THE IMPACT OF MAJOR ENVIROMENTAL, SOCIAL AND ECONOMIC FORCES ON THE FIELD OF INDUSTRIAL ENIGINEERING

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ABSTRACT

Every profession is bound to adapt in response to changes in the macro environments. Industrial Engineering is especially affected due to its broad application across various fields, i.e. manufacturing, customer service design, consulting and more. This article argues that the need for change is envisaged to be radical due the deep-rootedness of Industrial Engineering in specific areas where environmental, social and economic (ESE) forces are prompting fundamental transformation. This transformation often manifests itself in an evolving technology. The argument of this article is that 1) Means of production are changing due to 3D printing and additive manufacturing 2) Employees work arrangements and corporate structures are changing 3) Customer behaviour is changing due to sharing and knowledge economy 4) Supply chains are changing (supply/demand) due to drones and radically different supply/demand relationships 5) Human concerns/values (such as education, health and other concerns) are changing. Therefore, Industrial Engineering must adapt to these changes due to its connection with these fields. This article further addresses the major forces impacting Industrial Engineering from 3 starting points: top down (macro-landscape challenge view), bottom-up (technology impact view) and middle ground (IE sub-discipline point of view).

Keywords: Industrial Engineering, Economic Forces, Social Forces, Environmental Forces, Impact Analysis

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1. INTRODUCTION

The world is changing and so is Industrial Engineering. A Coldwell Banker Richard Ellis (CBRE) report finds that "50% of occupations in corporations today will no longer exist by 2025" [1, pp.6]. Yet, this does not mean the other 50% are safe. Although they will not become obsolete, their occupations are most likely to change dramatically. The simple fact of the matter is, in the knowledge era, the inability to pick up on relevant forces shaping the context or work of a field of study can result in misalignment, outmodedness and deterioration of that field or its tools and techniques. "The next 15 years will see a revolution in how we work, and a corresponding revolution will necessarily take place on how we plan and think about workplaces" - Peter Andrew [2]. Technology is perhaps the greatest force that requires consideration. A failure to adjust and integrate technology into practice results in ineffective, minimally applicable and obsolete practices. It is important to remember, though, that technology development is often instigated by economic, social or environmental factors.

The topic of interest for this article is the occupation of Industrial Engineering. After rising to a high standard and developing capabilities that are seen as immensely valuable by industry, it would be disappointing to see that some of methodologies, tools and skills are no longer seen as useful (especially since it is possible to adapt them). The concern here is that creating something of value without the perception that it is valuable often results in similar effects as something not being valuable at all. Much like the companies that Industrial Engineers work in have contingency, human capability and risk plans; the Industrial academic and work departments have to be structured in a way that integrates and caters for all potential changes to macro environments. After all, the tools for change management and integration are being taught in those same departments; it would be unwise not to use them to do a self-analysis. In summary, in the words of Sperotto [3, pp. 8]:

> *Rapid changes in the social and industrial environment continue unabated, driven by accelerating technological developments, availability of information, networking, and globalization. Developments in polymers and new materials from nanotechnology, for example; the variety of energy sources; new manufacturing processes and paradigms, such as additive manufacturing and distributed manufacturing; aerial and robotic networking; neuromorphic technology and predictive intelligence; the Internet of Things (IoT); the spread of integrating techniques, technologies and systems throughout the whole supply chain and its parallel, waste flow management; the increasing value-adding applications in the service industries; and the blossoming world of virtual reality; will extend the complexity of integrated systems and change the focus of industrial engineering, the needs of industry, the nature of work, the human-machine relationship, and the culture and lifestyle of people. Inevitably, the industrial engineering profession and its institutions will need to embrace these changes in order to remain relevant and to contribute meaningfully to industry and society.*

1.1 Background and Summary of Argument

The Industrial Engineering profession faces many challenges in the 21st century. Yet, one can still argue that these forces are unlikely to completely change Industrial Engineering and the need for Industrial Engineers. Especially since, in many countries, it is considered a scarce skill (8th in South Africa) [4]. However, this does not change the fact that IE can remain ahead by conducting self-assessment and improvement studies. Additionally, doing so would be keeping true to the vision and core values of Industrial Engineering. There are, however, challenges arising from specific economic, social and environmental forces. Perhaps the most pressing issue is that the 21st century is experiencing the evolution of a new macro-economic system that is better suited for the needs of society and the environment. Many have labelled this new economic system as the "knowledge economy" and the "sharing economy" [5-6].

