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## INDUSTRIALISATION 4.0 - THE IMPLICATIONS OF THE FOURTH INDUSTRIAL REVOLUTION FOR INDUSTRIALISATION IN AFRICA

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### ABSTRACT

The traditional path to industrialisation by growing manufacturing output has leveraged two key sources of competitive advantage: (1) low-cost labour and (2) the economies of scale derived from centralised mass production. The maturing technologies of Industry 4.0 erode both of these foundational pillars. The implication for less developed countries is that the model for successful industrialisation going forward is likely to differ substantially from that of the past. This offers both challenges and opportunities, requiring a fundamentally different approach to driving industrialisation. This paper explores what this may mean for countries that are still seeking to become more industrialised.

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## 1. INTRODUCTION

The question of how to best facilitate economic development is particularly pertinent in an African context, as one of the most pressing needs across the continent is to enable a large portion of the population to move from poverty, to a more developed or industrialised status [1]. Ten of the only thirteen countries that have managed to achieve uninterrupted GDP growth of higher than 7% for 25 years, did so through manufacturing-led growth [2]. At a high-level, the basis of this model was to attract investment into developing a country's manufacturing industry i.e. building large factories that create significant employment and become competitive exporters to the global market, by leveraging the twin competitive advantages of:

1. the availability of low-cost labour [3], and
2. economies of scale achieved through centralised manufacturing and mass production

In simplified format, some of the theoretical outcomes of this model are that the resulting increase in tax revenues from the export of finished good allows for increased government spending on infrastructure to support rapid urbanisation. This, together with the increase in spending power of an employed workforce allows service and support industries to grow and flourish. There are also significant learning [4] and ecosystem benefits obtained. At a point in time, labour costs rise to the extent that the competitive advantage of cheap labour no longer exists and industries move "off-shore" to other geographies in pursuit of the low-cost labour advantage, leaving behind them a significantly more "developed", "post-industrial" economy.

This is the approximate model that has been followed by China since 1978 [5]. As China transitions into a more high-wage economy with a greater focus on domestic consumption and services [6], there has been some speculation on which country will be the "next China". The "MITI-V group of countries (Malaysia, India, Thailand, Indonesia and Vietnam) have been positioning themselves to take over the mantle [7] as have various African countries, notably Ethiopia. The pertinent question however, is "Will this model of industrialisation succeed in the new context of the Fourth Industrial Revolution?"

As the technologies and ecosystems of the Fourth Industrial Revolution mature, they will have a significant impact on the two main sources of competitive advantage that underpin this model of manufacturing-led economic development [8]. This paper explores, through a critical review of the extant literature, the likely disruption of these two key levers of the traditional industrial development model, namely (1) the availability of cheap labour and (2) the competitive advantage of centralised manufacturing that is realised through economies of scale.

## 2. INDUSTRY 4.0 IN CONTEXT

To understand how the Fourth Industrial Revolution will disrupt traditional industrial development models, its broader context needs to be explored. In brief, the Fourth Industrial Revolution is the simultaneous maturing of a number of technologies with the potential to transform the manner in which industrial activity will take place going forward.

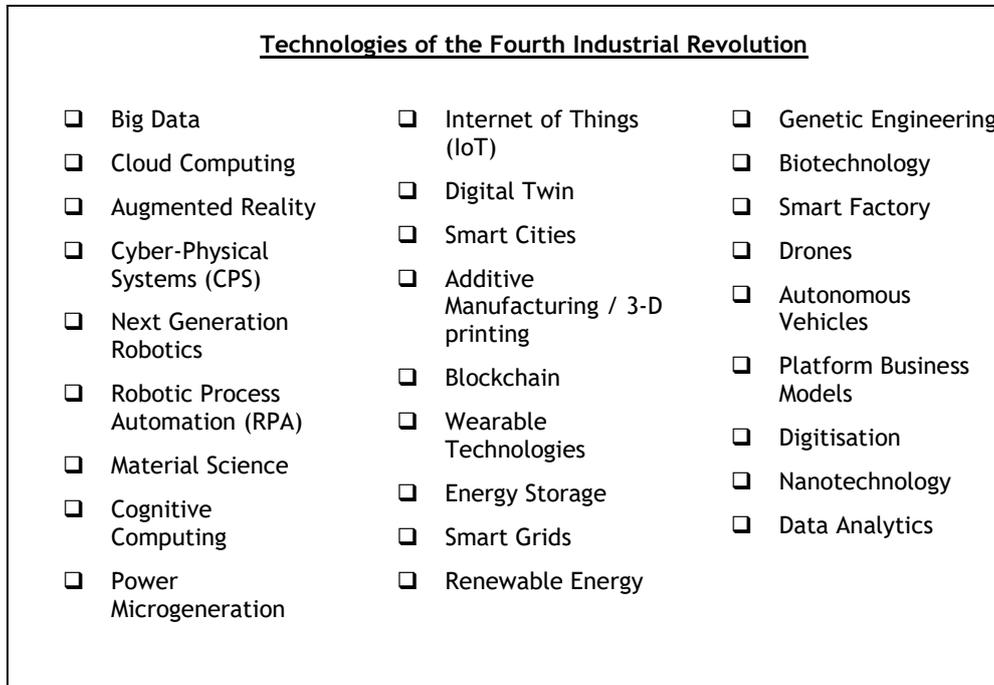
Seth Godin proposed that we are entering a "Fourth Industrial Revolution in his 2007 book "Meatball Sundae" [9], but the concept gained more rapid popularisation after the German Government endorsed the "Industrie 4.0" initiative, presented in 2011 by a group of prominent academics, as one of ten "future projects" forming Germany's High-Tech Strategy 2020 Action Plan [10]. In the words of German Chancellor Angela Merkel, Industry 4.0 is [11]:

