From: Diarmaid Upton [redacted]
Sent: 31 March 2017 11:32
To: National Planning Framework
Subject: Ireland 2040 Submission
Attachments: Ireland 2040 NPF_Archinomics_Submission_31032017.pdf

Follow Up Flag: Follow up
Flag Status: Flagged

Hi,

My name is Diarmaid Upton. I'm the founder/director of an architecture and systems design agency based in Limerick, called Archinomics. Please find attached here a brief submission for your consideration that attempts to outline the potential impact of what is being described as "the Fourth Industrial Revolution" on Irish Urban Development.

Our group are currently working with Johnson and Johnson, the University of Limerick, and local public development groups on a global "Industry 4.0" strategy for J&J and how the formation of that might positively benefit us here in Ireland. It is highly sensitive.

There is a vast amount to consider and this submission does not do it justice. So much of current urban planning is based on the direct repercussions of the last industrial revolution, most fundamentally in the form of rapid urban expansion and functional zoning. This latest industrial revolution offers us the possibility to address this urban sprawl whilst addressing a myriad of other key issues.

We see this as a critical component of future planning and would strongly advocate the inclusion of these themes and this kind of language in the formation of the NPF final report in order to be able to then address such language with proposals further down the line. If it was at all possible we would greatly appreciate an opportunity to collaborate and aid in the framing of this content in whatever way we can as it relates to the 2040 vision.

Feel free to get in touch any time and best of luck,

Kindest regards,

Diarmaid Upton

Ireland 2040 National Planning Framework: Public Consultation Phase 1	
Title:	"Ireland and the Fourth Industrial Revolution"
Submitted by:	Diarmaid Upton, Director, Archinomics
Contributions:	Dr. Stephen Kinsella, Professor of Economics, University of Limerick Mark McConnell, Director, Johnson & Johnson, Automation Centre of Excellence
xContact:	Address: International Business Centre 1, University of Limerick, Ireland Email: [redacted]

To whom it may concern,

The following submission outlines a series of industry-specific suggestions to be considered as strategically relevant in the creation of the 2040 National Planning Framework. Of the many forces and process that need to be taken into account in the formation of the framework, it is the objective of these suggestions that the implications for urban development brought about by what is being described as “the fourth industrial revolution” are considered and included in the final report. These suggestions do not attempt by any means to answer all of the issues and choices outlined in the consultation document. However, it is hoped that an industrial / digital / technological / entrepreneurial lens be applied to some of the challenges and that this would frame and guide some of the language present in the final document.

High Level Contents:

1. What is “Industry 4.0” / “The Fourth Industrial Revolution”?
2. Industry 4.0 and its Connections with Quality of Growth, The Green Urban Economy and Sustainable Regional Development
3. Intersectional opportunities and challenges for Ireland 2040.

Detailed Contents:

1. What is “Industry 4.0” / “The Fourth Industrial Revolution”?

    1.1 Industry 4.0 *(How we make things is changing)*
    1.2 Smart, connected products *(What we make is changing)*
    1.3 Smart service ecosystems *(How we augment what we’ve made is changing)*
    1.4 From pipes to platforms *(The dominant business model shift behind these changes)*
    1.5 The settings for the Internet of Everything *(The complex spatial foundations of all these changes)*

2. Industry 4.0 and its Connections with Quality of Growth, The Green Urban Economy and Sustainable Regional Development

    2.1 Industrial Revolutions & Urban Development
    2.2 Economic Growth
        2.2.1 Smart growth
        2.2.2 Sustainable growth
        2.2.3 Inclusive/shared growth
        2.2.4 Resilient growth
        2.2.5 Integrated growth
        2.2.6 Governance for growth

3. Intersectional opportunities and challenges for Ireland 2040

1. What is "Industry 4.0" / "The Fourth Industrial Revolution"?

The following is an extremely brief and high level introduction to some of the concepts and components that make up what is being described by the World Economic Forum as "the fourth industrial revolution". The relevance of this content to Ireland 2040's National Planning Framework is that the impact of an industrial revolution on society and the economy is both broad and deeply penetrative, and so a question like "what will Ireland be like in 2040", in terms of how we live and work cannot be correctly addressed without an understanding of such inevitable change. Each previous industrial revolution has had major repercussions for how our cities and towns are planned, perhaps most drastically and notably after the second industrial revolution and the mass production of vehicles which led to dramatic urban expansion and functional zoning. Fundamental issues of today such as urban sprawl were the direct result. For us as a country to get ahead of the next wave of planning and developmental implications it is critical we understand such a profound shift given it is yet in its infancy.

1.1 Industry 4.0 – How we make things is changing

First came the commercial steam engine and the mechanical loom in the 1700s. Next was electricity, the assembly line and the birth of mass production around the start of the 20th century. The third era of industry came about with the advent of computers and the beginnings of automation, when robots and machines began to replace human workers on those assembly lines.

The term *Industry 4.0* refers to the combination of several major innovations in digital technology, all coming to maturity right now, all poised to disrupt and transform. These technologies include advanced robotics and artificial intelligence; sophisticated sensors; cloud computing; the Internet of Things; data capture and analytics; digital fabrication (including 3D printing); software-as-a-service and other new business models; smartphones and other mobile devices; platforms that use algorithms to direct motor vehicles (including navigation tools, ride-sharing apps, delivery and ride services, and autonomous vehicles); and the embedding of all these elements in an interoperable global value chain, shared by many companies from many countries.

These technologies are often thought of separately. But when they are joined together, they integrate the physical and virtual worlds, through what are being defined as *cyber-physical systems*. This change enables a powerful new way of organizing global operations: bringing the flexibility and speed of software to large-scale production. The networks of traditional machinery that characterise industrial society are set to become hyper-aware systems of highly flexible technology, responding rapidly not just to human commands but to their own perceptions and self-direction.

