

# Reverse Logistics Related to Waste Management with Emphasis on Developing Countries—A Review Paper

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**Abstract:** This paper provides an overview of the state of art of reverse logistics and current status of waste management problems with special emphasis on developing countries. Logistics activities have been practiced and played a fundamental role in the global economic development for over 5,000 years. It has then been transformed into different logistics branches and elaborates the emergency of reverse logistics as one of the most important. The paper presents the evolution of logistics into reverse logistics and how it relates to waste management both in the developed and developing world. Reverse logistics is a relatively new phenomenon in the research area which is mainly referring to damaged goods, the take back of products that should be returned to the manufacturers or distributors. Reverse logistics is relatively more practiced in an organized way in the developed world than in the developing countries in that the latter provided less value additions on reversed products.

**Key words:** Logistics, reverse logistics, waste, waste management, recycling, Uganda.

## 1. Introduction

The number of people living in urban settings worldwide is expected to be doubled between 1987 and 2015 [1], and nearly 86% of this growth is projected to take place in the developing world, with Asia holding the largest number of urban dwellers by the year 2025. Today, over 50% of the world population is living in cities and is expected to rise even higher in the next 50 years and will be more pronounced in the developing world where a 95% increase is projected [2]. High population density typically implies lower per capita cost of providing infrastructure and basic services.

In most developing countries, on average, one to two thirds of the solid waste generated is not collected [3]. The rapid population growth rate especially in the urban cities of the low-middle income countries

overwhelms most municipal authorities in the provision of basic services including waste management [3, 4]. This high influx of people in the urban areas of these towns has led to increasing amount of waste and the resulting disposal has been one of the major environmental and economic problems in most developing countries [1, 5].

The lack of enough resources has made it difficult to effectively implement municipal waste management policies [6]. In most low and middle income countries, especially in sub Saharan Africa and Asia, waste management budget is allocated a minimal amount and this is due to the fact that these countries are looking at solving other pressing issues such as hunger, health problems, water shortages, and unemployment [4]. A significant amount of the limited financial resources is needed to collect waste in urban areas thus leaving most of wastes poorly managed and uncollected and indiscriminately disposed off as shown in Fig. 1a. About 20% to 50%

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of municipal budgets of developing countries are consumed by waste management [7].

According to Pearce et al. [8], waste management in most developing countries is normally not extensive and efficient, commonly characterized by the use of old second hand vehicles which tend to break down along their routing, with worn out truck beds that litter the route roads with garbage being transported to the land fill and are not adapted to the local conditions as shown in Fig. 1b.

The objective was to review the state of the art in reverse logistics, and to determine the extent of reverse logistics and waste management activity in low income countries. It was also intended to consider the waste management aspects including generation rates, composition, collection, storage, reuse and recycling and final disposal.

## 2. Emergence of Logistics and Reverse Logistics

### 2.1 Development of Logistics

Logistics is normally used interchangeably with supply chain [9]. All the views and definitions synchronize logistics as the provision of actions such as procurement, production, sales, and distribution with demands. Logistics involves planning, creating and monitoring flows of goods and information. All the definitions encompass processes of moving and handling goods and materials, from the beginning to the end of the production, sale process and waste disposal, to satisfy customers and add business

competitiveness [9].

The elements of logistics have been existing for over 5,000 years back and list examples of this fundamental progress among others as including the introduction of the first mailing shipping service in Europe around 1500 AD, the invention of the sea-cargo container and the creation of novel service systems during the 20th century [10]. According to Lambert et al. [11], logistics started about 1,000 years ago as organized trade, then he went on to assert that the Americans in the 1900s used logistics through the distribution of farm products which can be seen now as time and place utility because these farm products were provided at the right place in the right time. In America, during the World War II, there was a need for effective and efficient storage and distribution of military supplies and these were key factors for the US army. The term logistics was very vital in all the activities of armed-force units in support of combat units, including transport, supply, communications, and medical aid [11, 12]. Recent logistics researchers point out a shift from military logistics to business logistics due to the trade-off between transportation and inventory costs (Ref. [12]).

Zuo et al. [13] described the emergence of logistics in three phases: before the mid-1990s, from mid-1990s to the start of the 21st century, and since the start of the 21st century. The first phase was so general and little was being done. In the second phase, from the mid-1990s, focus was directed to realities but it was still narrow. More complex models that use



(a)



(b)

**Fig. 1** (a) Poorly managed waste in Kampala city; (b) Common vehicle used for collecting and transporting of waste to the disposal site.

simulation method to solve logistics problems were employed. In the third phase, logistic research widened to incorporate a system method that analyses and integrate a number of models. In this phase, simulation methodology that designs and evaluates decision support system for effectiveness is also used.