*'the comprehensive transformation of the whole sphere of industrial production through the merging of digital technology and the internet with conventional industry'.*

The World Economic Forum built on this, with the overarching theme for the 2016 Forum being "Mastering the Fourth Industrial Revolution", which focused on [12]:

*"mastering the speed, scale and force at which the Fourth Industrial Revolution is reshaping the economic, social, ecological and cultural contexts in which we live".*

Broadly speaking, Industry 4.0 encompasses the recent advances in the technologies of: artificial intelligence, robotics, the “Internet of Things”, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, augmented reality and cognitive computing [13].



**Figure 1: Landscape of technologies of the Fourth Industrial Revolution**

Although many of these technologies are not new, what is pertinent is that we are now reaching the inflection point[14] where the supporting ecosystems are maturing enough to allow them to be cost-effectively and widely adopted. Importantly, the way that they collectively interact is poised to revolutionise much of the world’s current industrial landscape.

An example of this ecosystem effect relates to 3D printing. Although the first 3D printers came to market in the early 1980’s, they needed specialised skills to operate and were expensive to buy. It took a series of advances in the overall supporting ecosystem for them to progress towards more widely spread, cost-effective adoption. Some of these advances included:

- Maturing Computer Aided Design (CAD) software packages that simplified the user interface (1990’s) and made it possible for non-specialists to create designs.
- Expiring of “Fused Deposition Modelling (FDM)” printing process patents in 2009 leading to a wider range of 3-d printer models being released and printer costs falling [15].
- Improved general computing skills within the general populous and the rise of internet sharing and the open source community where designs and modifications could be easily shared and design requests could be cheaply crowd-sourced.
- The falling costs of input materials (in the form of plastic spools) and improving ease of sourcing through online shopping platforms.
- Refined and improved design resulting in improved speeds and quality of printing through different technology variations and also the ability to print using different materials (plastic, metallic, organic).



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- The rise of crowd sourcing, internet commerce platforms and supporting small-scale distribution infrastructure (through couriers) that allows an individual to make a viable business by utilising their 3D printer to create custom ordered objects.

The theme of this is not that the technologies are new, but that the maturing of their supporting ecosystem means that an inflection point has been reached that will shortly be followed by rapid adoption as well as radical disruption to existing business models [16].

### 3. ERODING THE PILLARS OF “TRADITIONAL” INDUSTRIALISATION

To understand the impact that this will have on industrial development, we need to examine its effect on the underpinning pillars of “traditional” industrialisation mentioned above

#### 3.1 The eroding of the low-cost labour advantage

The first is the eroding of the low-cost labour advantage. A number of technological advances in Industry 4.0 are making it easier to produce the same production output with fewer people. Examples of these advances include:

##### **Smart Machines**

These are factory (or other) machines that are equipped with sensors and software that allow them to self-diagnose faults and to exchange information with other machines thus, allowing automated handover along a production line and a reduced need for human operators

##### **Digital Twin**

This refers to factories for which a virtual copy or “digital twin” has been created. This involves visualising the real time operations of physical factory equipment as a “digital twin” on-screen display that updates in real-time to reflect actual production status and location of goods in progress. This potentially allows for centralised control from one location, instead of requiring a machine operator for each individual machine. It can also allow real-time monitoring of data to detect potential problems before they occur [17].

