Fourth industrial revolution and the future of recycling and waste management

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Introduction

Our world is becoming more controversial than ever. We are capable to identify the quantity and quality of water in March, in a distance which ranges between 35 -100 million km but, due to poverty and lack of appropriate global response, roughly 700 million people (1 to 10) lack access to safe water. We are discussing how to utilize the Internet of Things in industrialized economies but, according the recent ISWA's "*Wasted Health: The tragic case of dumpsites*" report, the health impacts of dumpsites are worst than malaria in India, Indonesia and Philippines. On the bright side, the third industrial revolution creates new, unimaginable opportunities for making sustainability a cornerstone of each and every industrial sector. On the dark side, the recent "*Global Waste Management Outlook*" (GWMO) report revealed that roughly 2-3 billion people lack the most elementary waste services.

As far as we know, industrial revolutions are long historical waves that gradually cover the planet. In reality, even now, there are parts of our world that have not been so much affected by the second industrial revolution. So no one expects that the third industrial revolution would soon transform the whole planet. But the current industrial revolution is based on technologies that follow exponential rather than linear paths of development – practically it means that the change that is coming will be too big and too fast. And this change is happening with the current shift of power (from global "north" to global "south") and the continuously growing global interconnectivity. It is expected that the current industrial revolution will affect mostly the developing world (roughly 40% of the planet's population). The poorer part of the world will benefit much more than the richer one, for the first time in the history of industrial revolutions.

In this rapidly changing landscape, disruption of traditional industries will very soon be the new "business as usual". A recent IDC report, published on November 4 this year, predicts that by 2020 one third of the top 20 firms, in every industry, will be seriously disrupted or even failed. The recycling and waste management industry seems unprepared for substantial changes – unfortunately, a good, even if complicated and expensive, adaptation plan is not enough. What is coming is a radical redefinition of what is called waste and how it will be managed.

Redefining waste

Industrial revolutions redefine products, industrial processes, supply chains, raw materials, labor and, of course, consumption patterns. The meaning of "waste" is redefined in each industrial revolution – and this is what we already live now. E-waste is an emblematic stream that characterizes the current technological shift. CDs, old tapes, outdated photovoltaic panels, batteries, composite packaging and very soon nanomaterials, wearables, first-generation drones and laptops are just some other products that will be included in the near – future waste!

But it's not simply about new products that will become new waste types creating new challenges for their management. It goes much further: as the industrial processes will gradually involve smart sensors, robots, expert – systems, 3D printers and systemic integration through appropriate big data systems, it is reasonable to expect that industrial waste will be certainly reduced or even eliminated in certain parts of the supply chain.

Digital manufacturing

3D printing is the newest and most promising form of digital manufacturing. The traditional digital manufacturing is using computer – controlled routers, lasers and other tools for making high accuracy equipment. This is done by slicing and dicing (which means creating waste) a piece of wood, plastic or metal until it comes to its final shape. 3D printing is quite the other way round.

Instead of slicing and dicing, 3D printers operate using additive manufacturing, where laying down successive layers of materials (including plastics, metals, biomaterials and recently a form of concrete) can create a 3D object. When the final product is extracted from its mold, the leftovers are immediately added back to the initial additive material. The process is wasteless in this particular part of the supply chain.

3D printers have the potential to allow anyone, anywhere to make certain items as long as the digital design of the item is available. Within next 5-10 years, billions of people will have access to a 3D printer, just as we have access to laser and ink-jet printers today. In some products this will be the new rule: long-distance shipping will not be necessary anymore, it will be much easier to download the digital blueprint and just print the item you need in a nearby 3D printer. Certainly this will create a reduced CO2 footprint for many products, but not for all, as there are items with high-energy requirements involved in 3D printing.

Internet of Things

The use of RFID tags on bags and bins is streamlined in many cases in Europe. The use of RFID tags, as well as the use of barcodes, allows much better accountability and monitoring of the waste management systems. It contributes substantially to improve the traceability of certain waste and recyclables. And, most importantly, it puts the basis for the creation of big data systems in waste management services.