This technological infrastructure is still in its early stages of development. But it is already transforming manufacturing. Companies that embrace Industry 4.0 are beginning to track everything they produce from cradle to grave, sending out upgrades for complex products after they are sold (in the same way that software has come to be updated). These companies are leveraging the oncoming reality of mass customization: the ability to make products in batches of one as inexpensively as they could make a mass-produced product in the 20th century, while fully tailoring the product to the specifications of the purchaser. This has huge implications in terms of the changing scale of industrial production, with concepts like urban micro-factories, and green carbon neutral production re-inhabiting inner city spaces provided there is basic infrastructure. As the technology and understanding of the implications develop, these trends will accelerate and so will the invention of new products and services, including new ways of tackling

today's most difficult problems: climate change and pollution, energy demand, societal wellness, the pressures of urbanization, and the problems that accompany aging populations.

Ireland 2040 Implication: the industrial components of functional zoning are changing in nature, because production and supply chains are evolving. The future relationship between residential and commercial zones to these industrial zones could counter urban sprawl, and change how we understand housing, urban regeneration, education, community building etc.

1.2 Smart, Connected Products *(What we make is changing)*

Information technology is also revolutionizing products. Once composed solely of mechanical and electrical parts, products have become complex systems that combine hardware, sensors, data storage, microprocessors, software, and connectivity in multiple ways. These "smart, connected products"—made possible by vast improvements in processing power and device miniaturization and by the network benefits of ubiquitous wireless connectivity—have unleashed a new era of competition. Under the Industry 4.0 model, product design and development take place in simulated laboratories that utilize digital fabrication models. The products themselves take tangible form only after most of the design and engineering problems have been worked out. Even when in production on the factory floor these products will communicate with the process cells that are to work on them. Instead of top down IT systems managing the 'recipe' of what is about to be made, the lump of steel itself will know what ingredient it is, and that it is about to become a car body part, and will communicate with a set of the nearest process stations and calculate in real time which one to call to it and what the optimal route to completion is. At all stages of the products life it is now dynamically affecting and is affected by its environment.

Smart, connected products offer exponentially expanding opportunities for new functionality, far greater reliability, much higher product utilization, and capabilities that cut across and transcend traditional product boundaries. The changing nature of products is also disrupting value chains, forcing companies to rethink and retool nearly everything they do internally. These new types of products alter industry structure and the nature of competition, exposing companies to new competitive opportunities and threats. They are reshaping industry boundaries and creating entirely new industries. Smart, connected products as a result raise a new set of strategic choices related to how value is created and captured, how the enormous amount of new (and sensitive) data they generate is utilized and managed, how relationships with traditional business partners such as channels are redefined, and what role companies should play as these industry boundaries are expanded.

The phrase "internet of things" has arisen to reflect this growing number of smart, connected products and highlight the new opportunities they can represent. Yet this phrase is not very helpful in understanding the phenomenon or its implications. The internet, whether involving people or things, is simply a mechanism for transmitting information. What makes smart, connected products fundamentally different is not the internet, but the changing nature of the "things." It is the expanded capabilities of smart, connected products and the data they generate that are ushering in a new era of competition. These shifts will affect virtually every industry, directly or indirectly. But smart, connected products will have a broader impact even than this. They will affect the trajectory of the overall economy, giving rise to the next era of IT-driven productivity growth for companies, their customers, and the global economy at a time when the impact of earlier waves of IT has largely played itself out and productivity growth has slowed down.

This not only will create step function improvements in product capability and performance but will radically improve our ability to meet many business and human needs. Across many fields,

products will be far more efficient, effective, safe, reliable, and more fully utilized, while conserving scarce natural resources such as energy, water, and raw materials.

Ireland 2040 Implication: the changing nature of work and the skills needed to operate in this world of new product typologies means that in order to both continue to attract private investment and to seed indigenous industry, a new type of spatial “innovation infrastructure” is needed, designed around reinforcing the new behaviours that cross-industry, cross-disciplinary collaboration demand. This implies a reimagining of how “innovation hubs” and research and development facilities are planned and integrated into our cities, particularly into our public spaces. Top talent can choose where they live and work. Quality of life is underpinned by quality of place. Nobody wants to work in shiny boxes on the edge of town. That logic flies in the face of place-making strategy. Urban regeneration that addresses new modes of work through integrated community building must be addressed to attract top investment.

1.3 Smart Service Ecosystems *(How we augment what we make is changing)*

Although smart products are indeed revolutionizing the manufacturing industry, they are already in some respects yesterday’s news. It’s the data generated by those smart products that is becoming the disruptive element across industry—disruptive to the traditional business/payment/service model. Data from the Internet of Things can be analysed, interpreted, correlated and supplemented and then refined into smart data. Such data then becomes the raw material from which innovative, “smart services” are created. When these services are connected we get what is called “the internet of services”. For example, a city’s traffic congestion management service triggers an emergency response service after it recognises a car crash, and also triggers the cities air pollution management service to deal with toxins, whilst also scanning the immediate location to identify and alert any potentially passing doctor, whilst in parallel also communicating with other vehicles approaching the crash site through wayfinding services to reroute incoming traffic and avoid traffic jams, all entirely independent of human intervention. The smart, connected traffic lights, cars, mobile devices, and ambulance are the products but it is the interoperability of these smart services that open up truly disruptive, industry blurring opportunities.

The new business models in the world of smart services will cause existing control points to shift towards service platforms. As a result, competitors will attempt to gain control of the platforms to become the leading suppliers of the digital control points for smart services. Moreover, these companies will seek to grow and increase scalability further by creating digital ecosystems. In other words, they will make their platforms available so that third parties can use them to develop their own web-based business models, thus making the platforms even more widely adopted and unlocking new sources of revenue.

Ireland 2040 Implication: Smart services by definition, must exist in digital ecosystems. To compete in this world, an ecosystem vision and strategy is necessarily required. Regional planning strategy that supported sector-specific service ecosystem development based on existing local industries could create a binding common cause and unifies regional development approaches. Eg. How might the NPF support the development of a smart farm service ecosystem in the midlands, or smart hospital service ecosystem in the west, or a smart food service ecosystem in the south? Or a smart pub service ecosystem anywhere! Globally these ecosystems are yet to be defined and dominant positioning competed for.