Although one cannot neglect the immense impact of the latter 2 macro-systems on the economy, it would seem that the economy is the one where humans have the most direct control. Therefore, it makes them the preferred option to influence change and actually 'do' something. This is mainly because participating in the economy is almost fully mandatory and virtually everything seems to be linked to it in some way or another [6]. Simple day to day reference to global warming, income inequality and employment wellbeing all have deep social and environmental instigators [6]. However, they seem to attract much more attention when one finds a way to display them on a balance sheet and show their link to the economy (carbon taxes, knowledge accounting, intangible accounting, talent capital…etc).

The problem of dealing with massive technological, social and economic changes is not unique to Industrial departments. "Rapid changes inevitably destabilise established institutions, and cause misunderstandings and stresses between conservative and progressive groups and individuals" [3, pp. 8]. The beauty of the field of Industrial Engineering is that it understands "that adapting to the new economic regime would require philosophies and methods tailored to the forms of work that defined the new mode of production" [7, pp. 737]. However, technological forces of the 21st century (reinforced by social and environmental forces of awareness) have completely changed the meaning of key words like 'supply chain', 'work', 'production', 'system' and even 'value'. Arguably, though, it is a key responsibility of Industrial departments to provide the frameworks, connections and strategies to deal with such rapid changes (since there is an implicit claim to understand this complexity best and since Industrial Engineers are often in management positions and are well known for designing the systems that deal with these changes). This is also partially due the broadness of IE sub-disciplines. These sub-disciplines can be defined as: "Management Information Systems; Systems Engineering; Modelling and Simulation; Mechatronics and Automation; Robotics and Artificial Intelligence; Operations Research and Operations Management; Facilities Management and Maintenance Systems; Quality Management Systems; Project Management; Logistics and Supply Chain Management" [3, pp. 6].

The solution, however, must not simply focus on future graduates (most likely from generation Y and Z). The Industrial Engineering department has to embrace a transformative role which develops existing graduates already in industry, similar minded professions in other disciplines and interested individuals willing to progresses their holistic abilities (both privately and at universities). Yet, the most valuable network to an Industrial Engineer might be fellow Industrial Engineers (and their networks within other industries) who have mastery over some skills and can further one's own connections. The common understanding between Industrial Engineers allows for ease of communication, while the clear distinction in specialty allows for a wide influence. This also requires understanding the perception of Industrial Engineers, both in academia and in industry, on the forces changing the environmental, economic and social landscape. The overall aim of this article is to suggest developmental areas for Industrial Engineering knowledge. This will help adapt, reform, integrate and promote sustainable and healthy changes, whilst opposing, eliminating and transforming obsolete theories and technology. In short the focus of the argument in this article is as follows:

1) Means of production are changing due to 3D printing & additive manufacturing
2) Employees and corporate structures are changing, and customer behaviour is changing due to sharing and knowledge economy
3) Supply chains are changing (supply/demand) due to drones and radically different supply/demand Relationships
4) Human concerns/values (such as education, health and other concerns) are changing
5) Industrial Engineering is deep-rooted in above systems

∴ **Industrial Engineering must develop to adapt to these changes**

Section 2 review the impact of major forces in the economic, social and environmental spheres. Section 3 further explores a specific technology (additive manufacturing) as a case study to show how specific research projects can contribute to adapting to these changes. Lastly, section 4 aims to classify the challenges into relevant IE disciplines.

2. MACRO CHALLENGES ON THE INDUSTRIAL ENGINEERING DISCIPLINE

2.1 Economic Specific Challenges

The rise of drone delivery, 3D printing, EBay, Airbnb, Fiverr and even Uber will challenge every conceivable industry. This is not only because they add complexity to the network, but also because they change the rules of the game with regards to supply and demand. This has led to the rise of supply networks (example shown in Fig. 1) which "should visually depict all the linkages between buyers and suppliers throughout the world" [8]. For example, large organizations offering services and products have very high overheads with shareholder expectations as well as big boss bonuses built into their pricing might be replaced by decentralized producers. The local 3D printer/Uber driver/Airbnb room simply have their capital repayment of their hardware, living costs and some savings built in. Additionally, there might be an interpersonal relationship between the producer and supplier of goods and services. Yet, they are producing the same product or offering virtually the same core service. In fact, these applications are going a step further in truly answering the customers need because they are offering only what the customer is willing to pay for. This in itself is an excellent display of value offering design, minimum viable product thinking and system thinking. The sharing economy is a result of complex socio-economic forces with some very positive environmental effects (due to less resources being used and more being shared). Part of the forces shaping this new idea are a disillusionment with consumption, need to connect, requirement for more specialized/customized service and a lack of opportunity in the mainstream economy [1]. Additionally, a CBRE report notes that "a growing proportion of jobs in the future will require creative intelligence, social and emotional intelligence and the ability to leverage artificial intelligence. And for most people that will be a route to happiness and fulfilment." [1, pp.33].

