TECHNOLOGY & URBAN INFORMAL WORKERS

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Technology is a key driver of change, not least in the world of work. In today's global economy, trends in technology and trade have led to changes in the system of global production and exchange and to reductions in the employment intensity of growth; and, thereby, to changes in the nature of work and the structure of labor markets; all of which have contributed to an increase in informal employment.[1] Recently, the use of on-line platforms to link providers and consumers of services has taken off around the world in what is called the gig economy, much of which is informal. Artificial intelligence and robotics are having increasing impact in certain industries, especially in the Global North. Yet little is known about what technologies are used by – or impact on – the working poor in the informal economy, and in what ways.

This paper is based on findings from a 2015 study by the WIEGO network and local partners on technology and informal workers in three cities: Ahmedabad, India; Durban, South Africa; and Lima, Peru (Chen et al 2016).[2] It examines three sets of technology that currently impact informal workers in these cities. It begins with describing the everyday technologies used by different groups of urban informal workers in their work. It then examines how information technologies are being used by and impacting upon these workers. Thirdly, it examines how technological choices made by cities in designing energy, transportation and waste management services impact on informal workers.

This paper does not consider the impact of robotics and artificial intelligence on informal workers. While the use of robotics in factories and warehouses and agricultural fields is on the rise, it is hard to foresee the use of robotics in public space, private homes or informal settlements where most urban informal workers are employed or to predict the indirect impact of robotic automation, much less artificial intelligence, on urban informal employment. Among the informal workers sampled in the 2015 study, there were no signs – or even mention – of how robotics or artificial intelligence might impact these occupations, at least in the near future.

Before discussing the findings of the 2015 study on technology and the informal economy, it is important to highlight the size and significance of the informal economy. Official labor force statistics show that informal employment[3] comprises more than one-half of non-agricultural employment[4] in most regions of the developing world: specifically, 82 per cent in South Asia, 66 per cent in Sub-Sahara Africa, 65 per cent in East and Southeast Asia and 51 per cent in Latin America. In the Middle East and North Africa, informal employment is 45 per cent of non-agricultural employment. Estimates for six cities in China show that 33 per cent of non-agricultural employment is informal.

Also critical to understand is the prevalence of self-employment relative to wage employment in the Global South. In all five regions with data plus urban China, self-employment outweighs

wage employment as a source of non-agricultural informal employment. Self-employment is particularly dominant in sub-Saharan Africa. In sum, the present-day reality is that most jobs are now informal, and most of those are in self-employment.

I. WORK TECHNOLOGIES
What follows is a summary description of the everyday work technologies used by the working poor in the urban informal economy in the three cities covered by the 2015 study.

Existing Technologies
The common tools used by informal workers in their work are quite basic and include:
- a polypropylene or jute gunny *sack* to collect and transport waste (waste pickers);
- a shallow *metal basin* for carrying bricks and cement (manual construction workers);
- a *trowel* (masons);
- a *wooden board* for hand-rolling incense sticks (incense stick rollers);
- a hand-pushed *barrow* or *trolley* (market porters and waste pickers);
- *cooking vessel* and simple *stove* (street food vendors); a *scale* (street vendors and market traders);
- *electric sewing machine* (garment makers).

No matter how basic, each tool of the trade has an inherent value to its users. In Ahmedabad, India, a widowed waste picker stated that the sack she uses to collect waste is her "life" and a home-based incense stick roller stated that the wooden board she uses to roll incense sticks is her "god". In Durban, a barrow operator took great pride in the barrow he had inherited from his father.

There were some differences in the basic tools used across the cities, reflecting differences in the local dynamics of each sector. Consider the technologies used to transport waste. In Durban, South Africa, waste pickers sell their recyclables to mobile waste dealers who drive around the market area looking for recyclable waste to buy, either from the itinerant waste pickers or directly from shopkeepers. The Durban waste pickers use trolleys to haul their waste around the market area: In Ahmedabad, the waste pickers have to transport their recyclables to the shops of waste dealers that are often at some distance from their collection routes. Most Ahmedabad waste pickers, therefore, have to hire rickshaws – bicycle rickshaws or (if they can afford them) motorized rickshaws – to transport their recyclables to the point of sale. As one waste picker group reported: "Bicycle rickshaw drivers charge thirty rupees round-trip whereas auto rickshaw drivers charge more than fifty rupees" (Ahmedabad, WP, FG 2). In inner-city districts of Lima, a few recyclers who deal in bulk used motorized transport (such as trucks) to transport recyclables. But, in the outlying districts, all waste pickers have to use pedal-pushed or motorized three wheelers to transport their recyclables to the nearest buyer.