1.4 From Pipes to Platforms *(The dominant business model shift behind these changes)*

Platforms are about orchestrating connections between producers and consumers. Platforms have existed for years. Malls link consumers and merchants; newspapers connect subscribers and advertisers. What's changed in this century is that information technology has profoundly reduced the need to own physical infrastructure and assets. IT makes building and scaling up platforms vastly simpler and cheaper, allows nearly frictionless participation that strengthens network effects, and enhances the ability to capture, analyse, and exchange huge amounts of data that increase the platform's value to all. From Uber to Alibaba to Airbnb, whose spectacular growth abruptly upended their industries, platforms are evident in every industry.

To understand how the rise of platforms is transforming competition, it is necessary to compare how platforms differ from the conventional "pipeline" businesses that have dominated industry for decades. Pipeline businesses create value by controlling a linear series of activities—the classic value-chain model. Inputs at one end of the chain (say, materials from suppliers) undergo a series of steps that transform them into an output that's worth more: the finished product. All of manufacturing has traditionally operated like this. Apple's iPhone business is essentially a pipeline. But combine it with the App Store, the marketplace that connects app developers and iPhone owners, and you've got a platform. This is what industry 4.0 promises for traditional pipeline business.

The move from pipe to platform involves three key shifts.

1. From resource control to resource orchestration.
The resource-based view of competition holds that firms gain advantage by controlling scarce and valuable—ideally, inimitable—assets. In a pipeline world, those include tangible assets such as mines and real estate and intangible assets like intellectual property. With platforms, the assets that are hard to copy are the community and the resources its members own and contribute, be they rooms or cars or ideas and information. In other words, the network of producers and consumers is the chief asset.

2. From internal optimization to external interaction.
Pipeline firms organize their internal labour and resources to create value by optimizing an entire chain of product activities, from materials sourcing to sales and service. Platforms create value by facilitating interactions between external producers and consumers. Because of this external orientation, they often shed even variable costs of production. The emphasis shifts from dictating processes to persuading participants, and ecosystem governance becomes an essential skill.

3. From a focus on customer value to a focus on ecosystem value.
Pipelines seek to maximize the lifetime value of individual customers of products and services, who, in effect, sit at the end of a linear process. By contrast, platforms seek to maximize the total value of an expanding ecosystem in a circular, iterative, feedback-driven process. Sometimes that requires subsidizing one type of consumer in order to attract another type.

The world's top 170 platform businesses are now worth over $4 trillion. They are predominantly US and China-based. Only 4% are European. None are Irish.

Ireland 2040 Implication: the evolution of platform business models as winner-take-all ecosystem strategies, is the single most disruptive industrial force brought about by digital technology. Entire ecosystems are generally orchestrated by singular organisations. In an industry 4.0 world, the internet of things is a catalyst for real time business models, and when ecosystems consist of cyber-physical assets, and not just digital assets like apps oR video content, the context for these physical assets become platforms too. Places are now the context for platform competition. So if places become the context for platforms, our national place-

making strategy should reflect this. Ie. How do our places become enablers of platform-focussed infant industries?

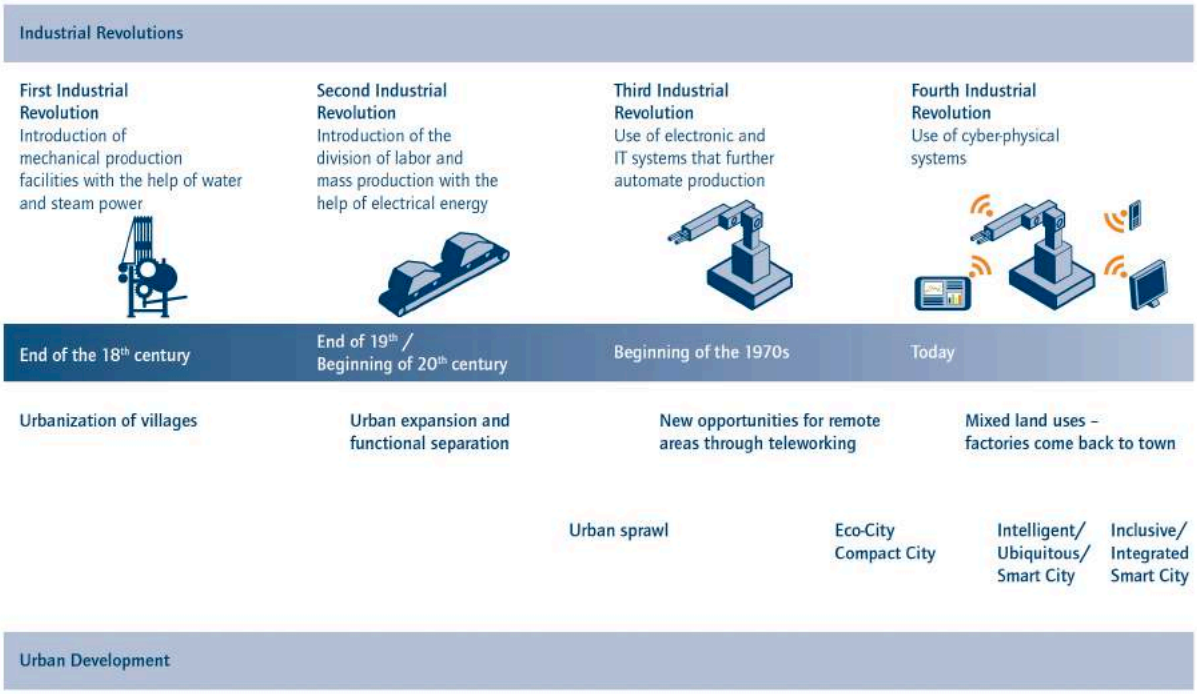
1.5 Settings in the Internet of Everything *(The spatial foundations of all these changes)*