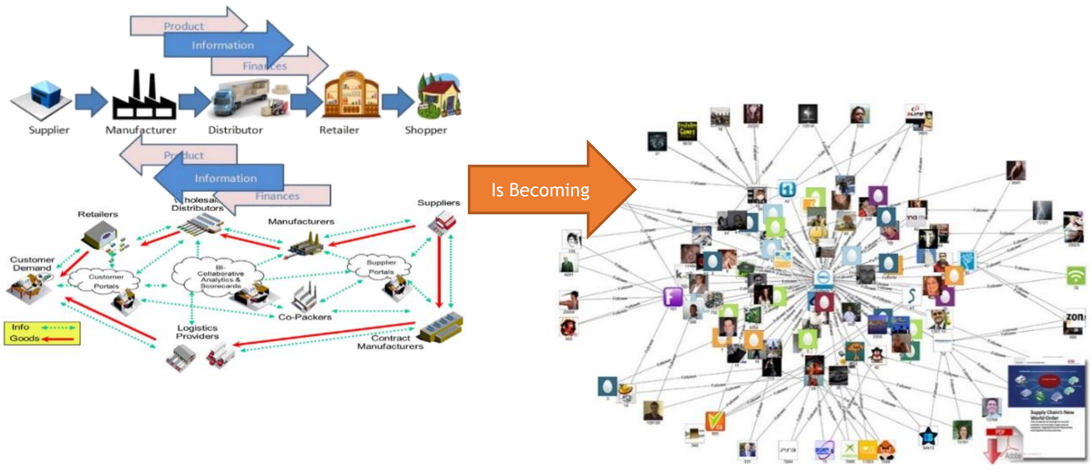


Figure 1: Supply Chain to Supply Network [8-10]

Additionally, the sharing economy seems determined to eliminate traditional hierarchical structures. It is also commonly referred to as 'collaborative consumption', "which is a trending business concept that highlights the ability (and perhaps the preference) for individuals to rent or borrow goods rather than buy and own them" [11]. Part of the reasons this shift is occurring are that traditional capitalistic and consumption models (idea that 'more' consumption holds the solution) did not create value for the overwhelming majority of agents participating in them [12]. For some, it showed a shift towards an inhumane way of living, especially since a large part of the assumptions of the previous model depend on less knowledgeable consumers who do not question as much. Additionally, the previous model resulted in more than half of the world's wealth being owned by 1% of the population [13]. Even though one might debate whether humanity has reached the sharing economy stage, it is commonly agreed that the knowledge economy is in play. The sharing economy is a natural progression stemming from the sharing of knowledge, experience and ideas. More often than not, this content has been freely available on the internet. The knowledge economy recognizes 'intellectual capital' and with that change "a significant part of a company's value may consist of intangible assets, such as the value of its workers' knowledge (intellectual capital)" [14]. The fact that more knowledge is freely available and attainable will naturally lead to more wealth distribution since wealth is no longer viewed merely as capital assets.

2.2 Social Specific Challenges

The concern for human well-being, health, ethics and culture is not just a passing concern in Industrial Engineering. It is a fundamental pillar of the engineering profession [15-16]. In the words of Nelson Mandela "like the gardener, a leader must take responsibility for what he cultivates" [17]. Engineers, in general, face a similar responsibility especially since the products, services, technologies and processes they design affect virtually every human being on earth [16]. Industrial Engineering are especially responsible since most of the time they are specifically responsible for the designs of the interfaces with society at large of engineering products (or at the very least, they are responsible for coordinating efforts with those who do). This is what makes humanity/society the second anchor of IE focus [15-16].

Industrial Engineering is not only capable of providing relevant approaches to managing the facilities, infrastructure and systems governing urban life; it can setup the collaborative approaches, adoption strategies and decentralization necessary to avert unhealthy effects. One of the key specialties in Industrial Engineering is the ability to adapt to scaling up and scaling down. This is why Industrials should naturally work with city planners to "modify the design and use of our cities [and] develop approaches to allow us to live in high-density ''urban villages'' separated by parklands, recreation facilities and garden plots, and connected by light-rail transport" [18, pp.1123]. In addition to traditional IE tasks, several vigilant IE postgraduates and professionals have noticed the immense benefits that IE can have in developing the systems necessary for governance and providing services (especially health and education). Uzosoy in Christensen discusses that "like industrial supply chains, the health care 'supply chain' consists of multiple independent agents, such as insurance companies, hospitals, doctors, employers and regulatory agencies" [19, pp.143] and "the task is complicated because demand for service is determined by both available technology and financial considerations (such as whether or not certain treatments are covered)" [19, pp.143].