Lambert et al. [11] noted that logistics allows and supports the flow of goods and services within an economy and this is done through:

- form utility through the manufacture of a good or the provision of a service for consumers to use;
- possession utility by adding value to a product or service so that the consumer is able to purchase it;
- time utility by providing an item when needed;
- place utility where an item or service is needed and provided.

The importance of logistics in an organization is being attributed to the concept of the market. The marketing concept derives its assumptions from the needs of the people. It is a customer driven perspective which is based on the ideology of producing what people need or demand. This concept is run by 4P principles as below [11]:

- product—set of utilities that a customer receives after purchasing the product;
- price—amount of money that the customer pays;
- promotion—selling and advertising the product to be known by the customer;
- place—availing the product at the right place and time.

### *2.2 Emergence of Logistics and Its Branches*

The emergence of the industrial revolution in the 18th and 19th Century led to changes in the agricultural, manufacturing, mining, transportation, and technology sectors and this had an effect on the socio-economic and cultural setting of people. This global occurrence started in the United Kingdom, through Europe, North America then spread globally. The rapid industrialization across Europe and increase in population led to a great increase in goods produced

as well as a demand for raw materials [14]. Waste generation especially of hazardous materials increased the impacted negatively onto the environment, hence the need to control disposal to ultimately helped protect the health of the growing population. This triggered the local and central governments later on joined by the private operators to engage in waste removal and recycling activities.

Logistics revolution has sparked businesses to become environmentally conscious [14]. Logistics branches (as shown in Table 1) are aiming at better quality of product-life, reducing waste and preserving natural resources. Global market demands, governmental regulatory pressures and consumer pressures are pushing businesses to become more sustainable [15, 16].

Blumberg [14] further asserted that several industrial countries in Europe enforced environmental legislation charging manufacturers with the responsibility for reverse logistics flows, including used products and manufacturing-induced wastes. Due to globalization, some companies such as IBM have gone ahead to carry on green logistics with facilities including interaction with suppliers, distributors and final consumers about the quality, proper disposal and product returns [11, 14].

It is from the integration of the green logistics that were mainly focusing on environmental aspects and the return back goods that there was the emergency of reverse logistics.

### *2.3 Emergence of Reverse Logistics*

Reverse logistics is a relatively new phenomenon in the research area mainly referring to damaged goods that should be returned to the manufacturers or distributors. Terms such as return logistics, retro logistics or reverse distribution are all used by many literatures to mean reverse logistics [19-21].

Reverse logistics is defined by Rogers et al. [22]: “The process of planning, implementing, and controlling the efficient, cost

**Table 1 The different logistics types and description.**

Logistics types	Description
Air freight logistics	Mainly relevant to high value and precious goods and perishable products that need to reach their destinations quickly. The services of air freight transportation are always high compared to the other modes of transportation.
City logistic	City logistics refers to logistic activities by organizations and companies in urban centers. It is characterized by high traffic, advanced information system, co-operative freight transport and public and private logistics terminals. However, city logistics is affected by problems such as increased traffic activities, congestions, noise, emissions and traffic accidents [17].
Construction logistic	This focuses on the efficient transportation of materials to the construction site to reduce on transport movements, reduce on stockholding, efficiency use of on-site labour, and generate less waste. This on the other hand will reduce construction time, improve quality, reduce risks to health and safety and also protect the environment [18].
Green logistics	Green logistics refers to minimizing the ecological impact of logistics, for example, reducing energy usage of logistics activities and reducing usage of materials. Green logistics is an increasing new emerging field that is spreading from the traditional forward logistic channel perspective [19, 20]. Green logistics is getting more attention from the supply chain management attributed to the deteriorating environment brought about by the increasing level of energy and pollution released into the ecosystems, high generation of waste and diminishing raw materials.
Lean logistics	Aims at eliminating waste (inventory) which affects the progress of work in process inventories and in turn will decrease process and cycle times and ultimately increase supply chain velocity and flow. When undertaken, lean logistics will improve inventory accuracy because storage space will be better utilized, products will be handled, moved, counted less and less damaged.
Manufacturing logistics	Refers to techniques that are developed by most firms in the supply chain aimed at efficiency and effectiveness for instance JIT (just in time) ideology.
Maritime logistics	Mainly associated with container shipping and involves an integration of maritime operations and supply chain management to meet the needs of regional, national, and international shipping. It is characterized with high carrying capacity.
Organization logistics	This is concerned with the entire management of firms or organizations both internal and external throughout the supply network, with primary focus on capacity of people to learn and share knowledge and information.
Retail logistic	Retail logistics gained recognition after the rise of the supply chain management. This was through the addition of value to products through manufacturing, branding, packaging, display at the store, and at each stage cost is added in terms of production cost, branding cost and overall logistics cost.
Reverse logistics	It is the process of planning, implementing and controlling the efficient cost effective flow of raw materials, in process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal.
Rural logistics	Refers to logistic activities that occur in the rural areas and spread to city centers aiming for market for supplying agricultural products.

effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal”. Reverse logistics is an integrated network structure of activities involving aspects of collection, inspection, sorting, pre-processing and the entire logistics and distribution [20]. It involves the backward flow of goods from the customer to a manufacturer aimed at adding value to the products returned and proper disposal [22].

The European Working Group on reverse logistics by De Brito et al. [21] defined reverse logistics as “the process of planning, implementing and controlling backward flows of raw materials, in process inventory,

packaging and finished goods from the manufacturing, distribution or use point of recovery to the point of proper disposal”. The European Working Group incorporates reverse logistics to include product recovery more to other product streams leading to another supply chain than to only products from consumers then back to the origin. De Brito et al.[21] further argued that the definition of Rogers et al. [22] just defined logistics and stressed that reverse logistics can be seen as sustainable development.

Reverse logistics has become an important service management activity involving the take back of products and the operations involved are more complex than the forward traditional logistic chain

[23-25]. The traditional forward flow of goods as put forward by Fleischmann et al. [26] involves the goods flow from the manufacturers to the final consumers yet reverse logistics moves the goods in the opposite direction that is to say from the customers to the point of origin or manufacture. The system is yet to receive much attention though it is still carried out by the unorganized sector for recyclable materials such as plastics and paper [20]. The effective and efficient product management in the manufacturing sector such as repair after sales services depend heavily on effective reverse logistics [15].

Reverse logistics put forward by Kopicki et al. [27] notes that the ultimate goal of a firm is resource reduction which includes minimizations of materials used and minimization of wastes and energy saved through the production of more environmentally efficient products. In the authors' work, the aim of the firm should be to reuse the materials followed by recycling of the waste to the maximum. It is crucial to note that at the end of the forward logistics chain, little attention was directed to what happens to the products at the end of the chain. Here focus is placed on the final disposal of waste at that point. In their discussion, Pokharel et al. [28] showed that reverse logistics has many aspects and abilities that differentiate it from just mere forward logistics. Reverse logistics is now being recognized as a driver of logistics and supply chain due to the increasing number of research publications in the subject.

Reverse logistics has gained a lot of popularity [29] and commonly has been used by automobiles [20] photocopiers and motor vehicle manufacturers [14]. The main concern is to establish the profit margin on whether the recovery of used products is economically viable than disposal. The value added onto the product could lead to increased customer services hence customer retention and sales [20]. This desired economic incentive by organizations and firms coupled with the ever increasing environmental awareness and customer expectations has greatly

promoted reverse logistics [30]. Economic incentives such as buy-back as put up by Fleischmann et al. [31] have induced higher revenue returns hence economies of scale. Dowlatshahi [29] asserted that reverse logistics has received a great deal of attention and increasing importance as a profitable and sustainable business strategy. The author emphasized that reverse logistics is a system that manages the flow of goods intended for remanufacture, recycle and disposal in the supply chain.

According to Pokharel et al. [28], reverse logistics has been a growing subject since the sixties but research done is still aimed and limited to network designs, production planning and environmental issues. The authors asserted that there should be integration of the subject in a much broader based perspective. They argued that reverse logistics should not only involve networking and inventory management but should also incorporate product collection, pricing, use, reuse and remanufacture through a conventional system. The conventional system should be set up in such a way that products are received in the right time, in the right place, the right price and the right quantities. This system if followed will lead to efficient, economically and environmentally sound remanufacturing of products than the production of new products.

The introduction of digital and high technology equipment on market meant that servicing, supporting and sub assembling these products had to take course down to the field and back to the manufacturer, repair, return to the field and final disposal [14, 25, 32]. More so, attention has been directed to the complex disposal of hazardous materials like toxic waste and industrial waste that could be recycled. Many high technology companies are increasingly interested in outsourcing reverse logistics activities to third party providers from a managerial point of view. And it has been shown by Cheng et al. [33] that companies that outsource their reverse logistic to third parties, their reverse logistics services have reduced to up 10% of

the annual logistics costs.