As has been described in the sections above, we are entering a world where the internet of things (products), augmented by the internet of services, become embedded in every aspect of our lives. Digital platforms are the dominant winner takes all business model and after 20 years of the internet as we know it, as this virtual place or communication mechanism in the cloud, digital platforms are eating into the physical world, and are based around places. This is why concepts like Smart City, Smart Hospital, Smart Factory, Smart Car and Smart Home are coming more and more on stream. It is clear that as the digital and physical merge, the context for competition is the broader context of our lives; the places we occupy. A 2015 study by management consultancy firm McKinsey and Company analysed the potential impact of the Internet of Things by structuring their analysis around nine physical settings. Whereas once the potential of a technological advancement was measured by industry vertical, the impact of the internet things on the automotive industry for example, must be measured by analysing the different physical settings a car might exist in. So to understand the value of a smart connected car, you must understand the effects of IoT on the car itself where local sensors might trigger predictive maintenance services, and also the home as a setting where energy from an electric car might be transferred to the houses local energy system, or the city setting it passes through where air pollution sensors monitor the cars omissions, and even the human body as a physical setting where the person occupying the car, has the internal environment adapted to their personalised needs.

Companies like Panasonic are partnering with cities like Berlin and Fujisawa to create place-based experiments. In a project called “SmartCity Berlin” Panasonic are building an entire city block and community, a physical place, where they will test smart home ideas, smart energy, smart travel, smart food, smart climate in an attempt to understand the future of living. Cincinatti, the home to the meat factories where the second industrial revolution was born has declared itself an industry 4.0 demonstration city. Melbourne has branded itself Melbourne 4.0 in an attempt to align its constituent parts around what it sees as the biggest threat in the next decade to its status as best city in the world to live. Melbourne did this as Australia’s first attempt at copying an approach first developed in the UK called “City Deals” where each City Deal is codified as a contract between an economic region and the central government. A City Deal generally runs for 10 years or longer. Each identifies a list of priority infrastructure projects to be delivered, along with economic performance benchmarks. The UK City Deal model explicitly targets a package of infrastructure projects that lift a region’s economic capacity over a long-term timeframe. This helps focus competing priorities into a coherent set of goals that can be communicated to business and the community.

Ireland 2040 Implication: The Ireland 2040 NPF could strategically use its regions as specific test beds for components of Industry 4.0. If Dublin is a Smart City test bed, Cork might be Smart Mobility / Logistics, Limerick - Smart Health / Wellness, Galway - Smart Sustainability / Energy etc. The National Planning Framework should mirror and catalyse a National Innovation Framework, now that places more than ever before are the context for platform-based entrepreneurship.

2. Industry 4.0 and its Connections with Quality of Growth, The Green Urban Economy and Sustainable Regional Development



2.1 Industry 4.0 and Urban Development

While the first industrial revolution was triggered by large, centralized water- and steam-driven mechanical production equipment that enabled products to be manufactured more quickly and in larger quantities than before, it took almost a century before they came to be ubiquitously employed in production processes at the start of the second industrial revolution. During this period, the new production technologies led to large-scale urbanization of former rural settlements and contributed to urban growth.

The second industrial revolution was triggered by the opportunity to decentralize the electric power supply, enabling the introduction of relatively inexpensive and much smaller drive units for conveyor belts. The assembly line concept broke down many production steps into individual processes so that employees could become more specialized and production costs could be significantly reduced. This had several consequences for urban development in an increasingly industrialized world. On the one hand, production sites became larger and increasingly disruptive and urban growth was accelerated, often leading to extremely poor living conditions for the working classes. This had an impact on the development of new suburbs with better sanitary and health conditions, as well as improved urban hygiene. On the other hand, mass production made automobiles in particular, increasingly affordable for the growing middle classes. This contributed to urban sprawl and the clear separation of land uses in the rapidly growing urban areas, e.g. between industrial and residential areas.

The start of the third industrial revolution was triggered by the introduction of the first Programmable Logic Controllers (PLCs), electronics and information technologies in the late 1960s that made individual production steps much smarter than in the past. On the urban and regional development front, new hopes were nurtured that ICT could help remote areas to become more competitive and more attractive to businesses and people. It was also hoped that the long commuting distances associated with living in remote locations or in cities on the periphery of metropolitan areas would no longer be a disadvantage thanks to the new opportunities that teleworking provided for working from home, at least on a part-time basis.

The debate about future cities up to now has been slow to incorporate Industry 4.0, even though it is directly connected with urban development in many ways. One of the initiatives that links Industry 4.0 and Advanced Manufacturing with urban development is the “Morgenstadt” (city of tomorrow) Initiative being carried out by Fraunhofer, Europe’s largest application-oriented research organization. This initiative describes the link between the city of the future and production and logistics as follows: “In the future, city transportation and handling of goods will happen fluently within intelligent systems of production and distribution - providing the backbone for sustainable trade, services and urban production. The city of tomorrow will be involved more deeply in the provision of production and logistic services by providing, planning and monitoring specific urban infrastructure and services for production and logistics.” Furthermore, “In the city of the future, life and work will be characterized by short distances and by the freedom to realize individual life- and work-styles. At the same time, people will have multiple opportunities to participate in decisions on the development of their city. Rigid value chains will be replaced by innovative and flexible value patterns. Regarding consumption and economy, the possession of goods will be less important than the sustainable use of goods and systems. Inhabitants of “Morgenstadt” won’t be exclusively consumers anymore – they become prosumers: producing consumers.” Fraunhofer has chosen “Production and Logistics” as one of its 7 research fields in the future city research initiative. The others research fields are Energy, Buildings, Mobility, Information and Communication, Urban Processes and Organization, and Security.