Government services (education, health and voting) face similar challenges and have had some benefit from Industrial Engineering intervention [20]. Although IE is still in very early stages of intervention in the public sector, one can only wonder how much benefit can arise from IE using systems principles to restructure government services to be more transparent, effective and consistent [20]. The most relevant point here is that humans naturally interact with systems. There is no doubt these systems are complex, but IE tools can extract relevant factors. Additionally, they can participate in designing systems which best reflect the virtues of its agents. Whether this system is education, healthcare or something else is not the issue. Industrial Engineers will naturally work with the available professionals and specialists in that field to develop a system which answers a principle need [15]. Part of answering a need requires Industrial Engineers to review some theory from industrial psychology and organizational behaviour. The increasing connectedness of the world has resulted in people's voice being better heard [8]. Social media is a great example of how each person can create an online presence which represents them as an agent [8]. The communication between these agents, their exchange of culture and mail has created an effect that converted this once disperse world into a small village. Another effect of this is rapid urbanization as more people try to find more opportunity, interact with similar minded people and experience new things as they setup their lives [1].

The most pressing issue, however, remains that modern human psyche is different and the impact of perception greater. Part of this lies in the fact that "evolutionary emergence of advanced symbolizing capacity enabled humans to transcend the dictates of their immediate environment and made them unique in their power to shape their life circumstances and the courses their lives take. In this conception, people are contributors to their life circumstances, not just products of them" [21, pp.164]. The prime role of an Industrial Engineer, with regards to the above, is aligning perception with reality. An additional focus can be on finding a way to "balance between the individual and collective aspirations" [15, pp.6]. Lastly, perhaps the Industrial Engineer should adopt a clear focus on application. There is no shortage of people creating knowledge/technologies, so Industrials would be perceived better if they focused on applying it for the benefit of society.
A good place to start benefiting society is radically changing the idea of work. When asked about work, the perception of an 8-5 workday comes to mind (with 1-2 hours each side for traffic) [1-2]. This is unfortunate and perhaps the reason flexible hours and deliverable based pay work systems came to be. The idea of work was largely developed to suit the needs of a previous century where it was believed that the 8-5 model provided the best productivity and health. When this pre-21st century idea is applied in the 21st century, family relations are strained (since working parents have less time to interact), time is actually wasted at work (due to an imbalance between pay and expectation) and so on [1]. Thus, overall productivity is lower and the perception is self-defeating. However, work, in the broadest sense, is a physical or mental effort directed towards the production or accomplishment of something. Due to the fact that this creates value, one can naturally expect a share of the value in the form of a salary, benefits…etc. Ironically, even in the definition, physics arguably reaches better results than the perception of fixed hours. The definition in physics is the transfer of energy from one system to another. If IE works on converting this definition to accurately account for work/energy coming from individuals and collectives, then Industrial Engineers will have something better to base a "work" theory on (which will determine remuneration).

2.3 Environmental Specific Challenges

The 21st century has seen a rise in environmental regulation. Interestingly, this is only partially due to government efforts. The devastating cycle of consumption has lead scientists, sociologists, engineers and others to seek alternative technologies. Customers all around the world are becoming more aware of the effects of their actions and consumer choices [15]. Additionally, a larger focus is being placed on sustainability, preservation and conversation of the resources that allow us to live our lifestyles. Although some of these technologies have existed for a long time, the reason they fall under the environmental section is because the rising interest in them as a true alternative only grew in response to environmental problems [15]. The technologies that will be discussed share a common idea in that they aim to be wasteless (in doing so, they are also sustainable and environmentally friendly). For Industrials, a wasteless process is an ideal process. Theoretically it is impossible to produce no waste at all; yet, when one studies nature, one finds that the idea is more about creating waste which is usable by another system as a resource.