##### **Quality monitoring via image processing**

Advances in camera captured image processing means that visual quality checks can be carried out by a machine, removing the need for a person to perform visual inspection and allowing defective products to be automatically side-lined as reject if they do not meet the required tolerances.

##### **Sensor-aided predictive maintenance**

The cost of installing and monitoring predictive maintenance sensors is falling [18], allowing them to be more widely used. Examples include attaching heat monitoring and vibration sensors to equipment motors that will trigger an alarm if the values go outside of acceptable limits. This aids personnel in knowing where to focus their attention and reduces the man-hours needed to conduct maintenance inspections.

##### **Augmented reality assistance**

Superimposing computer-generated information over the user’s view of the real world, for example using a head-up display, is being used in a number of applications to enable people to be more productive. An example is assisting a maintenance technician to complete a repair job faster by displaying the help manual and critical parts information in real time and leaving the technician with both hands available to conduct repairs to a piece of equipment. An extension of this technology allows a remote specialist technician to give real time coaching and advice, as they are able to see on their computer screen exactly what the maintenance technician can see, thanks to camera enabled streaming video linkage. All of this means that fewer skilled technicians can accomplish more work [19].

##### **Automated flows**

The ability to cost effectively embed tracking technologies into finished products (e.g. RFID tags) allows for automation of flows across the logistics chain, from warehousing to distribution. This reduces the number of

operations staff required as warehouse picking of products for a specific delivery order can be largely automated, utilising forklift equivalents that can independently retrieve the required items.

### **Improved Human/Machine interfaces**

As control software for machines continues to evolve, the human interface has also become more user friendly, requiring less specialised skills to utilise. For example, the programming of an industrial robot in the 1990's required specialist coding knowledge and time-consuming manual input of detailed code to make small changes to the basic programming [20]. The software interfaces of today have drastically simplified this, allowing for much faster changes to programming parameters, quick testing of new code in a virtual environment and a more intuitive interface that reduces the number of specialised technicians required to conduct changes.

### **Robotic process automation**

The applications of Artificial Intelligence (AI) software has expanded to encompass many traditionally “white collar jobs” through the technologies collectively known as ‘Robotic Processing Automation’ (RPA). This includes the automation of traditional back-office support functions [21] to manufacturing such as: inventory ordering and optimisation, finance functions of accounts payable and receivable and even legal contracting. Through the use of Natural Language Processing, which enables chatbots, this has also had an impact on removing the need for a person manned help desk support for or sales queries.

A key point relating to all of these examples is that the price of the technologies required to accomplish this has been rapidly falling so that they have become more cost-effective to implement. This applies to both new factory installations and to retro-fitting existing manufacturing operations. Moreover, the applicability of automation is advancing into types of manufacturing that have not historically been automated, for example clothing production [22].

The net result is that when making an investment decision as to where to locate a new factory, the availability of cheap labour may no longer a key consideration. Increasingly, a large factory can be cost-effectively run by a minimal work force with medium to high-level skills required. As the salary and wages bill has historically been one of the biggest cost-drivers in manufacturing, this means any manufacturing operation that wishes to be able remain cost-effective is going to be forced into adopting these new technologies.

## **3.2 Improving the economics of the decentralised manufacturing model**

Historically, global consumer goods manufacturing companies have tended to favour a centralised, rather than decentralised manufacturing model for production line type (continuous) manufacturing. A centralised model concentrates manufacturing into a few large factories with specialised production lines that are able to mass-produce specific items in large volumes, utilising extended production runs. This has traditionally resulted in a better Return On Capital Invested (ROCI) through high equipment utilisation rates and efficiencies, that were necessary to offset the high initial investment costs of factory production equipment.

A decentralised model on the other hand consists of creating a number of smaller manufacturing facilities or factories, located close to the markets that they intend to supply. These factories are typically much more flexible - producing multiple product types with much shorter lead times, but achieve less overall equipment utilisation due to the lost time needed to changeover between small production runs.

The disrupting effect of the Fourth Industrial Revolution is the way that new technologies are simultaneously eroding the benefits of centralised manufacturing and removing the disadvantages of decentralised or distributed manufacturing [23].