Reverse logistic activities, as classified by Rogers et al. [22], questions, whether the goods in the reverse flow are coming from the end user or from another member of the distribution channel or the material in the reverse flow is a product or a packaging material. When goods enter the reverse flow from the end user, chances are that the goods may be defective goods, or, the end user may have claimed it was defective in order to be able to return it. The authors stress that, all products in the reverse flow must be collected and sorted before being sent on to their next destinations. The customer may return goods that have not yet reached their end life for service/repair or due to manufacture recall. On the other hand, if goods reach their end of life, the customer may return the goods to the manufacturer for proper disposal or reclaim materials [14, 15].

Reverse logistics leads to competition of firms within the same industry causing the production of quality products and goods. Product disposal may no longer be a customer's concern basing on the fact that reverse logistics looks at the economics, environmental and legislative reasons. For instance, strict environmental and packing regulations have forced many firms to become responsible for the final residuals from the sale of products and goods [29].

In the last two decades and especially the nineties, there was the emergence of green laws in the European countries. These laws require the manufacturing companies of products to design and manage the ultimate disposal of certain products [14, 34]. In addition to that, the emergence of environmental legislations that required the return and proper disposal of wastes in accordance to the standard rules and regulations made it possible for the growth of reverse logistics for instance, the European Union Directive points out the basic waste management principles which require that waste should be managed without causing harm to human health and the environment. It incorporates waste prevention,

waste reuse, recycling, recovery and proper disposal [35].

E-waste has garnered public attention leading to policies and other efforts aimed to manage reverse supply chains for computers and other electronics. In Europe, the introduction of the WEEE (Waste Electrical and Electronic Equipment) Directive by the EC (European Commission) in 2003 which restricts the use of hazardous substances in electrical and electronic equipment and promotes the collection and recycling of such equipment [36] has given priority and supported the recycling of E-waste and hence reduced on its disposal in the environment. The Netherlands, Norway, Portugal, Sweden, Switzerland, Belgium, Denmark, Italy, Korea, Japan and Taiwan are countries that have already enacted the policy of take back of E-waste, the United States is on the move of enacting the mandate [37].

Linda [38] reported that the development of WIS (waste information system) tool in South Africa helped and supported the integration and implementation of waste reduction and pollution measures. The WIS acted as a government tool where workshops and information dissemination with key informants on waste issues were held on national level.

Banar et al. [39] used a LCA (life cycle assessment) tool to analyze different approaches that can be used to reach the required European targets on waste management in Eskisehir city, Turkey. LCA is a recent tool developed in the 1990s and currently used by many countries to analyze waste management options. In their study, the authors pointed out a solid waste management approach in a hierarchical format that involves prevention, minimization recovery, incineration and land filling. In waste management, planning is a very crucial aspect in identifying areas that need mitigation to solve environmental degradation notes [39].

In Portugal, Teixeira et al. [40] studied and came up with the model of improving recycling of paper,

plastics and metals. In the study, the author identified the route cycle for vehicles and the main objective was to minimize the total distance travelled by the waste collection vehicles and the route duration. Using a GIS (geographical information system) based tool to determine the distance travelled by the vehicle helped the authors to estimate the distances covered by the vehicles. With the application of the GIS tool, waste management operational costs improved and the level of service delivery rose.

Seadon [41] proposed a simple waste management system which integrated collection, transportation treatment and disposal including indirect impacts such as the use of waste materials for energy. The author noted that no single tool in waste management can work successfully on its own; there should be use of different management tools. A good integrated waste management system is one that involves the government, business and the community.

Dijkema et al. [42] in their work focusing on a new paradigm for waste management described waste as something that is experienced as or labeled a waste. What is considered as a waste to someone today may be a resource in the future asserted by the authors. They further point out that in recent industrial development, what is a waste in one industry may be a raw material in another industry. Waste to qualify to be branded waste is when it can not be put to its full potential use [42].