Environmentally-driven technologies are striving to provide the closest thing to wastelessness and symbiotic relationships humanity has known. They might hold the key to a healthier environment with less polluting chemicals and better sustainability [12]. If an Industrial Engineer is asked what an ideal manufacturing process would look like, there is no doubt that the definition will include eliminating the waste. Additive manufacturing and 3D printing not only do this, but they also simplify a production process which used to take 12 machines in a 100m line into a 3 by 3m build area. These developments are constantly brought to light in the media world. However, there is a need to understand how additive manufacturing affects the entire world around us. Beyond reviewing what techniques are available and what design processes are used today, a deeper understanding must be developed on how these developments affect our supply chains, facilities, customizability, quality of and even the way companies will design our products. The rapid destruction of our natural resources prompted a revision of our energy production [12]. Some countries were fast to convert fully to alternative energy while others remain sceptic. Whether there is direct links to global warming and natural catastrophes, it is no secret that the chemicals involved and created by non-renewables are harmful to the environment and everything living in it, both directly and indirectly. It also simplifies the energy conversion process immensely (from raw potential energy into usable energy). Alternative energy technologies include geothermal, solar, wind and various others. Yet, the problem does not seem to be with the technology, but rather it seems to be an inability to see the true financial benefit of alternative energy. Industrial Engineers naturally need to take a proactive part in resolving this problem by utilizing skills learnt in management accounting, engineering economics and other courses to accurately reflect the financial and non-financial benefits of alternative energy to companies and decision makers [15]. Accounting for the right things might lead to very different decisions and will facilitate a swifter transition to more sustainable energies.

Energy and products are definitely important but they are not nearly as important and vital as food to human survival. Food security is a growing concern across the globe. "Eating is the most important act of human existence" – Bob Cat [22]. The ability of the planet to produce food sustainably for 7 billion people has decreased due to environmental decay [12]. What adds more complexity to the issue of the food supply chain is the nature of its variability in the supply demand relationship. Different cultures have different diets and different people demand different types of food daily (which is perhaps one of the most unpredictable sources of demand). The question here is how does one provide demand locally (to ensure high quality), whilst ensuring rapid response times to demand (keeping low stock which also increases quality), and ensuring that minimal resources are used in the process?

Hydroponic and aeroponic faming might provide the answer since they utilize a water or air based medium to give plants the exact nutrients the need [22-23]. This is often done in a controlled environment, requires virtually no soil and produces high quality good consistently due to the lack of severe environmental changes typically encountered in normal farming [23]. The idea itself was largely conceived by recognizing that soil is merely a transfer agent. The actual nutrients are what is really required by the plants (differentiating perceived need from true need). Additionally, business cases can be made for both small scale decentralized production and large scale centralized production.

Sustainable food cycles recognise and utilize the waste of one organism to feed another until a complete cycle is achieved (forming symbiotic relationships) [24]. This naturally occurs in nature, but restaurants and businesses are starting to notice its positive impacts. A great example of this is a symbiotic relationship between beer, fish and plants which several restaurants have taken advantage of on [24]. The fish produce waste used to grow the beer, the fish eat some of the vegetation to grow and both of them are served at a restaurant which provides the funds to run the entire operation [24]. This shows that these methods can be applied to the business environment as well to create more sustainable and healthy competition less focused on the 'dog eat dog' metaphor. Drawing parallels between the natural world and business world can create for some very interesting answers.

3. TECHNOLOGY IMPACT REVIEW: ADDITIVE MANUFACTURING AS A CASE STUDY

During the past decade humanity saw the rise of consumer electronics due to the rise of the micro-processor. Moore's law predicted that processing power will double every 1-2 years with components becoming more affordable, reliable, usable and widespread; and he was correct. However, a new buzzword has hit the technology world: Additive Manufacturing. Additive manufacturing is a process by which components are built, altered or repaired using a variety of processes [25-27]. This concept mainly focusses on the addition of material rather than subtraction; thus creating less waste whilst saving time, money and ensuring top quality. Processes vary from laser manufacturing to cold spraying. Some processes (mainly known as 3D printing) only require heating and placing certain polymers into the preferred form. However, one thing is clear from the scientific literature and technology markets: Additive Manufacturing is here to stay [25, 26]. Additive manufacturing by nature is a superior process capable of very advanced designs. In the past 3-4 years there has been a trend developing within this technology and it is expected that the next decade will see the same effect as the processor (shown in Fig. 2).

Printing a pizza at your local shop or having an old piston rebuilt like new with metal powder were topics mentioned solely in science fiction only a couple of years ago. However, developments in the additive manufacturing world have led to a new production method which is not restricted by tolerances, geometries or complexities [25, 26]. Although somewhat expensive at this point in time, it is argued that additive manufacturing will be the way we produce any product in the future [26]. Whether it be our food, metallic service parts or even our organs; scientists have found a way to use additive manufacturing techniques to use raw powders to create an endless possibility of products [26]. These developments are constantly brought to light in the media world, however, there is a need to understand how additive manufacturing affects the entire world around us. Beyond reviewing what techniques are available and what design processes are used today, a deeper understanding must be developed on how these developments affect our supply chains, quality of our products and even the way companies will design our products [26].