Emerging Technologies
Across the three cities, each occupational group identified new or emerging tools in their sector. Some new technologies enable workers to increase their productivity or to compete in new markets. The garment makers in Ahmedabad mentioned newer models of electrical sewing machines; gadgets for stitching buttonholes, hemming, and interlocking; embroidery machines and cutting machines: which they need to enter the modern ready-made garment sector and to

better compete in the traditional tailor-made garment sector. Referring to the industrial-grade electrical sewing machine brand popular in both Ahmedabad and Durban, one garment maker in Ahmedabad stated, "The Juki machine is very expensive. It is useful for those who stitch ready-made clothes" (Ahmedabad, Garment Maker FG 4).

In Lima, some street vendors and market traders have invested in new technologies, such as digital scales, electric meat slicers and refrigerated display cases. As the price of digital scales has gone down, fewer vendors and traders are using manual scales. The type of display unit that is used also depends on the type of product being sold and the vending site; vendors who sell from the ground use a tarp; itinerant vendors of small prepared food items like cakes use a tray; and vendors with a fixed spot on the street may invest in a table, mesh display stand, trolley or mobile cart. A recent municipal ordinance in Lima mandates that street vendors must use stainless steel, rather than wooden, carts if they want to get their licenses renewed: a case of regulation driving technology use.

In Lima, motorized three-wheelers (moto-taxis) used to haul waste and other goods have been banned as too dangerous. This is because the cargo is stored in front and may obstruct the driver's vision and otherwise cause accidents. A few waste pickers, mostly men, have been able to modify their three-wheeler to store the cargo in back.

In Warwick Junction in Durban, South Africa, a weaving frame for making grass mats entered the market around 2011. Simple to operate, and halving the time required to make a mat, the weaving frame is now widely used. One of the users, Julia Michunu, attached wooden bobbins to the frame to hold the string or cotton she uses to join the strands of dried grass (see photo).

The energy crisis in South Africa today has prompted many informal workers to diversify their energy sources. Those who sell cooked food using electrical stoves have resorted to using salvaged wood, charcoal and petroleum gas. Those who operate other electrical appliances – for example, music vendors, street barbers and cobblers – have started using rechargeable batteries and inverters. This has given rise to secondary businesses, including re-charging services utilizing high-tech equipment, and the transport of heavy deep-cell batteries.

In Durban, the need for appropriate and cost-effective transport has spawned technologies such as the market barrow (modelled on those used in Covent Garden in the UK); the ingenious addition of wheels to a chassis made from salvaged items to form a conveyance; and the appropriation of commercially available equipment (notably supermarket trolleys). Operating or owning a conveyance is a risky activity as it is routinely confiscated by authorities or stolen, thus the ingenuity evident in the salvaging and adapting of technology has significant economic logic.

Consider the case of Nhlanhla, a water porter in Warwick Junction, who supplies water to cooked food vendors and other street vendors in the market. Earlier, Nhlanhla transported water containers on a shopping cart that he bought from other water porters. However, the police would harass him and often confiscate the cart. Since 2010, Nhlanhla has used a trolley, which he has modified by adding two bread crates, salvaged from the side of the road (see photo).

The idea for the modified trolley came from a fellow water porter who had earlier adapted his trolley in this way. Now all four of the water porters operating in the market use this particular model. The adapted trolley can carry more water containers per trip than the shopping cart, and the bread crates help to stabilize the water drums on the bumpy journey from storage facility to tap, to customer. The adapted trolley is also sturdy, does not break easily, but the wheels do require regular maintenance by way of greasing, and have to be changed about once every two months due to wear and tear.

An added advantage of these modified trolleys is that they do not draw as much attention from the police as the shopping carts do. But they attract thieves. Between 2010 and 2015, Nhlanhal's trolley was stolen more than 20 times. Each time, he is had to purchase and modify a new trolley. Until he was able to do so, he had to revert to using a shopping cart (Durban Micro-Narrative).

Those who work in public space also face the risk of being chased away, arrested or fined by the

police and other local authorities. In Lima, Peru, some waste pickers and market porters wear a uniform – a vest or a pullover with a logo – which provides some political protection by signaling that the municipality has authorized them as workers (see photo). The vests worn by some waste pickers have a reflective strip that makes them more visible when they work at night.

