.10345	2.60000	34.92255	**10.72700**
Landfilling	18.73151	0.00906	0.00000	0.17679	0.00812	0.00271	34.92255	**7.69300**

source: compiled from Weaver et al. 1995, Nilsson and Virtanen 1993, Rao 1989.

Appendix 3

Figure 13. Environmental Impact in Baseline Scenario

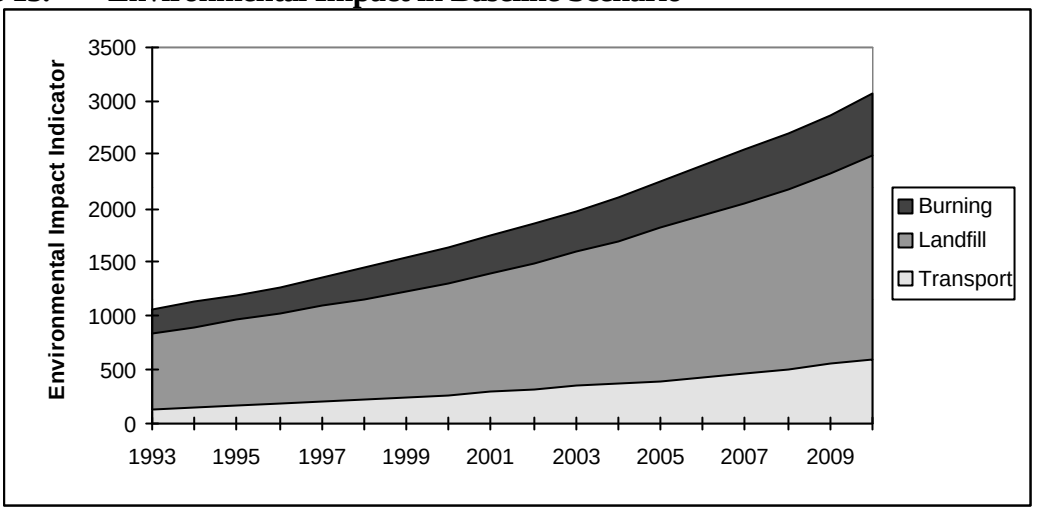


Figure 14. Environmental Impact with Informal Policy and high Public Response

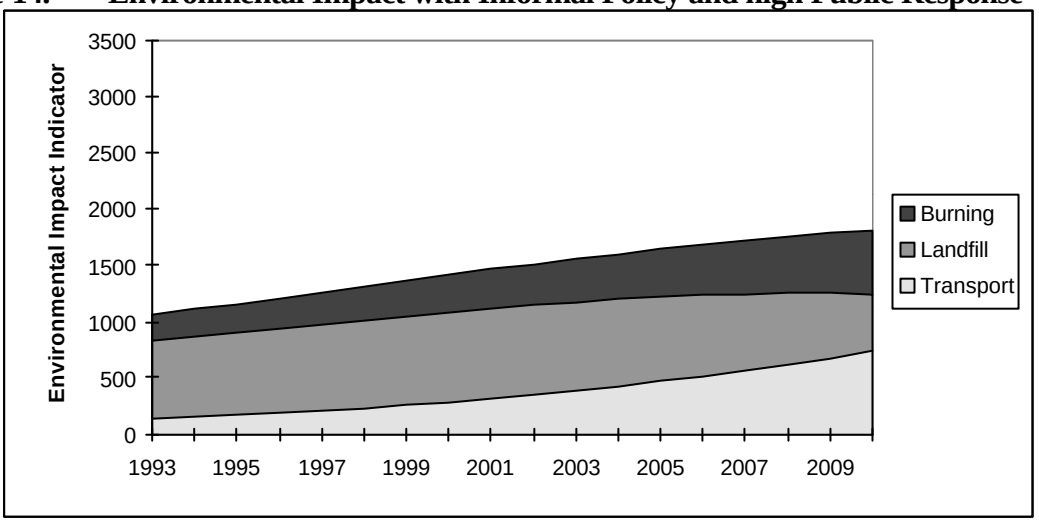
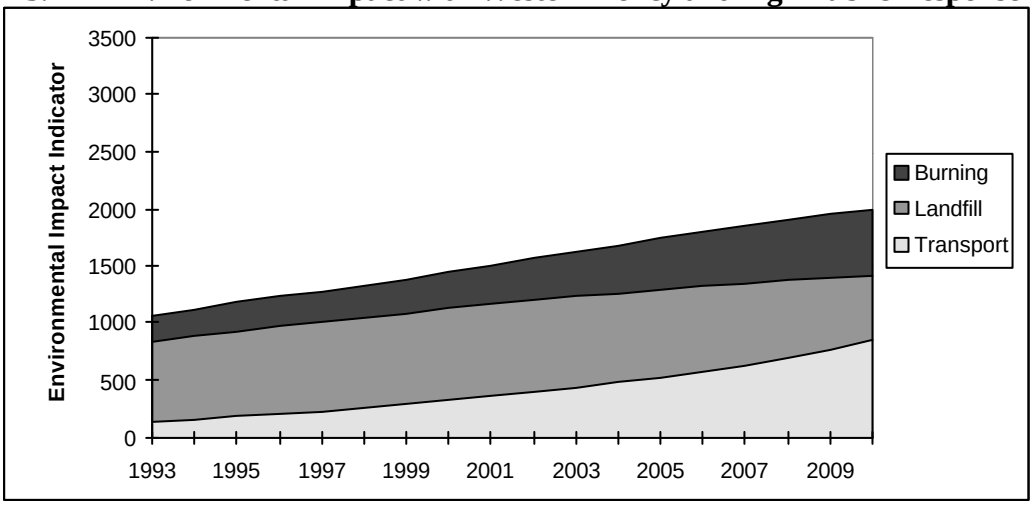