RFID and barcode systems are just the most low-hanging fruits of the of sensor revolution. But this revolution will soon deliver much more impressive results. Imagine that sooner or later, sensors will equip trillions of objects and each object (cars, TVs, toasters, light switches) will have its own IP address at the Internet of Things, allowing continuously monitoring and data exchange.

Optimization and efficiency will, then, prevail in every part of our daily lives. But the impact will be much more substantial in business. Companies will be able to match product demands to raw materials orders in an ideal way, minimizing stocks and waste. Energy efficiency will skyrocket, as we will have the possibility to activate any equipment only when required, automatically. Complete monitoring of products, preventive maintenance - repair and fit for purpose design will reduce waste, enhance reuse and make recyclability an integral component of every product.

The impacts to the waste management and recycling industry are going to be ubiquitous. Certain waste streams, like e-waste, will be easily reduced or even eliminated. Waste treatment facilities will be perfectly optimized, in short time with less trial - error costs than today. New landfill sensors, already under development, will allow better control of the degradation processes and the related environmental impacts.

New hybrid collection models, based on the interaction between sensors, mobile phones and vehicles will gradually remove the traditional centralized collection services – as an example, Seville municipality is already testing a similar approach through the LIFE EWAS project.

Robotics

Robots are already here. More than 22 millions of them are in use in several industrial applications, continuously working and connected to the Web. Although they have been proved both much more difficult and expensive than it was initially expected, the combination of robots with the new sensors and the advances of artificial intelligence have set the scene for an exponential growth of robotics within next 5-10 years.

Robots are already in use in the waste management industry. Back to 2010, Mitsubishi and Osaka University researchers presented a robot that identifies different plastic materials among rubbish and sorts them into piles. SADAKO in Spain has created a commercial model able to sort mixed household waste, equipped with a suction system adapted to small, light and very heterogeneous target objects. The Finnish company Zen Robotics is focused in C&D waste, with its robot capable of replacing up to 15 human waste sorters. VOLVO is currently working on a joint venture to develop a robot that interacts with the refuse truck and its driver to accomplish the work.

The potential benefits of using robots are countless but it seems that their use will be controversial: robots will replace hundreds of thousands or even millions of workers in recycling and waste management, creating a huge negative social impact and intense conflicts.

Artificial Intelligence, driverless cars and drones

Artificial Intelligence (AI) is already reshaping our lives. Either it is the rapid response of Google to any search we made or the speech recognition, AI has become a business as usual element of the daily lives of billions. Driverless cars and drones are equipped with advanced AI systems that are working in combination with powerful sensors. Their evolution goes really fast.

It is no surprise that many car manufacturers are beginning to think about cars that take the driving out of your hands altogether. These cars will be safer, cleaner, and more fuel-efficient than their manual counterparts. Yet, there are several issues to be resolved, but it seems that we are on the way to resolve them. If the experts are right, the most important problems will be managed before 2020.

Google recently announced that by 2017 they would start to deliver packages

with drones, on a massive scale. Amazon has already published its first efforts to use drones for delivering its products. The US Federal Aviation Agency is working hard to complete a drones traffic management system until the end of 2016 and the first US database with legally licensed drones will be completed next month.

Driverless collection of recyclables will not be that difficult in certain parts of the world. And if you imagine a drone delivering your supermarket supplies to your window and taking back your recyclables, you probably are close to a reality that's on the way.

The consequences to traditional waste management will be tremendous. On demand hybrid collection services will become mainstream and the road towards a completely automatic and auto-optimized collection system will open. Important cost reduction is expected by the use of drones and driverless cars, but first there must be substantial investments. But, there is a high risk of more or less jobless collection and recycling systems, especially in the most technologically advanced places of the world.

The social networks

The evolution of the so-called social networks has created a new, still unexploited field of innovation for more sustainable recycling and waste management systems. Marketers and advertisers are studying in depth the behavioral logistics involved in the flow of messages, ideas and trends within Facebook, LinkedIn and Twitter.

The massive use of mobile apps has created an enormous new potential, already described back to 2012 in the D-Waste report "White Paper on Mobile Apps and Waste management". There is a growing trend to use apps for the coordination of recycling activities and for residents' awareness – information purposes regarding collection and recycling services.