The lack of a secure space to store goods and equipment at night inhibits investment in tools and equipment as well as stock. This is particularly true for street vendors who need to store equipment – scales, display units – as well as stock overnight, every night. This is also true for

waste pickers who need a place to store recyclables they have collected, if they cannot sell them right away. The need for storage is particularly acute in Durban–eThekwini as most informal workers live in townships at some distance from the market area. In sum, the risk of harassment, confiscation and theft discourages asset building and investment in improved tools or technology.

Some of the new technologies are displacing workers. Consider the technological changes reported in Ahmedabad. First, incense stick rolling is being mechanized. This mechanization has the advantage of increasing production (the machines can produce 120-140 sticks per minute) and decreasing pollution and occupational hazards. As one hand-roller commented: "One machine can replace five to six women." (Ahmedabad, IS, FG 3). However, mechanization has displaced a significant number of manual incense stick rollers: some of whom have been hired by incense stick companies to operate the new rolling machines. Furthermore, a long variety of incense sticks is being imported from China and Vietnam, creating competition in the market. The future for women who hand-roll incense sticks is uncertain. Second, the construction sector is being mechanized. Diggers, bobcats, and other machines are replacing manual construction work – especially tasks like digging and lifting. As a result, there is less demand for manual laborers who use hoes to dig and basins to lift and carry.

II. INFORMATION TECHNOLOGY, WORK AND ORGANIZING

Information technologies have a clear and direct impact on the organization of production and distribution around the world. Consider the garment or apparel industry. Key information technologies facilitated the shift from assembly to full-package production in many developing countries, notably: digital graphics for conveying design specifications and electronic communication for placing orders. And the shift to "lean retailing" whereby traditional warehouses, designed to handle large bulk shipments, were replaced by automated distribution centers, designed to handle small replenishment orders was facilitated by bar coding and point of sale scanning (Abernathy et al. 1999, Gereffi and Memedovic 2003).

Over the past decade, techno entrepreneurs have developed on-line platforms to connect customers and suppliers of a variety of tasks and services, not just car services (Uber) and rooms (Air Bed & Breakfast), which have spread quickly around the world. This new economy is disrupting not only existing industries but also the nature of work. Tasks and services are being fragmented into bid-able gigs; jobs are being replaced by on-demand gigs. This is where the new economy meets the old. An Uber driver has much in common with the industrial outworker who stitches garments from her home for a brand-name global company: both own the equipment they use but both are dependent on a lead firm for work orders, payment and setting prices.

On-line platforms are being designed for many uses, including to facilitate access to public services and financial services. However, the working poor in the informal economy typically have limited access to these on-line platforms. Some informal workers are not even aware of information technologies other than simple mobile phones. A male waste picker in Ahmedabad, when asked whether he used the internet, replied: "I do not know what the internet is or how to use it." (Ahmedabad, WP). In Durban, a street vendor thought that only people who work in offices use internet and a barrow operator thought that only young people use internet. Among

the few who do use internet, the usage is mainly restricted to "WhatsApp", which allows them to communicate with customers.   Some informal workers do not own even simple mobile phones because they cannot afford one – they share phones owned by other family members – or they fear a phone would be stolen. As a waste picker in Durban reported: "While we rest or are sleeping, people who are passing by come and steal our cell phones." (Durban, WP, FG 15). In Ahmedabad, a group of women construction workers reported that their husbands would not allow them to own a phone, as they did not want their wives to communicate directly with the male recruiters and contractors.

Despite these constraints, many informal workers use mobile phones in their work primarily to get market information: to determine whether suppliers have stock available, whether contractors have work available, and what the prevailing price or wage rate is. A garment maker in Ahmedabad reported: "The covers that I stitch have the mobile number of the person who collects the stitched covers. I get orders for stitching covers over the phone."   A street vendor in Durban reported: "(A mobile phone) enables us to contact customers about their orders. It allows me to convey information in a speedy manner." (Durban, SV, FG 1). A garment maker at the Berea Station in Durban, South Africa uses her mobile phone to take orders from clients and to make appointments without meeting them face to face. In addition, when orders come in from further afield, like Cape Town, she asks her clients to SMS their measurements so that she can make their garments to order, an arrangement which has enabled her to expand her client base beyond her immediate geographical reach (Durban Micro-Narrative).

In South Africa, where mobile phone and internet costs are high, informal workers find intriguing ways to maximize the capability of their phones for phone calls and text messaging, notably by acquiring multiple sim cards from different networks. By using the sim cards interchangeably informal workers are able to access the preferred or discounted rates competitively offered by the networks.