There is also a very interesting link with recent development in India. The Indian government is in the process of implementing a new “100 Cities Program”. It wants to create 100 eco- and “smart” urban settlements all over the country as a path towards smart growth and sustainable urban development. Although the details of the program are not yet clear, re-urbanization schemes and urban retrofits seem to be among the elements included in the program. Conceptually, the aim is to have a portfolio of urban settlements all attempting to solve pieces of the same larger puzzle so that learning can be accelerated collectively and the country can develop as an interdependent network.

2.2 Growth

High-quality economic growth is seen as a prerequisite for productive and decent employment, which is in turn crucial for poverty eradication and for promoting equitable economic and social development. The following are the dimensions of high-quality growth:

1. Smart growth, i.e. the promotion of productivity and competitiveness by encouraging the development of a knowledge- and innovation-based economy.

2. Sustainable growth, i.e. environmental sustainability where the economic development of one generation does not constitute a burden to future generations, as well as the transition to a green economy.

3. Inclusive/shared growth, i.e. the productive participation of all sectors of society in economic processes.

4. Resilient growth, i.e. the reduction of economic volatility and mitigation of vulnerability to economic crises and their impacts.

5. Integrated growth, i.e. improvement of the framework conditions for the cross-border exchange of goods and services.

6. Governance for growth, i.e. the establishment of strong institutions and transparent, participatory decision making processes.

2.2.1 Smart Growth

Industry 4.0 by definition contributes to smart growth by promoting the development and transformation of metropolitan regions and cities into more holistic innovative business regions. It is the manifestation of the next stage of the digital knowledge economy and cannot come to be without the significant development of innovations such as Cyber-Physical Production Systems (CPPS) and the Internet of Things (IOT) and Services. These are crucial to driving broader innovation in Advanced Manufacturing and Advanced Logistics. The requirements for new hardware devices, sensors and software architectures to handle the complexity of the processes in global production and supply networks will lead to completely new solutions, including Internet services through Internet applications for manufacturing and logistics. This development will occur mainly in metropolitan regions and larger urban areas.

As logistics also plays a very important role in agriculture and the service industry, there will be an additional benefit to the economy through technology spill-over effects between the different sectors. As the technologies for Advanced Manufacturing and Logistics are already available in principle, industry and government are called upon to take the necessary steps to facilitate the integration and implementation of the following:

- strong ties between academia and the private sector to foster innovation through research,
- transparency of organizations and information exchange in value networks,
- examples of good industry practices through necessary innovations, such as pertinent use of ICT throughout businesses,
- the synchronization of materials and information flow within seamlessly integrated transport and logistics systems,
- active participation in international standardization,
- a high standard of education and lifelong learning for human resources,
- updating of the legal framework
- to reduce the risks for MSMEs,
- to reform the tax regime in order to reduce the tax burden on firms engaging in R&D,
- to establish strict protocols for intellectual property rights and to remove trade restrictions.

2.2.2 Sustainable Growth

Industry 4.0 also makes a contribution to sustainable growth. It contributes to the green urban economy by reducing environmental impacts and fits well with the notion of metropolitan regions as dense “nexus” networks by providing them with the opportunity to improve their materials and energy efficiency. Sustainability combines environmental, economic and social factors into a single concept. Legal instruments demanding sustainability have been used for a number of years to implement national and European sustainability objectives, e.g. the requirements to incorporate energy management systems and CO2 emissions certificate trading. The data basis available for Advanced Manufacturing and Logistics is far superior to anything that existed

previously, thanks to the collection of data by sensors throughout the manufacturing and logistics processes. Additional processing of the data on energy and material flows is required in order to generate up-to-date information such as key performance indicators. This is where recent cloud technologies and Big Data analytics come into play. This information can be used to measure and support sustainable growth, since the use of sensor systems and the associated rise in the volume of available information, coupled with flexible and intelligent control concepts, will result in more efficient control and deployment of manufacturing resources in general. In order to measure industrial sustainability, a Product Environmental Footprint (PEF) conceived as an instrument for the standardization and creation of a shared understanding of products' environmental impact is under development in Europe and has already been defined for selected sectors.

The PEF specifies and quantifies the environmental impact of a product over its entire life cycle. The equivalent CO2 emissions during manufacturing, use, recycling or disposal can contribute to the PEF assessment of the product's environmental impact.

In view of the requirements for sustainability, it is vital to embed resource efficiency within business processes in order to meet the demands of both energy management systems and energy conservation targets. It is important to note that in addition to technological factors, both organizational and social aspects in particular exert considerable influence on any such effort. In the longer term, it will be essential to conduct life cycle assessments automatically, without the need for large amounts of manual inputting. Cyber-Physical Production Systems provide the ability to implement new forms of energy and resource efficiency in manufacturing. This is of special significance where the development of new production facilities in an international context permits the introduction of new forms of resource-efficient production.

- energy optimization,
- location and adaptability risk,
- cost-effectiveness of manufacturing products under sustainability constraints in India,
- financial risks of new processes,
- growth in throw-away culture and changing consumer demands,
- resource scarcity,
- climate change,
- waste disposal, waste and pollution control,
- energy security,
- carbon emission crediting and low ceiling of carbon accounts,
- resource depletion, resource conflicts and resource-based political power,

The multiple opportunities for resource optimization will promote manufacturing sustainability, especially in the automobile, pharmaceutical, energy, aerospace and electronics sectors where there is also a strong need to develop the following:

- strong links between academia, the private sector and government are necessary to follow through on sustainability,
- effective skills training programs pertinent to the different target sectors and customized for all levels of the skill pyramid ranging from technical to business skills,

- design of new collaborative resource consumption models,
- design of business models for managing waste and recycling and adopting cleaner technologies,
- encouragement of new industries based on energy management and renewable energy concepts,
- development of environmentally-friendly materials,
- in contrast to the present dominance of road transport, infrastructure alternatives could take the shape of intermodal transportation including a high-speed rail freight network with cross-docking and distribution facilities