With any growth of this kind it is natural to see problem areas such as: inefficiency, quality, process and other multidimensional problems. Since this technology deals with aspects of man, money and machine; it is vital that an Industrial Engineering perspective is developed to help save millions in future and assist in advancing this fantastic technology. Additionally, the simplified supply chain and facilities can be a research area on their own within IE. Perhaps due to the smaller facility sizes and improved power efficiency, alternative energy can be used.

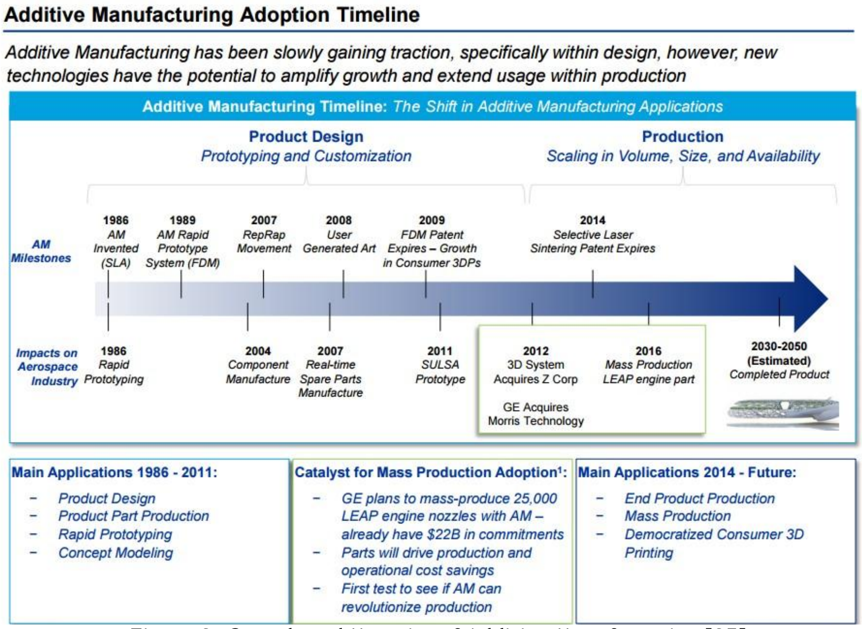


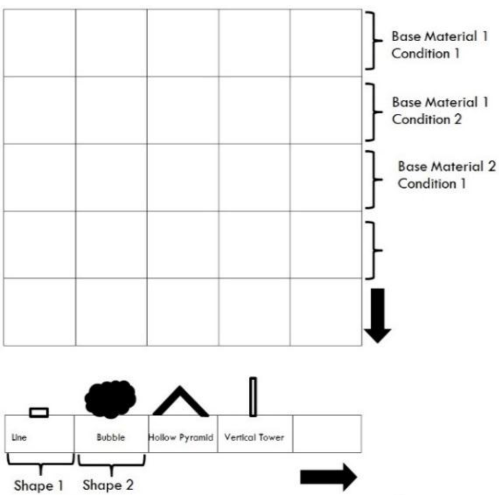
Figure 2: Growth and Maturity of Additive Manufacturing [25]

3.1 Potential IE Research Topics in Response to Additive Manufacturing Technology

3.1.1 Quality Standards & Decision Support Data for Additive Manufacturing

A potential idea is to create a universal test jig/board, using quality management and design of experiment tools, to be able compare different additive manufacturing technologies to each other and thus be able to understand to what industry they can be used in. The aim is to test one powder material at a time on the base given below with different scenarios such as different base materials and conditions to create a variety of shapes and figures designed to test the full capabilities of the technology.

Each technology will be compared on the basis of 3 aspects: Cost, Quality and Time. Each of these aspects has sub qualities indicated in the table below to show the exact area where technologies surpass each other. Such a deliverable will provide a very good platform for analysing the different technologies. Different "boards" can be developed by experts for different test fields and material however the concept must test a variety of operating conditions, materials and builds while ensuring that accurate data is recorded about the time, cost and quality. This can help create a way to compare apples with apples. Overall this would provide an excellent platform for companies to test machines, technologies, materials or suppliers. This will give them an excellent test before commencing production with that specific supplier and will ensure that their criteria are met. A visual representation is shown in Fig. 3.



Quality	Cost	Time
Strength Properties	Cost of Material	Experiment Time
Curvatures	Cost of Operator	Post Analysis Time
Angles	Cost of Overhead	Preparation Time
Tolerances	Power Costs	Downtime
Micro-Analysis	Idle Costs	Idle Time
Other	Machine Costs	Other

Figure 3: Universal Additive Technology Test Jig/Boards [Own Work]

3.1.2 Production and Manufacturing Requirements & Specifications

From this above it can easily be seen how specific requirements can arise for different industries. Industries will most likely be grouped by product size and complexity; changing the way in which production and manufacturing requirements are classified and communicated (shown in Fig. 4 below).