In Lima, some street vendors and market traders use phones to contact their suppliers and place orders for supplies so that they can save time and money related to transportation (Lima, SV, FG 12 and 16). Cell phones are used to provide better services, as the case of Mario Quispe, who sells vegetable at Rosa de las Américas Market in the district of San Martin de Porres. In the last few years, Mario has changed the way he trades and now offers a "take out" grocery service for his most loyal clients, his *caseros*. He recognized that his clients are always in a hurry and have very little time to shop for groceries. So one day he decided to give his cellphone number to his steady customers so that they could call him and place an order for groceries. He takes the orders, calculates the cost, and packs the groceries for his clients who drop by to pick up and pay for their orders. In addition to these steady customers, whose time he saves in this way, his clients include restaurants from the surrounding areas (Lima Micro-Narrative).

Some informal workers use mobile phones to advertise their products or their selling hours. Some waste pickers in Lima use their free-wheelers to transport goods for others, using their mobile phones to advertise their transport service. Some informal workers use radios or televisions to learn more about their trade. A group of waste pickers in Ahmedabad said they listen to the radio and watch television to get information on how to store and recycle waste.

In Lima, there is a pilot project between the Municipality of Santiago de Surco and a local waste pickers organization (Asociación de Recicladores Ambientales de Santiago de Surco). The objective is to enable the waste pickers, who work at night in certain parts of the district, to alert the municipal security force (the *Serenazgo*) of any incident or suspicious activity that they encounter on their routes. The Municipality has created two direct phone lines to their public safety call center for the waste pickers to use but only one is free for the caller (Lima Micro-Narrative).

Through a phone survey of 18 organizations of informal workers across Asia, Africa and Latin America, to supplement the findings from the three-city study, WIEGO confirmed that informal workers use mobile phones in their work and their organizing efforts. Ninety per cent of the organizations reported that their members use a mobile phone; forty per cent said their members use smart phones and social media; one third reported that their members use "apps" or other internet technologies. Only five per cent of the organizations reported that their members do not use ICTs on a regular basis in their work. In terms of what ICTs are used for, seventy per cent of the organizations said that their members use ICTs to contact suppliers (e.g. to check the availability and price of supplies or stock they need); and over half of the organizations said that their members used ICTs to contact customers and for organizing purposes. However, many of the organization leaders acknowledged that low levels of literacy or skills represent significant barriers to their members being able to use ICTs in their work. In South Africa. High network costs pose a significant cost barrier (Key Informant Interview).

All of the organizations reported that ICTs improve their ability to organize. Two-thirds of the organizations use mobile phones and social media in their organizing work; and half also use smart phones, email/internet and websites as organizing tools. However, traditional forms of organizing still remain important, particularly to reach people in remote rural areas where there is limited cell phone or internet access or to reach older members who do not use ICTs.

Some organizations of street vendors use mobile phones to warn their members about police raids. A home-based worker in Thailand used an app called Line as a source of evidence in court against a subcontractor who refused to pay her for a completed order, arguing that he had never placed an order with her. The home-based worker had received legal training from HomeNet Thailand so she knew she required evidence to prove the subcontractor had made the order. She could not find any written documents but found Line messages with the contractor that showed that he had in fact placed the order. She was able to use this as evidence in her claim against the contractor.

Over the past decade, from Brazil to India to Canada, organizations of waste pickers, in collaboration with private sector, government and civil society actors, have developed software or mobile applications (apps) to connect those who generate waste (households and businesses) with those who collect, sort and recycle waste. The apps facilitate communication between waste pickers ready to pick-up waste and households, firms and industries with waste available for pick-up. For example, in Bangalore, India, a web platform called "I Got Garbage" allows businesses and apartment complexes to hire a waste picker as their recycling manager who takes dry waste to collection centers where it is sorted and passed on to other waste pickers to recycle and who sends wet waste to be converted into biogas and compost. I Got Garbage also allocates

collection routes to waste pickers and maintains a data base of local scrap dealers so that the waste pickers know where to find the right buyer for the recyclable waste they reclaim (Bell and Fox 2017).

III. CITY-LEVEL TECHNOLOGICAL SYSTEMS
The technological choices made by cities in regard to large infrastructure systems have major, but not well understood, impacts on the livelihoods of informal workers: as does the decision by some cities to privatize these systems. In the three-city WIEGO-led study on technology, occupation-specific focus groups were asked to discuss three city-wide technological systems – energy, transport and waste; and to rank the degree of impact the system had on their livelihoods and whether the impact was positive, negative or mixed.