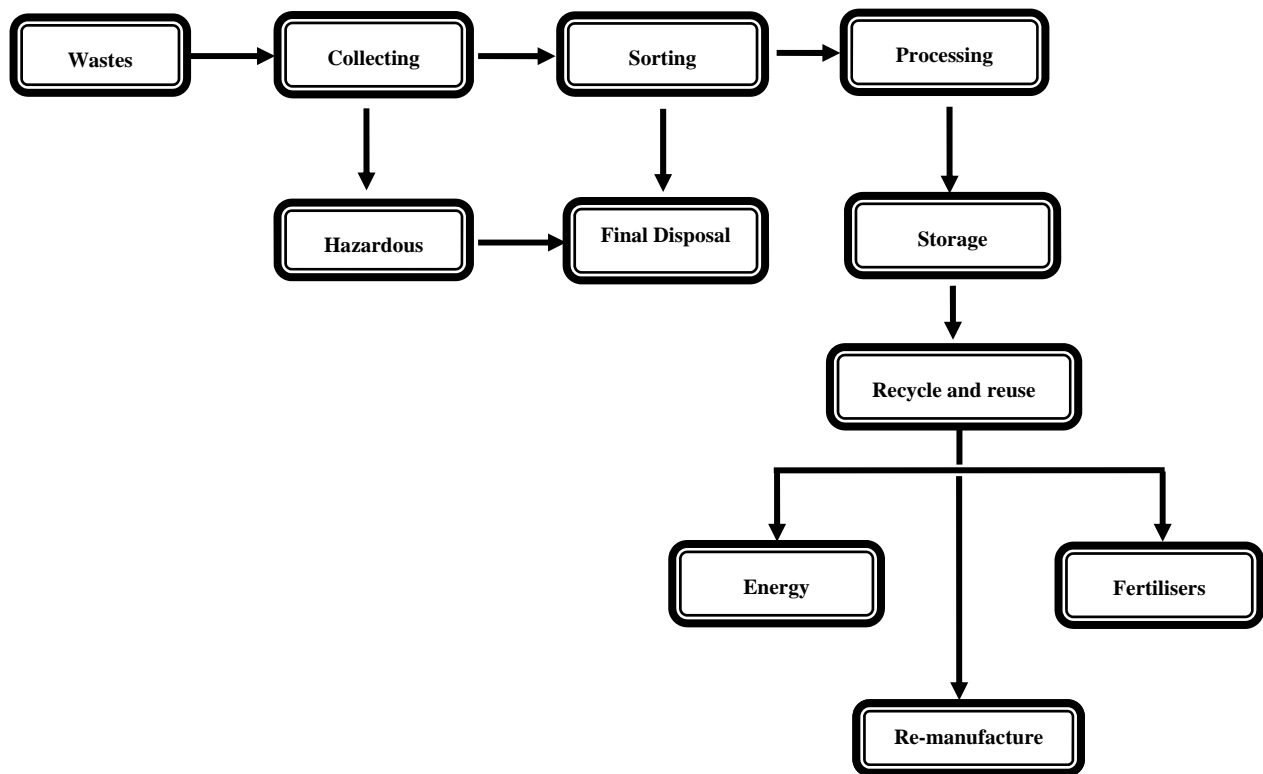
Reverse logistics of waste in Uganda is taking course as a result of partnerships of the private enterprises and the municipality. Recovering of reusable materials is undertaken by the informal people driven by poverty and the activity acts as a source of income to many poor communities. Waste that is recycled and reused includes plastics, metals, food wastes, polythene bags and sludge. There are no clear definitive conclusions that can be made on how much waste is recycled or reused due to the current lack of information. Reuse and recovery of materials and products is done by the scavengers who collect and sort out paper, scrap metal,

cardboards and plastics which they sell to private middlemen and plastic recycling companies.

### **3. Reverse Logistics versus Waste Management in the Developed and Developing Countries**

Reverse logistics differs from waste management in that it focuses on the addition of value to a product to be recovered and then the outcomes do enter a new supply chain while waste management involves mainly the collection and treatment of the waste products that have got no new use [21]. A reverse supply chain is the network of activities involved in the reuse, recycling, and final disposal of products and their associated components and materials. The public is only concerned with the aftermath environmental impacts of the products at the end of use life. These normally find their way from developed countries to developing countries [37]. William et al. [37] noted that on the economic point of view, reverse logistics leads to employment and revenues to the people engaged in the activities while socially it widens the technology industry evidenced from the sectors which are interested in the E-waste recycling. The re-use and reprocessing of products back in the supply channel requires separation and sorting to produce new products which sometimes are of lesser value [43]. Hu et al. [44] looked at reverse logistics as the basis of improving and protecting the environment from hazardous materials and stressed this from the definition of reverse logistics being referred to as the process of logistics management involved in planning, managing, and controlling the flow of wastes for either reuse or final disposal of wastes. The observations by the authors can be clearly illustrated in Fig. 2.

From Fig. 2, it clearly shows the basic traditional reverse logistics of waste management dealing in the return of unwanted products to a central location for processing, stored and then recycled and reused into different streams in new markets.



