On Globalization and Versatile Manufacturing

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Abstract

To eliminate waste of energy and reduce CO2 emission, it is necessary to drastically reduce global supply chains and business travel.

This is possible to achieve by transforming traditional manufacturing plants into “Versatile Manufacturing Systems” capable of cost-effectively producing a variety of goods in small or large batches and locating them close to points of consumption. Almost like “corner shops”.

Achieving national self-sufficiency in critical goods by moving manufacturing closer to points of demand would resolve a number of serious issues that emerged during current pandemic.

The report outlines how this innovation could be realized and identifies the major obstacle, the out-of-date mindset of decision makers.

What is Globalization?

According to Wikipedia, "globalization refers to an open flow of information, technology, and goods among countries and consumers. This openness occurs through various relationships, from business, geopolitics, and technology to travel, culture, and media".

Intended Benefits of Globalization

Again, according to Wikipedia:

Access to New Cultures

Globalization makes it easier than ever to access foreign culture, including food, movies, music, and art. This free flow of people, goods, art, and information is the reason you can have Thai food delivered to your apartment as you listen to your favourite UK-based artist or stream a Bollywood movie.

Access to Technology

Many countries around the world remain constantly connected, so knowledge and technological advances travel quickly. Because knowledge also transfers so fast, this means that scientific advances made in Asia can be at work in the United States in a matter of days.

Lower Costs of Products

Globalization allows companies to find lower-cost ways to produce their products. It also increases global competition, which drives prices down and creates a larger variety of choices for consumers. Lowered costs help people in both developing and already-developed countries live better on less money.

Higher Standards of Living across the Glob

Developing nations experience an improved standard of living—thanks to globalization. According to the World Bank, extreme poverty decreased by 35% since 1990. Further, the target of the first Millennium Development Goal was to cut the 1990 poverty rate in half by 2015. This was achieved five years ahead of schedule, in 2010. Across the globe, nearly 1.1 billion people have moved out of extreme poverty since that time.

Access to New Markets

Businesses gain a great deal from globalization, including new customers and diverse revenue streams. Companies interested in these benefits look for flexible and innovative ways to grow their business overseas. International Professional Employer Organization (PEO) make it easier than ever to employ workers in other countries quickly and compliantly. This means that, for many companies, there is no longer the need to establish a foreign entity to expand overseas.

Access to New Talents

In addition to new markets, globalization allows companies to find new, specialized talent that is not available in their current market. For example, globalization gives companies the opportunity to explore tech talent in booming markets such as Berlin or Stockholm, rather than Silicon Valley".

The benefits specified above have been largely realised and we find particularly satisfactory the reduction of poverty and the increase in living standards in developing countries.

Unintended Negative Consequences of Globalization

However, our research uncovered rather serious negative consequences of globalization, as currently practised.

Waste of Energy and Increased Pollution

Locating factories on sites remote from the points of demand to save manufacturing costs, increased transportation distances for manufacturing goods and expanded business travel to a level that is unsustainable.

Amplified “Butterfly Effect”

Intercontinental supply chains and excessive business travel increased propagation of small disruptions (such as a movement of air caused by a butterfly wing) turning them into extreme disruptive events at faraway points on the planet. The notorious example being the rapid spread of coronavirus infection, which converted a single case in Wuhan into a global pandemic in a matter of days.

Vulnerability of Nations in a Worldwide Crisis

Coronavirus pandemic clearly demonstrated that, in a global crisis, nations focus on what they think is the best for them ignoring needs of others. Even within the European Union nations competed rather than cooperated for access to resources in short supply, such as protective equipment. “America first” slogan gave to others an example to follow.

How to Preserve Benefits and Avoid Pitfalls of Globalization

All three negative consequences, identified above, could be removed by building smaller “versatile” manufacturing plants close to the points of demand.

We now have digital technology for rapidly switching between manufacturing of a variety of similar products as demand changes and cost of this technology is decreasing.

We are leaving behind the industrial era where the economy of scale was the key for gaining competitive edge. In the new digital age the adaptation, rather than the economy of scale, is the secret of prosperity.

Versatile Manufacturing Systems

The concept “Versatile Manufacturing System” is new and, to the best of author’s knowledge, it is articulated for the first time in this research report. It basically means that *the manufacturing system can be rapidly reconfigured and rescheduled to switch from producing one type of product to producing a different type.*

The production is in batches, which may be small (even a batch of one), medium or large. The goal of a versatile manufacturing system is to meet demand for a range of manufactured goods in the close proximity and, as a result, to reduce delivery chains as much as practically possible.