In terms of *degree of significance*, the citywide systems were ranked quite similarly across all three cities. Garment makers in both Ahmedabad and Durban ranked the energy system as most significant; as most of them use electric sewing machines, as did incense stick rollers in Ahmedabad who need electricity to be able to work at night. Street vendors, market traders, market porters and transport workers ranked the transport sector as most significant; as did the garment makers in Durban who operate at a train station. The waste sector was very significant to the waste pickers but of limited significance to the other sectors.

However, in terms of *whether the impacts were positive, negative or mixed* the rankings varied a good deal across the study cities, depending largely on the dynamics of the system in each city, as follows:

Energy
In South Africa at the time of the study, there was a national energy crisis: with frequent unpredictable load shedding and power outages which were having significant negative impacts on all sectors in the Durban sample.
- Garment Makers: "Electricity is a problem due to the existence of load shedding: while we are in the middle of our work electricity just shuts down" (Durban, GM, FG 6); "Customers blame us for incomplete work when the electricity goes off" (Durban, GM, FG 8).
- Waste Pickers: "When there is load shedding, the shops from where we collect recyclable materials close and we do not have access" (Durban, WP, FG 10); "In winter, if the street lights are not on, we hesitate to arrive before the DSW workers due to the risk (of operating in the dark)" (Durban, Female WP, FG 11).
- Street Vendors: "Electricity is used in the production of petrol. If there is no electricity there will be no petrol; and there will be no transport" (Durban, GM, FG 6).

In marked contrast, since electrical supply was privatized over 15 years ago, Ahmedabad City has had regular electrical supply but high unit rates. Despite the cost, the regular supply of electricity is a great boon to the home-based garment makers, most of whom operate electrical sewing machines, and to both garment makers and incense stick rollers who work at night. While the supply of electricity was steady and widespread across Ahmedabad City, the presence of street lighting was spotty. One waste picker noted that street lighting along her route helped her sort and collect recyclables during the early morning; while some street vendors compensate

for the lack of street lighting at night by running solar-powered lanterns. But alternative energy sources cannot always be accessed or afforded by informal workers. Key informants in both Durban and Ahmedabad made the point that such products, whilst allowing workers some independence from the city electrical supply, generally require a large upfront investment which is often unaffordable to the poor (Key Informant Interviews).

In Lima, Peru, more than 95 per cent of households have electricity. While the price of electricity rose during the course of the study, market traders and street vendors were relieved to have electricity in their market areas.

> "Almost all the market needs electricity, but as we have it and the prices remain the same, there is no major impact on our work, there are no changes. If we didn't have it, sure, there would be concerns because without electricity we wouldn't have water." (Lima, SV, FG 12)

Transport
The lack of affordable and accessible public transport is a key concern to informal workers in the study cities, as in most cities around the world,[5] Public transport between their place of residence and place of work tends to be costly, infrequent and unreliable. Moreover, most cities ban the transport of goods on public transport. Most informal workers resort to private transport of different kinds or commute and transport goods on foot. A 2012 study by the WIEGO network found that home-based workers in three Asian cities (Ahmedabad, Bangkok and Lahore) spent 30 per cent of their earnings on transport; and of those who spent on transport one-quarter operated at a loss (Chen 2014).

Given the spatial legacy of apartheid in South Africa, whereby the poorer black population still lives in townships at some distance from cities and business centers, transport is a key system for the informal workers in Durban. Here is what the different groups of informal workers in Durban had to say about the importance of transport to their livelihoods:

- Street Vendors: "Without transport we can't reach our workplaces" (Durban, SV, FG 1); "To us, transport is the most important system" (Durban, SV, FG 3); "We cannot go anywhere without transport: it is the main key system" (Durban, SV, FG 3); "If there are no customers come to town, we are not able to sell or have work. It is important for customers to come to us" (Durban, SV, FG 3).
- Transport Workers: "If we don't have transport to come here, we won't be able to provide for our families" (Durban, TW, FG 13); "We deliver items of people who use transport; we take the goods of people from a certain point to a taxi or bus rand" (Durban, TW, FG 16).
- Mielie Cooker: "Where we collect mielies is too far; we need a car to collect them" (Durban, MC, FG 15).

Despite the critical importance of transport, public transport in South Africa is inadequate, unreliable and very costly: forcing the informal workers to use private vans and taxis. The informal workers in Durban reported that taxi fares are on the rise. As one street vendor group noted: "When the fares go up, we end up working to cover transport costs, not to earn a profit" (Durban, SV, FG 4). Several focus groups also noted that strikes by local taxi drivers have a major, negative, impact on them.