**Fig. 2** Integration of waste management and reverse logistics.

Waste reduction has become a prime concern in the industrialized countries. Waste reduction is the new trend that is being advocated due to government legislation addressing product recovery and proper disposal of end of life products, economic benefits gained from the returned products, and environmental concerns [45, 46]. Most industrialized countries are aiming at significantly cutting the amount of waste generated, through new waste prevention initiatives, better use of resources, and encouraging a shift to more sustainable consumption patterns. The primary objective is to decouple waste generation from economic activity, and there is evidence that this is beginning to happen [47]. These countries which have well developed economies and high GDP per capita do conduct high level research and development for environmentally sound mitigations for the waste problems. Based on this, fiscal policies in these countries are targeted to environmentally acceptable waste disposal avenues. Such approaches are missing out in the developing world and where they are, they

are not fully effective quotes [47]. Developed countries have enacted policies and regulations to manage and dispose of waste [48]. From the start of the nineties, the western world has mainly focused on the reduction of environmental impacts through waste treatment and conservation of resources from the waste [47-49]. The authors further go ahead and provide an example from the European Union directive which mandates that all member states are required to establish the collection of paper, plastic, metal and glass by 2015 and reuse and recycle 50% of the recyclable materials from households by 2020.

In Germany, waste policy has evolved over the last 40 years through a series of environmental action plans. The first was the Waste Disposal Act in 1972 with a primary aim of stopping uncontrolled refuse dumps and replacing them with central regulated landfill sites. The Waste Avoidance of 1986 stipulated avoidance and recycling of waste was to be given priority. Then onwards, a number of ordinances, series of legislation were put in place. In Singapore, the



legislation governing body is the Environmental Pollution Control Act enacted in 1999 which advocates for a recycling society through the 3R (reduce, reuse and recycle) [47].

The introduction of the Ordinance on Producer Responsibility SFS, 1994, required all citizens in Sweden to participate in waste recycling and sorting their wastes at household level led to the development of a number of different collection and source sorting programs in the local municipalities [50].

In the Korean Government, a price is levied to the households waste collection and disposal services given the externalities and returns to scale involved in the activity [51].

### *3.1 Waste Generation and Composition*

The ever increasing world population has increased demand of raw materials globally hence increasing on the waste that is being produced [52]. The major common waste generation streams worldwide are from households, offices, shops, markets, restaurants, public institutions, industrial installations, water works and sewage facilities, construction sites, and agricultural activities. Throughout the developing world, biodegradable waste is the highest because it is unprocessed, contains high moisture content, high organic matter content and is characteristic of heterogeneity that further obstructs source separation [52-57]. The developed world produces more of industrial waste that has ingredients of toxicity or hazardous. This explains why most wastes from developing countries like China (Chongqing city) have a high moisture content but low calorific value (about 3,728 kJ/kg) as compared to wastes from Singapore whose calorific value is about 8,000 kJ/kg [58].

### *3.2 Storage*

The major waste storage practices are mixed waste and segregated waste [52], and the latter is more pronounced in the developed world while the former is seen in the developing world. Storage of waste

before collection by municipal authorities for proper disposal has attracted importance as a policy problem. In many countries especially the developed world, legislation and policy schemes target not only the household waste but also focus on an economy-wide effort to minimize waste. For instance, Choe et al. [59] took an example from Canada and USA where the local communities have introduced systems of household waste collection by use of the curbside method and levied a charge for the services and the target is to minimize waste generation. In the developed world, emphasis during waste storage is aimed at minimizing the risk to health and safety against access by vermin and prevention of environmental contamination.

### *3.3 Collection*

Collection of household waste is one of the most difficult operational problems faced by local authorities in waste management in most developing cities of developing countries where they serve only a limited part of the urban population leaving out the populations of low-income living in unplanned urban areas which are in most cases inaccessible because of their width, slope, congestion or surface [4]. The responsible party to deal with the waste is the municipality working with a few private contractors and informal waste collectors whose participation is limited [60].

Waste collection in most countries accounts for a large proportion of the waste budget. For instance, in India, about 85% of the total expenditure on waste management is directed to waste collection and transportation [61], and an average of about 70% of the waste budget [61, 62] as such proper design of the collection system would save funds.

According to Ayininuola et al. [63], in Nigeria like in many other urban areas of the developing world, solid waste is a serious problem. The authors critically studied solid waste collection in Ibadan city, the largest city in Nigeria and probably West Africa, used

an approach of waste generation rates, composition and biochemical water quality tests. The survey revealed that the waste management system in existence was not adequate. About 54.5% of the waste generated in low income areas was collected and disposed off while the rest was left to litter on the streets. The water testing results showed more high levels of lead, chlorides, cadmium and manganese levels than the WHO (World Health Organization) 1996 guidelines stipulated [63].