A historical reason for centralised manufacturing and building a large factory, is that the cost of producing the equipment needed to produce even just one product item was so high that it required manufacturing large volumes in order to achieve a reasonable payback period on capital invested. New technologies are changing this by:



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### **Reducing factory building costs**

The design process of the factory can now be done virtually: Full computer aided design and simulation which reduces the final capital costs of building and equipment by ensuring that layouts are optimised and minimal changes to design are required once construction has started.

### **Reducing factory machinery costs**

The man-hours required to both design and fabricate specialised manufacturing equipment is reducing thanks to the productivity enhances of Computer Aided Design (CAD) and improving Computer Aided Manufacturing (CAM) technologies (e.g. better interfaces to computer driven CNC (Computer Numerical Control) and metal working lathe machines). This means that Original Equipment Manufacturers (OEMs) are able to provide machines at lower costs.

### **Reducing prototype and tooling costs**

3-D printing reduces costs to make prototypes and jigs [24]. This has historically been a large initial outlay cost, particularly in the automotive industry, where “tooling up” costs form the major portion of the Capital Expenditure (CAPEX) to produce each new model in an existing assembly facility.

### **Improving changeover efficiencies**

Previously, long production runs were more efficient because of the amount of non-productive time and manual effort needed to changeover to produce a different product. With improvements in technology, this can now often be automated.

The consequence of this is that the capital investment cost needed to manufacture a small number of units has reduced. This means that there is less pressure to recoup sunk costs by producing large volumes - i.e. less benefit derived from maximising economies of scale. These advances also remove the disadvantages associated with small scale decentralised manufacturing, by reducing the capital costs and improving the efficiencies.

In this changing environment, decentralised small-scale manufacturing environment provides distinct advantages. Smaller production runs and greater changeover flexibility [25] means that the factory is able to be more responsive to swings in market demand. In a highly automated environment, it may also be easier to dial up production output incrementally, as utilising machinery longer does not necessarily require an additional labour shift. When logistics costs replace labour costs as a key driver, it is more efficient to transport finished goods short distances than long distances. Whilst this may require a more sophisticated input material supply chain, input materials are generally more efficient to transport in their raw, bulk format as there is less wasted space caused by packaging and less need to add padding and special measures to protect from transport damage. All of this adds up to less cost per tonne moved.

## **4. THE IMPACT ON THE FUTURE OF MANUFACTURING**

The net result of this is that the future of some manufacturing industries that are currently dominated by the centralised manufacturing model are likely to shift future production to smaller, decentralised factories. This brings with it its own challenges of managing decentralised operations, quality control and intellectual property protection, but a tipping point is being reached where the benefits are starting to outweigh the challenges, meaning that manufacturers who get this right will reap the rewards of changing competitive advantage.

Another name that has been used to refer to this trend is “reshoring”. The advantages of smaller scale production being located closer to market is being recognised and acted upon [26]. The changes in manufacturing cost drivers is also helping to drive the “mass-customisation” trend away from mass produced goods, towards goods specifically customised to end-user requirements.

The relative advantages and disadvantages of small-scale decentralised manufacturing obviously vary per industrial sector. The diagram below shows illustrates a prototype model for which types of manufacturing could have early potential to move towards a decentralised, small-scale manufacturing model.

In this model, types of manufacturing operations have been loosely ranked (free-form comparative ranking) on two axis. The first axis compares centralised vs. decentralised advantages: i.e. where that type of manufacturing

would benefit more from being closer to input materials or closer to end market in order to maximise logistics savings. This is based on compactness and ease of transport of finished goods vs. input materials. The second axis compares comparative cost advantages of producing at scale.