In Lima, transportation was ranked as a major challenge, second only to the lack of security. Since the public transport system was privatized in the 1990s, a chaotic mix of small and medium private companies has provided transport services. In addition, road infrastructure has been insufficient, resulting in increasing congestion, chaos and paralysis. In recent years, the government built two subway lines and a metropolitan bus line in Lima. However, these investments have proved to be insufficient to meet demand. The previous municipal administration began a reform of the transport sector that the current administration has not continued. The central government is now building a third subway line.

The need of informal workers to transport goods not been considered in urban planning or the design of transportation systems. "Busses are not designed for that sort of carting", stated a Durban transport planner (Key Informant Interview), but this is precisely the demand in all sectors studied in this project: waste pickers, street vendors and market traders especially have to resort to using taxis or private cars to transport their goods.[6]

Another problem is that the schedule of the trains and buses does not meet the needs of informal workers. Waste pickers, for example, said, "(The transport system) does not help us. Sometimes the buses do not want to pick us up." Another said, "Sometimes I might wait until very late [in the night] and they (buses) do not pick us up" (Lima, WP, FG 6).

Furthermore, urban infrastructure projects, including transportation projects, have major impacts on the livelihoods of informal workers. In Ahmedabad, the municipality has recently implemented several large-scale urban development and infrastructure projects including a Bus Rapid Transit system (BRTS) (2006), a model roads scheme (2011), a riverfront development scheme (2004), and road widening. In the design of these projects, natural markets of street vendors and the vendors themselves were not considered: with the result that many natural markets have been destroyed or evicted in the process. In many cases, the alternate space provided to vendors was not in a centrally located area where the vendors could attract customers.

The implementation of a Bus Rapid Transit (BRT) system is currently in its early stages in Durban. The municipality is aware that the system will realign urban space and potentially disrupt natural markets throughout the city (Key Informant Interview). With the collaboration of the NGO Asiye eTafuleni a paper plan of a model transport node that incorporates informal traders has been developed, but whether this will be implemented is questionable (Key Informant Interviews). Asiye eTafuleni continues to be critical of the BRT system, arguing that it is based on a model that favors "frictionless" public transport, which minimizes interactions with public spaces and thereby decreases economic opportunities (Key Informant Interview).

Waste
Technology choice is a central decision in the design of waste management systems, at every stage of the process: from how waste is handled by those who generate waste to the collecting, transporting, sorting, storing, transporting and disposing of the waste. Technologies which disrupt or displace traditional or informal waste pickers include the initial disposal of waste into containers, especially underground containers; single-stream collection and transport of waste by

garbage trucks; mechanized, including magnetic, separation of waste; the use of incinerators, including in waste to energy projects; and the use of gasification or pyrolysis processes to convert solid waste into synthetic gases or oils. Waste burning facilities are toxic, expensive and polluting. Sending unsorted waste to burn prevents the reclamation of recyclable materials by waste pickers to be used as raw materials and packaging materials by industry. In cities around the world, including Lima, underground containers are being installed, which prevent the waste pickers from accessing the waste for recycling and which require expensive technologies to extract and haul the waste.

Technologies which facilitate or enable waste pickers include the mobile apps connecting waste pickers with waste generators, mentioned earlier, as well as separation at source schemes with separation bins; door-to-door collection; labor-intensive sorting systems; space and infrastructure for sorting, processing and bundling waste, including manual or hydraulic presses, plastic pellet making machines; and anaerobic digestion and composting technologies;

Around the world, the collection, transportation and disposal of waste is being privatized as municipal governments offer waste collection contracts to private companies. However, private garbage collection companies, typically, do not reclaim recyclable items. The informal waste pickers continue to do this important task using the same basic tools. But their task has become more difficult because they have to compete for waste with the private garbage collection companies who are paid by the ton for hauling waste to landfills or incinerators and whose workers often syphon off some recyclables for themselves. Further, available waste is no longer in open spaces, but in large bins, depots or landfills, making access more difficult.

In Ahmedabad, around 2010, the city began to privatize waste management; today, the private waste collection system now covers about 70 per cent of the city (estimate of Indian Academy of Self-Employed Women). In those parts of the city where there are municipal waste bins, the waste pickers can reclaim waste from those bins. However, not all areas have municipal bins and in some areas that do, the municipal street cleaners or the private garbage collection workers reclaim waste for themselves. Whilst co-operatives of informal waste pickers in India may theoretically apply for local government waste management tenders, in Ahmedabad they are required to first deposit a large sum of money. This effectively excludes the organizations of waste pickers from the tender process.