The collection and transportation of fecal sludge is inadequate and usually discharged untreated into the urban and peri-urban environment, posing great risks to water resources and public health. This is due to the high capital investment required [64]. Consequently, the urban environment gets polluted, thereby posing a great risk to the lives of the urban dwellers especially in the informal settlements. Introduction of effective fecal sludge management options such as adequate collection, transportation and safe disposal can reduce on these dangers [65].

In Ethiopia, waste collection and disposal were undertaken by the municipality, in Mekelle city, using the traditional methods faced with lack of man power and capital equipment. The method provided for household collection was the door to door using containers of 8 m<sup>3</sup> and loaded onto tractors. The population raises, so it has later increased the waste generation volumes and waste collection services which have tended to be irregular [60].

The status of waste disposal in Kenya is not any better than other developing countries of Africa as noted by Rotich et al. [66]. The use of trucks older than 10 years for waste collection for over 10 years has limited the waste collection capacity in Nairobi. This is even worsened during the rainy season when roads are inaccessible and impassable coupled with the worn out tyres of the trucks. The use of many old vehicle trucks was considered a good example [66].

Ghose et al. [61] developed an appropriate method of waste transportation using a GIS based model that

included the provision and planning of waste disposal bins, vehicle and optimal routings. From his conclusions, the model could be used as a decision support tool by the municipal authorities for efficient management of waste.

Findings from a research project aimed at efficient household solid waste collection and transportation in Kuwait studied by Koushki, Al-Duaij et al. [67] indicated seven private companies as the main contractors for the collection and transportation of solid waste to the landfill disposal sites by the municipality. These private companies have been in the business for over 10 years and their contracts are always renewed because the waste collection and disposal is done satisfactory.

### *3.4 Waste Recycling (Processing)*

Increasing interest in product recovery and recycling is gaining attention due to the declining landfill capacities and rising real costs of disposal where a good example is of United States [21, 51]. In the United states, the rising disposal costs and the restrictions on cross-state transport of waste have forced communities to get involved in programs that advocate for product recovery of paper glass and plastics [68]. Moo-Young et al. [69] investigated the use of paper mill sludge considered to be a waste as an alternative impermeable barrier to land fill cover which may reduce the construction by US \$20,000 to \$50,000 per acre. This was because of the high disposal prices for waste sludge in the US.

Sonesson [70] developed a model that solves the collection and transportation of recyclables. He notes that a waste management system that contains a lot of recyclable materials requires more transport due to the separated waste stream that is availed. This is not economically viable and environmentally friendly. The study was centered on the calculation of the cost of fuel and its consumption in Sweden.

The economies, labor and waste disposal costs do favor reuse, recovery and recycling of wastes in

European countries. The waste management sector in these countries has developed towards resource management [47]. For instance, in Germany, the total generated waste in 2007 was 1,618,000 tonnes, 968,000 tonnes was recycled about 59.8% and 650,000 tonnes about 40.2% was disposed off. Other industrialized countries do focus on approaches aimed at resource conservation through an intensive and coordinated effort at developing a recycling industry [47-49].

In Denmark, the recycling rate is defined as the amount of source separated waste in relation to the total amount of waste generated. There has been an increase in the recycling rate by 25% due to the introduction of curbside collection of waste that has increased the sorting efficiencies. This in turn has reduced the amount of land filled household waste from 12% to less than 1% [49]. This was not the case with Everett et al. [71] who argue out that curbside collection in the United States is costly due to the limited amount of waste collected per residence compared to the total waste route time spent driving and tasks such as debagging.

Most of the waste generated in the developing world has a high fraction of organics with greater than 55% organic matter [72]. This is due to the unprocessed fresh foods consumed by the people [53]. These wastes are normally converted into compost and also used to produce biogas [73], lowering on the production of leachates, reducing landfill gas, less collection and transportation of waste to the landfill [54].

Polprasert [74], through a composting system, studied human excreta waste recycled under tropical conditions where excreta was mixed with water hyacinth and vegetation leaves as a waste treatment method. The author further states that most of the waste treatment technologies developed in the western world are mainly water borne and conventional waste water treatment such as activated sludge and these systems have really failed to solve the sanitation

problem in developing countries.

#### **4. Discussion**

Many definitions have been put forward to describe logistics, and all do aim at planning, creating and monitoring the flow of goods and information. Logistics streams aim at value added to a product and is typical of a traditional supply chain where product flow is from the producers to consumers.