Sustainability gains may also come from spatial issues. Industry 4.0 may facilitate mixed urban development and contribute to the realization of the “compact city” and the “walkable city”. Cleaner production and higher environmental standards lead to better compatibility of industrial sites with other land uses. Thus, industrial production can occur in close proximity to residential areas. Moreover, Industry 4.0-based urban production has the potential to operate with smaller lot sizes due to the modularization of production, meaning that fewer storage facilities will be required. This will allow production facilities to be better integrated into existing urban structures or even located as infill developments in urban regeneration areas. However, these new urban development opportunities induced by Industry 4.0 will not come about automatically. Market failures and inadequate governance structures, characterized e.g. by unbalanced and uncontrolled land markets and inadequate and unreliable infrastructure facilities, may force companies to continue to locate on the periphery of metropolitan regions. This is not only counterproductive in terms of the realization of compact sustainable cities but it also unnecessarily increases environmental impacts, e.g. due to large employee commuting distances, especially in cases where an efficient public transport system is not in place. Like in the case of “smart growth”, this demonstrates the need for good governance, cooperation and modern urban-regional planning.

2.2.3 Inclusive/Shared Growth

At first glance, the contribution of Industry 4.0 to inclusive or shared growth may be less apparent than in the case of the other dimensions of the “quality of growth” approach. It may also not be immediately obvious how Industry 4.0-based production promotes a green urban economy, e.g. in terms of inclusive economic growth and poverty reduction, or how it can support metropolitan regions as inclusive labour markets, which is one of the characteristics of urban-regional sustainability. Industry 4.0 is often said to be a job killer rather than a job creator, due to its inherent automation of production processes. And it is often seen as exclusive rather than inclusive in terms of socio-economic development. Thus, it may be argued that Industry 4.0 will not be able to substantially contribute to making cities more inclusive.

However, these assumptions are not necessarily true in every case. Industry 4.0 is oriented towards the modularization of industrial production and the facilitation of lot size 1. However, this does not mean that production requires fewer employees and that all production processes along the supply and value chains have to be automated. Nevertheless, job profiles will change in general, with increasing numbers of higher-skilled jobs. This will require sound education programs and vocational training activities in respective cities and regions in order to increase regional Industry 4.0 readiness.

Moreover, it should be remembered that Industry 4.0-based production may create new opportunities for small local suppliers and start-ups to become involved in national and/or

international value chains thus strengthening the economic development of cities and regions. Furthermore, new job creation opportunities in ancillary industries and in the related service sectors should also be taken into consideration.

Industry 4.0 concepts promoted through cooperation can provide the necessary preconditions for fostering much greater participation of MSMEs in national and/or international value networks, thereby creating or securing more jobs. Moreover, as MSMEs usually lack the necessary R&D capabilities, such cooperation will enable them to keep up with global manufacturing innovations.

2.2.4 Resilient Growth

Resilient growth does not imply the avoidance of all risks at all costs – it is strongly connected to risk management. In the past, resilience in businesses was mostly driven by experience. However, with data- and process-driven Advanced Manufacturing based on Industry 4.0 concepts it is now possible to model the processes involved to a much greater extent. Accordingly, risks can be mitigated by deploying joint risk management procedures designed by cooperating enterprises and backed up by government policies to integrate resilience into international Advanced Manufacturing networks.

- MSMEs' business models should provide robust protection against multiple external factors, such as changes in technology trends, frequent variations in customer demands and global recessions resulting in low demand.
- Involvement of multiple stakeholders from government, academia, Foreign Direct Investment and the general public could mitigate the risk of insolvency due to highly investment-intensive activities, such as innovations, disruptive technologies and high-end technology acquisitions.
- Government must update the legal framework to create easy business exit policies for MSMEs in the event of business problems.
- Regulatory bodies must work towards reforming the tax regime in order to reduce the tax burden on firms engaging in R&D activities and innovation.
- Strict protocols for intellectual property rights (IPR) must be adhered to at the international level.
- Firms must form international and national industrial networks to facilitate the adoption of innovative mechanisms to cope with uncertainty through participation in the provision of systemic solutions.
- The treaties and policies regarding promotion of sustainability and environmental obligations, such as ceilings for carbon trading, formulation of global renewable energy policies, etc., must be optimized to provide equal industrial development opportunities to all countries.
- Large companies and global conglomerates that have already established their risk management policies for cyber risks and knowledge management could mentor MSMEs or work with their suppliers in order to improve their structures and mitigate their vulnerabilities, in the interests of promoting growth.
- The major risk of delays to business operations could be minimized by optimizing the variables such as the choice of manufacturing location, decisions on customer interactions, total business cost and target market segment.

Specific Industry 4.0 concepts can contribute to risk mitigation as follows:

- The implementation of new sensor concepts to record field data enables resilient production processes to be developed and operated.
- Reservations relating to opening up interfaces and large-scale data analysis must be overcome jointly by the participants in international value networks.
- Test procedures to check manufacturing and logistics resilience at all tier levels must be jointly designed and agreed upon among cooperating value networks.
- Resilient process chain design can be achieved by the order-dependent combination of manufacturing steps.
- Process fluctuations can result in uncontrolled instabilities in the process chain ("bull-whip effect"). Broad recording of process fluctuations and real-time control will return processes to a stable state even before risky events can pile up.
- Suppliers of industrial information technologies must resolve the challenges associated with classical data recording, cloud technology and data analysis concepts.
- Risk management and resilience management should be promoted at both the corporate level and the level of the authorities responsible for infrastructure management in order to reduce the frequency and impact of disruptions to industrial processes in production and logistics

In globally distributed supply networks, disruption occurs regularly. Robust supply chains that are able to cope with unforeseen events are a vital business capability in rapidly changing value networks. In addition to a resilient and flexible supply network infrastructure, businesses need highly accurate risk detection capabilities that employ Big Data tools and techniques. Moreover, logistics providers can secure customer operations by performing predictive analytics on a global scale.