Let’s try to introduce some formality into the definition of versatility.

*A manufacturing system is **versatile** if it is capable of selforganising in response to a request for changing its product type, by (1) instantly detecting whether the requested product type is within its portfolio, (2) rapidly identifying which manufacturing resources are required, and (3) configuring and scheduling required resources.*

Production profile** is a list of product types, which a versatile manufacturing system is capable of manufacturing.* It defines *the **range of products of a versatile manufacturing system.

***Product type** is a type of the product that a versatile manufacturing system is configured and scheduled to produce* (e.g., type of electric motors or batteries for electric cars).

Selforganising *means autonomously* (without human intervention) *changing system resource configuration and/or schedule,* e.g., switching from producing batteries type A (for a car brand X) to producing batteries type B (for a car brand Y).

Let's note that for a manufacturing system to be versatile, it must be adaptive.

A manufacturing system is ***adaptive*** *if it is capable of selforganising in response to unpredictable external or internal changes in operating conditions, by (1) instantly detecting any unpredictable disruptive event (i.e., a change in demand or supply, human error, failure of resources, fraud or electronic attack), (2) rapidly identifying which parts of the system will be affected, and (3) autonomously rescheduling affected resources to eliminate, or at least, reduce consequences of disruption in real time, i.e., before the next disruptive event occurs.*

Background

In developed countries the standard practice has been to outsource manufacturing to developing regions, where low wages and favourable investment environments ensured competitive prices for manufactured products. Additional costs of global supply chains and long-distance transportation of manufactured goods were, and still are, relatively small. Such an arrangement seemed to be a win-win situation. Both the developed and developing countries have gained.

However, recent widespread concerns about manmade pollution and climate change, have made the outsourcing of manufacturing to faraway parts of the planet untenable - transporting huge volumes of goods from one end of the world to another, even if cheap, is wasteful of energy and harmful to the environment.

Manufacturing will have to be located as close as possible to consumption. As it happens, we have technology, which could enable this transformation. The problem is with attitudes of decision makers.

Generations of economists and engineers have been brought up to accept without questioning the notion that the critical success factor for manufacturing is the *Economy of Scale*. This notion was correct under conditions of stable markets and predictable demands, the situation that prevailed in the 20th century. Dynamics of markets in the 21st century, however, has drastically changed, as briefly described below.

During the last 20 years, the number of people *actively using* the Internet has increased from 360 million to 4.6 billion, which represents about 60% of all the people that are currently alive. The consequences of this unprecedented acceptance of new technology are yet to be fully appreciated.

The Internet has become the backbone of the new *Digital Economy*. The Internet-based global market spans the whole planet and is populated by billions of suppliers, consumers, middlemen, dealers, brokers, consultants, investors, bankers, insurers and retailers, engaged in making, breaking or modifying business transactions with unprecedented speed and frequency. As a consequence, the market is so *complex* that it is no longer possible to forecast demands and supplies with any certainty, whilst human errors, failures of resources, delays, fraud and cyberattacks are on the increase.

As dynamics and volatility of the market increases, we have to accept that the critical success factors for businesses cannot stay the same. Big, hierarchical corporations, designed to take full advantage of the economy of scale, have rigidity caused by long delays between the detection of a change in demand and the decision on how to reschedule resources to meet the identified change.

It is quite obvious that under conditions of frequent, unpredictable changes in demand and supply and frequent occurrence of various disruptive events, the critical success factor must be *Adaptability*, the ability to detect any disruptive event, as it occurs, to rapidly identify the part of the business that will be affected by the disruption, and to eliminate, or at least reduce consequences of disruption by rescheduling the affected resources [1], [2]. Since only Complex Systems can be adaptive, the clear conclusion is that manufacturing systems must be designed to be Complex (for adaptability), rather than big and rigid (for the economy of scale).

Once the decision makers accept this premise, it will be possible to start designing small, adaptive and versatile manufacturing units and locate them close to the demand for their products.

The key to achieve results is changing old-fashioned mindsets of decision makers.

The next section contains a brief review of Complex Systems for benefit of readers who are not familiar with fundamental concepts and principals of the new Science of Complexity.