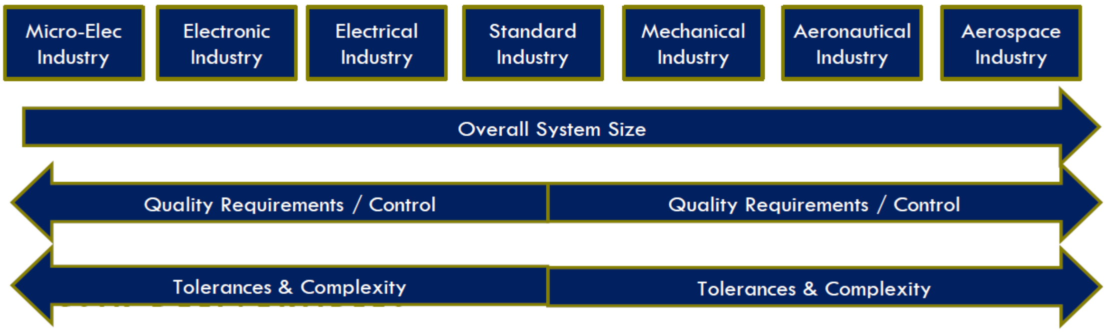


Figure 4: Production and Manufacturing Industry Classification [Own Work]

3.1.3 Wasteless Design Methodology

The development of this new hardware will naturally require a new industrial design methodology. The design processes available today are somewhat lacking if we try to apply them to additive manufacturing. The main problem is that they do not take the full spectrum of possibility when it comes to additive manufacturing. There are modern techniques on how to define and design a product which allow rapid prototyping and testing. In addition to this most design processes do not consider the ability to refine designs in real time. Additive manufacturing allows easy additions to designs as well as reconstructions. There is much less waste involved and designs are modified relatively quickly. Even manufacturing errors can be corrected easily without creating unnecessary waste. If the product has already reached the customer, a simply process can allow them to get their product fixed on site without scrapping or returning the product. Products can be upgraded in this manner as well. This is why a define-design-refine and manufacture technique should be considered when designing products for the 21st century.

Figure 5: Design Process [Own Work]

3.1.4 Supply Chains, Facilities Planning and other Considerations

In addition to having immense impact on our products, the additive manufacturing technique has major impacts on the way we source our products, produce and store raw material (powder in this case) and even on the facilities that will produce products. Some argue this might be decentralized but some products will have to be proceed in centralized facilities (for intellectual property, legal and health reasons). Designing a future manufacturing facility, as well as the considerations that need to be taken, can form the basis of many studies. These facilities can be decentralized or centralized, multi-product group focused or single product group focused, produced on order or customized from stock. More importantly, traditional location models, production scheduling, inventory management (which has to adapt to powder based inventory) would have to adapt massively to these changes.

4. IMPACT ON SPECIFIC INDUSTRIAL ENGINEERING SUB DISCIPLINES

Without context on where the literature and case study (from sections 2 and 3) fit within the broader structure of the Industrial Engineering body of knowledge; several vital questions and connections can be missed or overlooked. This section explores the impact of some of the developments and arguments discussed above on specific sub disciplines of Industrial Engineering in dialogue format.

System Engineering/ Project Management: It would seem the forces above will definitely result in more and more projects becoming available to Industrial Engineers. Although some of them will be large scale, it is likely that a large proportion will be small scale development and management projects. However, traditional project management and system engineering tools and methodologies simply do not cater for these types of projects. Industrial Engineering must be proactive in finding ways to distil the core of the theories and tools and develop appropriate module based models to assist in implementing successful project management and system engineering regardless of scale. The focus, then, will be on adapting theory to the specific scopes and requirements of each respective project.

Logistics and Supply Chain: The fact that most additive technologies are powder/particle /nutrient based will most likely radically change the technology, vehicles and methods of warehousing and delivery of products. The biggest question with regards to the above is: will supply chains be reduced to a simple 5 step process that: 1) converts ores/raw materials into powers 2) transfers them to appropriate warehousing facilities for storage 3) delivers them to relevant AM technologies for conversion to parts 4) assembles them into final products and 5) ships them to clients? Will returns management be a corrective process where a 3D printer is taken to client site to correct product? Is the carbon footprint for this activity significantly less than existing supply chains? The interesting thing here is hydroponic farming is very similar to additive technologies in that it simply adds what is required by the plant (natural machine in this case) in order to produce the final product. Does this make the future of everything we eat and use (accounting for most products) additive based?