In Durban, solid waste management is still a public sector function: through the department of Durban Solid Waste (DSW). One group of waste pickers reported: "The DSW often comes early and takes all the waste including cardboard, so it is important for us that we arrive before the DSW" (Durban, WP, FG 11).

In Lima, solid waste management is a public sector function but the municipalities are able to hire private enterprises for specific activities. Metropolitan and district municipalities share this function, so the quality of service differs from one municipality to another or between metropolitan and district avenues. A few district municipalities work well with the waste picker associations and include them as part of the waste management system or provide them sorting or recycling centers. In other districts, the conditions of the waste pickers are more difficult: the

waste pickers have to reclaim recyclables before the municipal garbage trucks collect waste, often having to work at night.

Finally, in addition to changes in these citywide systems, the unpredictable, often hostile, policy and regulatory environment serves to inhibit the livelihood strategies of informal workers, including their choice and use of technologies. The lack of legal recognition and protection means that informal workers often face demands for bribes, confiscation of goods and equipment, evictions, and other forms of harassment: which inhibit their ability or willingness to invest in improved technologies or enhanced stock. For instance, street vendors without secure vending sites are discouraged from investing in expensive or heavy technology, as they have to be able to pick up and move their equipment and stock when they see the police coming.

Most critically, the lack of a secure workplace and a secure storage space, high costs for permits and rents, and high costs of transport inhibit investments in both technology and stock. Consider, for example, the situation of Benedict Matlalo and other metal scrap recyclers in Durban. The essential tools of their trade, used to break down appliances and other sources of metal, are a hammer, a chisel, a screwdriver or spanner, and an axle saw. In an ironic twist of fate, possession of these tools – which are essential for their livelihoods – also make them vulnerable to police harassment and confiscation. As Benedict explained, the tools they use in their scrap metal recycling business are the same ones that criminals use to break into houses. The police therefore assume that they possess and use these tools because they *are* criminals and are plotting to use them to carry out burglaries. This is further aggravated by the fact that their job requires them to walk around local neighborhoods looking for scrap mental and cardboard, in an environment where there are already heightened fears of crime. The police response is to confiscate their tools or to surround them at the park where they work, forcing them to run off and hide. On occasion, they have even been shot at with rubber bullets: one of Benedict's colleagues lost his eye, but being a migrant he chose not to report the incident, as he was afraid of being deported. On other occasions the police have loaded them up 'like sardines' into police vans, and taken them somewhere to be 'hosed down', or driven them far away to a dump in Springfield, from where it has been difficult to get back to their work site (Durban Micro-Narrative).

In sum, how a city perceives and approaches the informal economy as well as major infrastructure development projects are critical determinants of whether the working poor are able to take advantage of technology. As Richard Dobson of Asiye eTafuleni put it: "Provision of infrastructure is a defining pathway for the uptake and use of higher-order technology."

IV. TECHNOLOGY AT THE BOTTOM OF THE PYRAMID
The research findings presented above shed much-needed light on the reality of work and technology at the bottom of the economic pyramid. The findings suggest that:
- both existing and emerging work technologies, in all the sectors across the three cities, are quite basic.
- informal workers and their organizations are beginning to use ICTs in their work and organizing: but informal workers use mainly simple mobile phones while organizations of informal workers are beginning to use internet and online platforms

- emerging technologies impact the working poor in several ways – both positive and negative
- informal workers can and do adapt to technological disruptions; but their ability to do so is helped or hindered by a variety of external factors, not least the fear of confiscation or theft of improved technologies

Finally, and most importantly, the findings suggest that city-level systems and city-level policies and practices have significant impact on informal workers, their livelihoods and their ability to adapt to technological change. An unpredictable, often hostile, policy and regulatory environment serves to inhibit the livelihood strategies of informal workers, including their choice and use of technologies (see Box 1). A street vendor in Lima summed up this reality succinctly: "I sell from a small bag. If I sell more, the municipal police (*serenos*) come and seize my things." (Lima, SV, FG 12)