Risk mitigation must therefore be a part of regular logistics operations rather than an intervention carried out after the event as is usually the case today. The operations manager is familiar with normal conditions and also how anomalies arise and should be tasked with handling abnormal situations. With regard to stable Advanced Logistics for Advanced Manufacturing in international value networks, there is also a set of strategies for helping government, corporations and individuals to manage the risks so that they can either be avoided or so that process resilience can be achieved if avoidance is too expensive:

- Avoid the risk whenever possible: It is risky to source from countries where there is a possibility of war or weather problems, or from companies with troubled finances.
- Mitigate the risk directly by improving flexibility in order to reduce the impact or likelihood of the risk at its source. Dual sourcing is one simple solution.
- Adapt to the risk by preparing for it, e.g. earthquake-resistant building construction, rapid evacuation in the event of floods and securing access to buildings.
- Transfer the risk to a third party such as an insurer or through more sophisticated hedging strategies.

- Mitigate the risk using order-based governance involving partner selection, coordination, monitoring and execution. For each order, a 4PL can select the logistics partners in order to minimize the risks associated with the logistics processes.

As regards the relation with urban development, resilience and risk reduction is very closely related to the capacities of the urban and regional planning system, the available planning tools, and the existing governance regime. Sound planning and implementation can contribute to minimizing risks by promoting better organized and reliable city patterns and infrastructure systems. The availability of appropriate and effective urban planning tools is decisive for the implementation of planning concepts oriented towards risk reduction. And the governance regime may help to provide for transparency and participation.

2.2.5 Integrated Growth

There can be no doubt that Industry 4.0 contributes to integrated growth. As the global manufacturing industry relies on international value chains, integrated growth is a direct consequence of Advanced Manufacturing and Advanced Logistics at the international level. An important prerequisite is the international transport of materials and goods. A more integrated approach is required to be taken of transport as a whole. Transport should be guided by a modal mix that will lead to an efficient, sustainable, economical, safe, reliable, environmentally friendly and regionally balanced system. Choices will need to be made on the priorities to be placed on different investments. Decisions on road expressways, dedicated rail freight corridors, high-speed trains or coastal shipping must be taken holistically so that the objective of speed and efficient energy usage is achieved. Policy decisions should be based on life cycle energy costs of different transport modes. In order to enable smooth international logistics, it will also be important to foster the transition from Second-Party Logistics Providers to Third-Party Logistics Providers offering a one-stop solution for all manufacturers' logistics services. Given that the technologies for Advanced Manufacturing and Logistics are already available, industry and government are called upon to take the necessary steps to resolve the legal, economic and infrastructure constraints, e.g.

- clear and simple import and export regulations,
- the logistics system should consider import and export regulations for delivery management,
- the necessary innovations on the basis of industry 4.0 concepts, such as
- pertinent use of ICT throughout businesses,
- the synchronization of materials and information flow within seamlessly integrated transport and logistics systems,
- updating of the legal framework to reform the tax regime in order to reduce the tax burden on firms engaging in R&D, establish strict protocols for intellectual property rights,
- remove customs restrictions and prevent goods from experiencing long delays at customs.

A well-functioning logistics and transport infrastructure is of the utmost importance for urban development and the location of production facilities. If these are not in place, and if reliable transportation of materials and goods cannot be guaranteed, it will not be possible to convince enterprises to locate their facilities in the urban core areas. In fact, transportation problems are

among the reasons why enterprises are currently still “moving out” to the periphery of urban areas. In such a situation, the potential benefits of Industry 4.0 such as the generation of mixed urban land uses and the location of production sites in inner-city regeneration areas are lost. Moreover, commuting distances grow instead of becoming smaller, and place-making is almost impossible.

2.2.6 Governance for Growth

Industry 4.0 is closely related to governance for growth. Especially for Advanced Manufacturing and Advanced Logistics in international value networks, it forms part of all the growth drivers for businesses and governments. In addition to the necessary efforts of businesses to integrate ICT and CPPS functions for Advanced Manufacturing, there must be committed efforts on behalf of governments to determine current deficits and implement timely remedial policies.

- Providing access to risk capital
- Establishment of standards for industry
- Improving industry/research institute/academia interaction, mostly in clusters

Technology and quality improvements are identified as a top priority, along with supporting entrepreneurial and management development. Emphasis is placed on raising awareness for investment in intellectual property. A holistic framework of IPRs in collaboration with international authorities is therefore indispensable in today‘s competitive manufacturing environment in order to empower the Irish technology base.

Governance also plays an important role in creating the right urban framework conditions for Industry 4.0, e.g., regarding urban planning, development strategies, infrastructure, logistics, etc. In this context, metropolitan regions and urban areas should be seen as governance systems. They need to be reformed so that they are able to organize and control the multi-sectoral challenges facing them, especially those linked to Industry 4.0.

3. Intersectional Opportunities and Challenges

The following is a table of the opportunities and challenges that exist at the nexus between advanced manufacturing (Industry 4.0) and urban development. It purposefully considers Industry 4.0 from a factory and supply chain perspective only, and not in terms of the broader digital business ecosystems those same factories will exists within. It is less about the impact of the smart, connected products made within these smart, connected factories and more about the implications of planning for this new emerging world of industrial production. The categories addressed are: urban economy, urban-regional development, value creation, integration and networking, knowledge creation, socio-economic development, technical infrastructure, environmental effects, urban structures and land use.