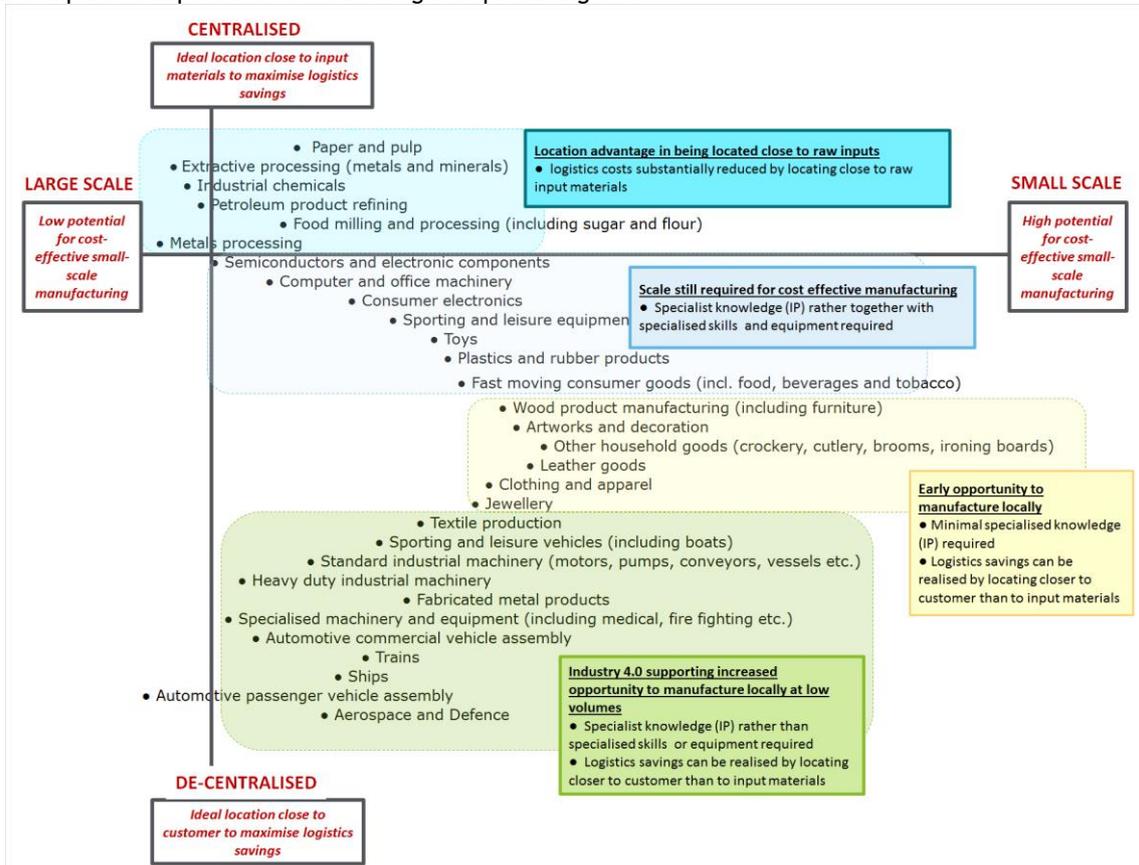


Figure 2: Illustrative view of manufacturing sectors that could have early potential to move towards a decentralised, small-scale manufacturing model

For example, if one looks at the paper and pulp industry, from a logistics efficiency perspective, it makes sense to locate the wood processing mills close to where the wood is felled, rather than close to the end markets. This is because processed paper for example is much more cost effective from a weight and space utilisation perspective to transport over long distances than raw, unprocessed timber. Paper and pulp processing/manufacturing therefore currently favours a centralised manufacturing model. On the other hand, in automotive assembly, where many different components come together from different sources to form the finished vehicle, there is no logistical advantage gained by locating an assembly plant nearby to the original raw material source of any individual component - i.e. no advantage in locating close to an iron ore mine or steel mill in order to minimise steel transport costs. It makes better sense to locate an automotive assembly plant where the route to market logistics costs for the final product are minimised - i.e. a decentralised manufacturing model. Looking at the horizontal axis, in the case of automotive assembly, current technologies still favour large scale production facilities as tooling up costs to create the first vehicle need to be spread out over a large production run to make economic sense. The interesting consideration is how the horizontal positionings of different on this diagram may shift as the impacts of Industry 4.0 technologies reduce the cost efficiencies to be gained from large scale manufacturing. For example, a large FMCG goods manufacturer currently will typically have one centralised factory making branded shampoo and supplying an entire region. The main component of shampoo by weight is water. It is not efficient from a logistics perspective to be transporting soapy water in bottles by road or rail from one central location to outlying regions. Emerging technologies may well mean that

the model of the future is to have a small scale, highly flexible shampoo-making factory located in every major metropolitan area.

## 5. CONCLUSION

The key takeaway from the above, is that the route to furthering industrialisation in African (and other) countries the model for successful industrialisation going forward is likely to differ substantially from that of the past. In particular, there may be few, if any large scale industrial projects that will make a significant dent in unemployment. A new pathway needs to be forged.

While this is daunting, it is also exciting. The fact that these two historical sources of competitive advantages are being eroded means that developing economies (the majority of Africa's economies) are not necessarily starting at a disadvantage. They may even have certain advantage as there is less inertia and pushback to cling to the old, and more willingness to make use of any available opportunities to improve living conditions

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