Information System Design: Advances in payment, booking and tracking technologies is forcing traditional information systems out of their comfort zones due to a significant difference in user interaction available (arising due to new supply-demand relationships). Additionally, the sheer amount of data required to understand this complexity is engulfing. Yet, the widespread use of smartphones as a data collecting tool is becoming a reality. The concerning questions are: how will the data be collected? How can it be stored effectively? How does one best make use of this data for competitiveness? And, most importantly, how does this data transition to information and then knowledge and perhaps artificial intelligence in the near future? The customer is most likely going to want answers to these questions especially because of rising concerns on privacy.

Simulation/Automation: The ability to simulate this uncertainty and adapt automation technologies to react appropriately is most definitely a challenge. With so many factors to test for sensitivity, is it even practical to conduct simulations? Or is there a way to simplify the chaos into specific agent based characteristics? Can this be done proactively or is it destined to be reactive? Additionally, simulations models will most likely have to develop a way of simulating generational human culture and ethics, especially if this sub-field hopes to create convincing models/arguments for government services.

Business Engineering: With the rise of the sharing economy comes the reality that many business engineering tools will have to be restructured to cater for the individual instead of the corporate structure. The biggest impact of the forces above is that money that is used to flow to traditional business hierarchies will now go directly to individuals. Thus, traditional strategy development, process modelling and business models need to adapt. The question is: does each individual then become his own business or do they follow the business model of the app which brings them customers? If they are unique and are not app reliant, how will these individual 'businesses' differentiate their processes/value offering? Will the sharing economy find symbiotic relationships with the traditional economy or remain competitive?

Operations Research: The algorithms in the code of every application are constantly determining the most effective 'route', 'producer' and more broadly 'connection'. These optimization algorithms are essentially the decision makers. Yet, with this continuously changing environment, a static decision maker will result in tremendous waste. Dynamic decision making and optimization is the most likely the future of operations research. Whether it is a que, production or infrastructure problem: optimality is based on dynamic factors and thus will have a dynamic answer. The question remains, however: is it possible to truly get the optimal answer in these scenarios or will optimization radically change to accept certain confined area as 'optimal'? What if this confined area radically changes in the solution space? Does that mean the introduction of sensitivity as a core element in operations research problems?

Operations/ Facilities Management: The sharing economy will perhaps more accurately reveal the meaning of the word 'facility' and 'operation'. In a nutshell, the facility will become the encompassing structure that facilitates business operations to take place. People are most likely to convert their garages, gardens and bedrooms to facilities (production, servicing and other). However, with this comes massive facilities designs and safety regulation problems. Are there realistic methods to properly oversee such operations?

Quality Management: Perhaps the biggest question for quality management going forward into the knowledge economy is how one assesses the quality of intangible assets (mainly knowledge, human capability and talent). As for the sharing economy, will new standards for decentralized producers come to existence? Will perception play a bigger role in quality? Or will technology facilitate a way to create more accurate quantitative measures for perception?

General IE: The sharing economy and knowledge economy are most definitely challenging legal and business regulations both nationally and internationally. The simple fact of the matter is they create interactions and assets that governments and lawmakers are not traditionally accustom to deal with or account for. More worryingly though, some sharing economy transactions are not even trackable by most governments and some knowledge assets require a whole set of new depreciation and taxation laws.

5. CONCLUSION

It would seem, at some level, that adopting and adapting to even a few macro ESE trends will naturally lead to the others. Maybe this is because once a new ideology of wastelessness, equality and humanity comes into operation they indicate and make us realize (individuals and collectives) how bad the previous ideology was; which can naturally result in a continuous cycle of reconsideration and improvement. There is no doubt in the Industrial Engineers ability to deal with economic changes. However, environmental and social changes are unfortunately more difficult to adapt to and require an authentic focus. This paper recommends, for example, that Industrial Engineers naturally need to take a proactive stance in resolving environmental problem by utilizing skills learnt in management accounting, engineering economics and other sub-disciplines to accurately reflect the financial and non-financial benefits of alternative energy to companies and decision makers. Accounting for the right things might lead to very different decisions and will facilitate a swifter transition to more sustainable energies. Additionally, although there is no doubt that humanitarian engineering projects exist, yet, they represent a minority of projects. This is not to say that projects don't take human concerns into consideration, but, it does show that most projects have a different central focus: money, enormity or competition. Over time this can lead to human factors being disregarded and left to satisfy the minimum. Industrial Engineering should be the champion of the humanitarian engineering movement. After all, the roots of IE are so intertwined with workers, their rights, their health and balancing or superseding it over financial considerations.

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