Opportunities	Challenges
Urban Economy	
- Competitiveness of cities may be enhanced through core functions and pioneer establishments related to advanced manufacturing. - There may be additional opportunities for new entrepreneurial activities and small scale enterprises, especially unconventional and creative ones, to connect with larger companies, and to offer new or better services to them. This may lead to more inclusiveness, economically and socially. - Urban economy may benefit from an increase of advanced manufacturing companies: taxes, income generation, multiplier effects, supply chain, etc. - Specialization may make better use and enhance local development potentials.	- Competition may become stiffer as companies have more locational choices due to their shrinking dependence on local production factors. - Integration into advanced manufacturing value creation chains may contribute to socio-spatial disintegration within cities (between those groups and areas which are linked with and those which are not linked with advanced manufacturing); growing social segregation as well as rising disparities between urban districts may be among the consequences. - Specialization may lead to higher economical and development vulnerabilities and risks and it may diminish resilience in case of crisis. - Good urban governance and fruitful cooperation between stakeholders (state, business community) are necessary and crucial factors for successfully raising competitiveness. This is not easy to achieve.
Urban Regional Development	
- Enterprises become, to a higher degree than today, multi-locational entities. - Individual locations of companies may take over more specialized and focused functions in value creation chains. - Advanced Manufacturing may diminish the companies' dependency on locational production factors. It may enlarge degrees of freedom regarding the sizes of their enterprise units and production facilities as well their locational choices. - Location factors will be re-defined. Also remoteness will be redefined. Formerly "remote" areas have more equal chances to compete successfully. - Competitiveness of regions and urban-regional development may benefit from advanced manufacturing. - Regional development may profit through regional value-added production, specialization, additional income generation, regional ancillary industries and services, multiplier effects etc.	- The availability of knowledge creation institutions (universities, research institutions), research and development activities, for example within companies, and interest of companies in regional connections are important prerequisites. - Advanced Manufacturing strategies are helpful, like smart specialization or urban (economic) development strategies. These require respective initiatives by the public and private sectors. - Advanced Manufacturing may widen (inter-) regional disparities (and those between cities), that is those which are and those which are not integrated. Specialization may lead to higher risks for regional development.
Value Creation	
- Advanced Manufacturing may enhance production and enlarge local and regional value creation chains. - Advanced Manufacturing may create new opportunities for local regional companies and the informal sector.	- Experience shows that in many cases Advanced Manufacturing puts more emphasis on international orientation and worldwide integration than on regional embedment.
Integration and Networking	
- Advanced Manufacturing leads to more networked economic structures and processes. Industrial production will be more and more characterized by multi- locational networks. - Advanced Manufacturing furthers the creation of dynamic and flexible enterprise networks. - Advanced Manufacturing facilitates related companies to associate for a given time span and to form temporal virtual production or service clusters. - Advanced Manufacturing manufacturing raises the international inter-connectedness and visibility of cities and regions.	- Networking has high transaction costs and investment (for example time, efforts, personnel). - Network access may be difficult. To a high degree, it depends on decision making by company involved in Advanced Manufacturing . - Interests of companies and local/regional stakeholders may be different (for example orientation on competitive production on the one hand, and socio-spatial integration on the other).
Knowledge Creation	
- Advanced Manufacturing may contribute to raising the educational level of a city as it requires a well-qualified labour force.	- Advanced Manufacturing may contribute to social exclusion by making the access to knowledge creation for certain groups of society (for example urban poor) even more difficult.

- Advanced Manufacturing may contribute to facilitating the establishment and strengthening of universities and research facilities. - Advanced Manufacturing may support public-private partnerships for knowledge based urban and regional development.	
Socio-economic Development	
- Advanced Manufacturing may contribute to creating new jobs and more income opportunities for the urban population. - Advanced Manufacturing may contribute to the formation or stabilization of a strong middle-class population. - Advanced Manufacturing may contribute to poverty alleviation through the creation of additional jobs in the industry and the service sector which are more accessible for the urban poor.	- Advanced Manufacturing may contribute to the loss of (especially less-paid and less-qualified) jobs through rationalization and automation. - Advanced Manufacturing may restrict job opportunities of the urban poor and the less-qualified. Thus it may contribute to increasing poverty.
Technical Infrastructure	
- Advanced Manufacturing may support better urban infrastructure, for example digital and transportation infrastructure. - Advanced Manufacturing may have positive influence on logistics.	- Weak and un-coordinated planning and implementation may contribute to severe deficits regarding the provision and reliability of infrastructure. - Digital infrastructure may only be provided on demand to those who request and pay for it, thus excluding a large part of the population, especially the urban poor. - Due to inadequate availability of funds and limited fund generating capacity of funds on the one hand and high investment needs, it may be difficult to put the adequate infrastructure in place. - The speed of urban growth may override the capabilities to establish necessary infrastructure thus widening the gap between serviced and non-serviced (or in the case of companies: auto-serviced) areas. - Cyber security may be difficult to be established.
Environmental Effects	
- Advanced Manufacturing will lead to cleaner production and more energy efficiency through sensor technology, high precision control and real-time information. - Material consumption and waste will be reduced. - Advanced Manufacturing will make a contribution to climate change mitigation. - Advanced Manufacturing may require less storage capacities due to real time information processing. This may result in less land “consumption” for industrial purposes. - Smart products may be easier recycled. This reduced the amount of waste.	- There may be rebound effects. As production sites may be located at the edge of the city or metropolitan area, commuting distances may grow. Because of difficult traffic conditions, time and energy consumption through commuting may increase. - Production sites may be designed as to deal with a variety of difficulties, for example regarding infrastructure provision. This may lead to increased land “consumption” by industry. - Companies may want to secure safe infrastructure provision at their production sites and install basic infrastructure by themselves. This may lead to an un-coordinated and increased consumption of water and energy as well as to environmental damages in general. - Real time production requires just-in-time delivery. This may lead to higher pressure on transportation. More trucks become mobile storage facilities (like in just-in-time production).
Urban Structures and Land Use	
- Modularized production allows that individual manufacturing entities become smaller. - Advanced Manufacturing may facilitate more mixed urban structures through the enhanced possibilities of environmentally friendly integrated “urban production” (for example with management units, design offices or clean production sites within or close to housing areas). - Advanced Manufacturing may have positive effects on the realization of the concept of the “walkable city ”. - Synergies of more mixed urban functions may be used. - This may also bring back life to formerly depressed urban areas (urban retrofit).	- There may be more new urban development outside or on the edge of cities due to better and less expensive availability of land. This may contribute to increased urban sprawl. - Difficult transportation and logistics issues may make it advisable to locate production sites at the edge or outside of existing cities. This may be counterproductive to the concept of the principles of the “walkable city”.