But there is a bigger challenge. Using all the data available in the social media and the data that voluntarily is provided by the app users, there is the realistic potential to develop personalized communication and awareness campaigns that will enhance and develop recycling clusters in each and every neighborhood. Towards this direction, there are many controversial issues to be managed like privacy, but sooner or later we will be able to use behavioral science in order to boost recycling performance in a way that we can't even imagine it today.

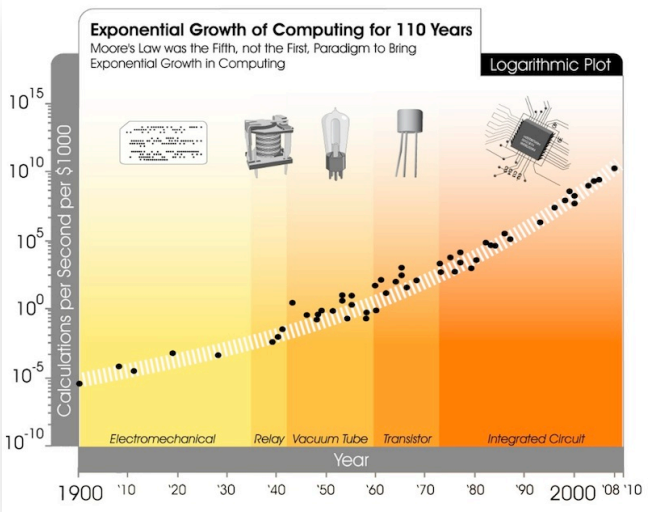
The challenge of governance

When I am making seminars and keynote lectures on the third industrial revolution, some people are asking me: are we heading towards a wasteless future? My answer is "no way, there is no sign for that". In my 2009 article "Waste Management 2030+", I stated *"…our waste management systems and our market conditions, even in their best form, are incapable to handle the growing waste generation that is coming globally. And unless a new paradigm of global cooperation and governance will be adopted, a tsunami of uncontrolled dumpsites will be the prevailing waste management method*". I believe this is still true. But, speaking frankly, in this 2009 article I really underestimated the power of the exponential technologies that were described above and the pace of change that we live now.

I am rather more optimistic than I was at 2009. The third industrial revolution represents a potential for substantial benefits in recycling and waste management, because with the new cheap and energy efficient sensors, many industries will have the possibility to follow closely all the life cycle of any item sold. This will allow product designers to optimize the design, minimize useless functions and materials, prevent damages, improve maintenance and finally develop closed loops of clean materials. Zero waste approaches will be more realistic than ever, reuse, recycling and material recovery will be much more easy, from a technological point of view.

But the elimination of waste in certain parts of the supply chain will not create wasteless supply chains. Take the example of 3D printers. As discussed above, any wasted material during the production of 3D printed products can be reused in the additive manufacturing process. So, this phase of the supply chain will be, in many cases I guess, really wasteless! But, what is the raw material of additive manufacturing? A plastic powder (polyamides, thermoplastic elastomers, polyether ketone, polystyrene) is the most commonly used. So, how those plastics are prepared? Are the 3D printed products going to be recyclables? Is it better or worst to make production of plastic products much easier (and with the potential to be fully decentralized in each and every household)? And how about the recyclability of the 3D printers themselves?

It seems more logical that in most cases, the waste will be eliminated from parts of the supply chain, but it will be relocated, in new forms, in other parts of it. It is also obvious that the new solutions will create new questions, feeding with new fertilizer the evergreen tree of human knowledge and intelligence.



The exponential technologies have the potential to resolve many of the global challenges we face. But this is not possible to be done by the market itself. Although the technological means are more than enough to create clean closed materials loops, they will never be realized on a massive scale if eco and modular design will not prevail the mass consumption markets. So this enormous positive potential relies upon the adoption of the Extended Producer Responsibility principle by the major industries. As everyone understands, this will not come easily, soon and for free, unless there are strong, global and systematic policies as well as social demand for that change.

The third industrial revolution and the exponential technologies make this clearer than ever. It is not the technologies we miss, it is the right global cooperation and governance required in order to utilize the third industrial revolution potential for a shift to sustainability. We can't manage exponential technologies with a linear evolution of global governance. The case is still open, we still can hope for a better future, under the condition that a new paradigm of global cooperation and governance will be adopted.