Reverse logistics is a relatively new term in the research area and is also referred to as reversed logistics, returns logistics or reverse distribution. All the definitions describe recovery aspects and as such should be considered to mean the same. It is crucial to note that although reverse logistics involves recovery aspects, it differs from waste management as the latter aims at the collection and processing of waste where no new products are produced efficiently and effectively. Reverse logistics concentrates on addition of value to a product.

Environmental sustainability has been an important issue to business practice. Blumberg [14] notes that the last 30 years inspired a new array of products and goods from the traditional forward supply chain. Such products include failed products but repairable, obsolete products, unsold products on retailer shelves, recalled products and parts and assemblies.

Government regulations with respect to the storage, handling, transportation and disposal of residuals from manufacturing processes have forced organizations to establish formal disposal systems. It is imperative to note that much of the focus in the subject of reverse logistics and logistics as a whole was targeted on narrow application to areas such as computer technology, advanced office automation, and military and weapons systems support. It is the emerging green laws and environmental concerns that have had a great impact on many logistics decisions [75]. For example, many products can no longer be placed in landfills and manufacturing enterprises are now forced to take back their products at the end of their useful lifetime.

**Table 2** A summary of literature review on reverse logistics and waste management from previous works.

Reverse logistics and waste management	
Description	Literatures
General	[3, 4, 9, 11, 12, 13, 14, 16, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 32, 34, 38, 39, 41, 42, 43, 44, 45, 47, 52, 54, 55, 57, 60, 66, 69, 73, 75]
Modeling and simulation	[26, 32, 44, 46, 61, 62, 68, 70, 75]
Designs and application approaches	[16, 17, 20, 31, 33, 45, 63, 67]

Reverse logistics concerns all activities that are associated with product returns involving activities of collection, inspection separation sorting and so on leading to remanufacture or recycling. Reverse logistics is largely practiced in the developed world by many industries including among others: computers, automobiles, commercial aircrafts, steel, electrical appliances and medical items. Reverse logistics when practiced by these firms has provided far reaching costs and strategic advantages and has created a highly competitive atmosphere leading to better quality products.

Environmental aspects and existing governmental regulations have motivated and induced producers and suppliers of products to take more responsibility of availing their products on the market. This as a result increased interest in reverse flows. The idea of reverse flow is caused by the product returns and recycling activities.

Waste management in the developed world is aimed at reduction and this is being motivated by governmental legislation, economic value to be recovered in returned products, and environmental concerns. Government legislation is strong in Europe where firms are directed to address recovery and disposal of end-of-life products in an environmentally sound manner. In the United States, motivation has largely been due to economic factors focused on resource recovery value where there is an economic incentive. The wide spread legislation especially on electronics products disposal (E-waste) has compelled many firms in the US to set up systems of resource recovery and safe disposal.

In the developing world, reverse logistics work is characterized with low value addition due to the low

reprocessing involved for example from recycled electronics, paper, automobiles, scrap, plastics and food waste. This may be because of the inefficiencies got from product specific knowledge on recycling or reprocessing.

Literature is reviewed on reverse logistics and waste management by authors and is described in phases of general, modeling and simulation, design and application approaches and is given in Table 2.

## 5. Conclusions

The experiences from some developed countries indicated that reverse logistics related to waste management, if fully incorporated, is a promising solution for developing countries. The potential for reverse logistic activities such as coordination, route optimization, and innovative materials handling will solve the urban waste problem if applied.

In most developing countries, especially in Africa, waste management currently receives very little attention even if the waste generation is escalating. Therefore, there is need to develop an integrated approach where the public, private and community sectors work together to develop local solutions promoting sustainable waste management especially in the developing countries which have loop holes in waste management. This can be done through making waste a priority by governments, researching and availing data on the generation, composition, reuse and recycling of waste, and public awareness about waste.

Effective and efficient logistic systems, if fully incorporated into proper waste management and better and cheap transport routing system, will help in resource recovery as also emphasized by earlier researches [43, 45]. This will also comply with national

laws and policies concerning the protection of the environment.

With increased industrialization and globalization, reverse logistics is bound to take course. And this is expected to rapidly increase in the developing countries. This will lead to economic gains while protecting the environment. In Uganda for instance, there is a demand of metal scraps from old automobiles, farm equipment, household appliances, steel beams, and food packaging and other containers; plastic waste is picked and diverted from landfill; faecal sludge is taken as manure for compound vegetation while food waste is fed to animals like pigs and cows.

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