Box 1
Summary of Key Findings:
City Systems, Policies & Practices

o **City-Wide Technology Systems have Significant Impact on Informal Livelihoods**
  o most significant system:
    - electricity for garment makers & incense stick rollers
    - transport for street vendors & transport providers
    - waste for waste pickers
  o current systems: largely negative
    - electricity: irregular supply (Durban) & high cost (Ahmedabad)
    - public transport; inadequate and unaffordable & cannot be used to transport goods
    - waste management: not inclusive, sometimes exclusive, of waste pickers
o **City Policies and Practices have Significant Impact on Informal Livelihoods**
  o city policies and practices are unpredictable and often hostile
    - informal workers face bribes, confiscation of goods and equipment, evictions and other forms of harassment
    - informal workers lack secure workplace and storage space
    - informal workers face high costs for permits and rents
  o basic infrastructure and transport services are unreliable or unaffordable
  o all of these factors inhibit investments in both technology and stock

Technological Adaptation
The available evidence suggests that individual informal workers adapt or invest in technologies to increase productivity and incomes, to address occupational health and safety concerns, and to compensate for wider structural constraints. However, the adaptations or investments are quite modest, as follows:

To Increase Productivity and Income
- construction workers: seek training in specialized skills & invest in tradesmen tools
- garment makers: invest in improved electric sewing machines & specialized gadgets
- street vendors: invest in improved displays & digital scales to attract customers
- street vendors & waste pickers: invest in improved barrows, trolleys and carts
- all workers: use simple mobile phones to contact suppliers, buyers, contractors

To Address Occupational Safety and Health Risks
- construction workers: use top knots woven out of string or plastic to cushion weight of headloads
- market porters; use boards, as ramps, to cushion weight when loading/offloading heavy bags or boxes
- street vendors & waste pickers: put reflection strips on their trolleys, barrows or carts

To Compensate for Lack of Basic Infrastructure Services
- street vendors: use solar lamps to extend selling hours

To Compensate for Lack of Accessible/Affordable Public Transport
- all workers: hire private transport, sometimes jointly

The evidence also indicates that organizations informal workers can and do help their members to make technological choices, to jointly acquire expensive technology, and to negotiate the wider environment. Organizations of informal workers help their members negotiate access to raw materials (including waste); workplaces and storage spaces; basic infrastructure services at their homes and workplaces; affordable transport services; permits or licenses to work; and contracts to provide public goods and services – all of which make it more likely that informal workers can invest in improved technologies.

To sum up, little, if any attention, has been given to development of technology for the working poor in the informal economy. Meanwhile, informal workers have been adapting their existing work technologies to match new work opportunities and adapting their existing work to meet new technological challenges: but largely on their own in a negative policy and regulatory environment. As one street vendor in Lima observed, informal workers belong to "a different world": a world that is either invisible to or stigmatized by government, the private sector and the public. To make cities more inclusive and technology more just for informal workers, governments and other key stakeholders need to recognize and value informal livelihoods and workers; to take them into account – to listen to their needs – when designing not only technology but also city-level regulations, policies, and systems.

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[2] The WIEGO Network seeks to improve the status of the working poor in the informal economy through stronger organization, greater representation, improved statistics and research and a more equal and just policy and regulatory environment: see www.wiego.org. The 2015 study of technology and informal workers in three cities used a quantitative survey as well as focus group tools, work histories or narratives of selected workers and key informant interviews: these methods are references as sources of information or data in this paper.

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[3] These statistics are based on international statistical norms according to which the "informal sector" refers to employment and production that takes place in unincorporated, unregistered or small enterprises while "informal employment" refers to employment without social protection through work both inside and outside the informal sector. The "informal economy" refers to all units, activities, and workers so defined and the output from them.

[4] Due to differences in the way countries define "urban", non-agricultural employment is used as a proxy for urban employment.

[5] An urban expert in Bangkok refers to the BTS Sky Train and subway systems as "class-transit", not "mass-transit", as the poor cannot afford to ride on them. In fact, the poor cannot afford the more-informal modes of transport in Bangkok: the two-wheel and three-wheel motorized taxis. The poor tend to walk and take public buses or, if they can save enough money, buy their own motorcycle or car. (Apiwat Ratanawaraha, personal communication January 2014)

[6] In an interview, Gustavo Guerra-García, former Vice Minister of Transport and former adviser to the Management of Urban Transport of the Municipality of Lima, pointed out that the user profile of the public transport system did not include goods of any type or amount. Responding to the information found in the study, he noted that specific services would be required to transport goods in the municipality: "Not being able to find a suitable way of solving the normativity of freight instead of change the nature of public transport. This could lead to the design of a corrective measure as another urban public transport that allows heavy loads. (…) the logic of a freight bus is very different from a passenger bus where you need to think about providing comfort, you would have space big enough in case someone gets on with a big package because the problem is the movement and that includes a risk factor. It's not easy finding one solution." (Guerra-Garcia Interview)