Figure 15. Environmental Impact with Western Policy and high Public Response



Appendix 4

Table 7. Labour distribution in the "baseline", the "informal", and the Western policy scenario with maximum public response in 2010.

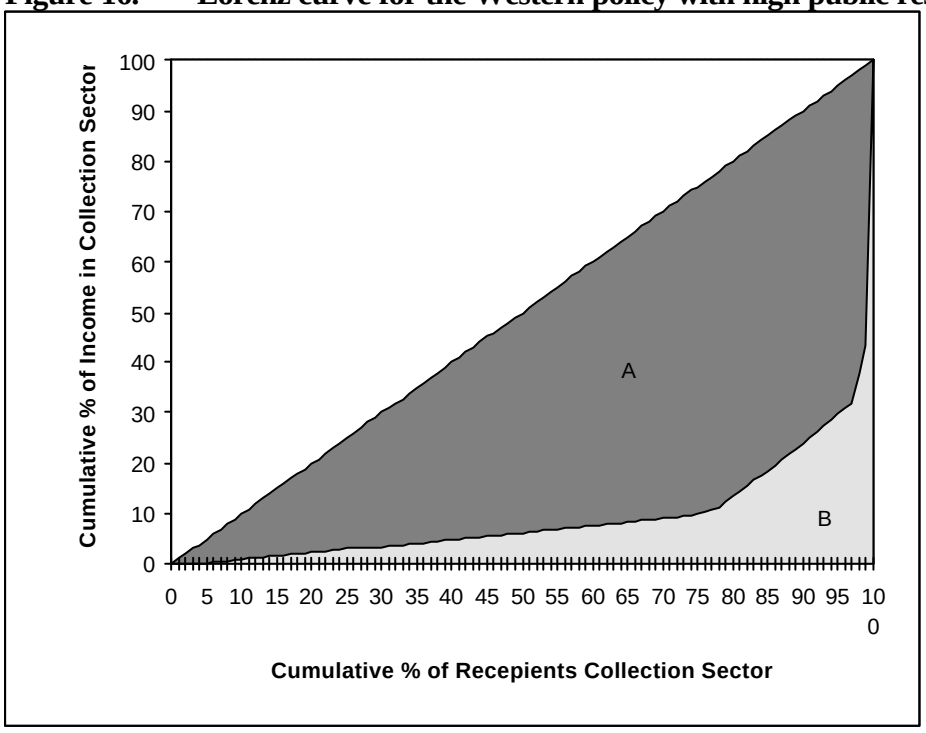
	Baseline		**West 5**		**Informal 5**	
	number	share	number	share	number	share
unemployed waste pickers	0	0.000	974	0.039	5233	0.180
waste pickers	18462	0.708	17487	0.708	13229	0.454
buyer employees	965	0.037	542	0.022	2714	0.093
IWBs	364	0.014	205	0.008	1694	0.058
wholesaler employees	1291	0.050	1631	0.066	2515	0.086
disposal workers	3993	0.153	1195	0.048	1049	0.036
formal recovery workers	0	0.000	1981	0.080	0	0.000
buyers	830	0.032	466	0.019	2336	0.080
wholesalers	182	0.007	230	0.009	355	0.012
Total	**26088**	**1.000**	**24711**	**1.000**	**29126**	**1.000**

Appendix 5

Gini-coefficient

The most common method for calculating income distribution is the Lorenz curve, which is illustrated in figure 16. To draw a Lorenz curve, income Recipients are ranked from the lowest income to the highest along the horizontal axis. The Lorenz itself shows the percentage of income accounted for by any cumulative percentage of recipients. The shape of this curve indicates the degree of inequality in the income distribution (Gillis *et al*. 1987). The curve must by definition touch the 45^{o} line at the lower left corner (zero percent of recipients must receive zero percent of income) and at the upper right corner (100 percent of recipients must receive 100 percent income). If all recipients had the same income, the Lorenz curve would lie along the 45^{o} line (perfect equality). The inequality of the distribution curve is greater the further it bends away from the 45^{o} line of perfect equality (the greater the shaded area A, the greater is inequality). The Gini concentration ratio is the value of area A divided by A plus B in figure 16.

Figure 16. Lorenz curve for the Western policy with high public response



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