Complex Systems

A system, or a situation, is said to be *complex* if it is *open* (exchanges information with its environment), consists of many *diverse*, partially *autonomous* and richly *connected* components, called *Agents*, and if it has *no central control*. Behaviour of complex systems is uncertain without being random. The global behaviour *emerges* from the interaction of constituent agents. The autonomy of agents is limited by constraints imposed on them by the system to which they belong.

The word “complex” derives meaning from the word *plex* (interwoven or interconnected) and should not be confused with words like “complicated” (as a jet engine), “cumbersome” (as bureaucracy), “unwieldy” (as an aged empire), “chaotic” (as a disorderly administration) or “difficult to understand” (as a verbose document).

Since the key feature of a complex system is that it is *Adaptive,* it is customary to call complex systems *Complex Adaptive Systems*. Complexity is discussed in detail in [1].

Using *Uncertainty* as a criterion, we can divide all systems into 3 classes:

- *Deterministic*, whose behaviour is predictable (uncertainty = 0). Examples include man-made systems such as cars, aircraft, bridges and clocks, as well as closed models of physical system such as pendulums and planetary movement.
- *Complex*, whose behaviour emerges from the interaction of agents, it is not predictable in detail and yet follows discernible patterns (1 > uncertainty > 0). Examples include natural ecology, social, political and economic systems, businesses and markets.
- *Random*, whose behaviour is completely unpredictable (uncertainty = 1). A good example is movement of molecules.

RANDOM	COMPLEX	DETERMINISTIC
Uncertainty = 1	1 > uncertainty > 0	Uncertainty = 0
Full autonomy of agents	Partial autonomy of agents	Agents have no autonomy
Disorganised	Selforganising	Organised
Unpredictable behaviour	Emergent behaviour	Predictable behaviour

Table 1. Classification of systems

The key features than differentiate complex systems from deterministic are: (1) Connectivity, (2) Autonomy, (3) Emergence, (4) Nonlinearity, (5) Nonequilibrium, (6) Selforganisation, and (7) Coevolution.

Connectivity of an agent denotes the number of other agents to which the agent is connected. Complexity of a system increases with connectivity. The highest known connectivity is associated with neurons in the human brain, which is of the order of 1,000. Connection strength is also an important in assessing the level of complexity. Complexity is higher when connections between agents are weaker and can be easily disconnected and new ones established. The right side of the human brain has weaker connections between neurons than the left side, which explains why it is responsible for creativity – the ability to discard old and create new, more effective patterns of behaviour.

Autonomy of agents denotes the degree of freedom of agent behaviour. Complexity of a system increases with autonomy of agents. For example, old-fashioned large families with strict rules of behaviour and hierarchical structure are less complex than modern arrangements where individuals are subjected to few constraints. Nevertheless, in complex systems agents always have restricted freedom of behaviour. In the extreme, when agents are given full autonomy, the system behaviour becomes random.

Emergence - Complex systems have properties that cannot be found in constituent agents. They emerge from the interaction of agents. For example, human intelligence and creativity are emergent properties of the brain, they emerge from the interaction of neurons.

Nonlinearity - Links among agents are nonlinear and include amplification, self-acceleration and auto-catalytic property. As a result, small, insignificant disturbances my cause extreme events, phenomenon known as *Butterfly Effect*. More importantly, the accumulation of small disturbances over time may cause a *Drift into Failure*.

Nonequilibrium - The operation of complex systems is typically affected by frequent disruptive events. If complexity level is high, disruptive events occur with high frequency and the system has no time to return into equilibrium before the next disruption.

Selforganisation - When disrupted by a disruptive event (arrival of an unexpected demand, failure, delay, fraud, electronic attack or similar), the system rapidly identifies affected parts and reschedules constituent resources to eliminate, or at least, reduce the effect of the disruption before the next disruptive event occurs. Selforganisation is an extremely useful property of complex system, making them *Adaptive* to changes in their environment and *Resilient* to attacks/fraud. Selforganisation may also lead to *Self-improvement*, when agents, by trial-and-error selforganise to improve system performance.

Coevolution - Complex systems coevolve with their environment, they are affected by changes in the environment and, in turn, affect the environment.

Transforming a Conventional Manufacturing Plant into a Versatile Manufacturing System

The basic premise of Complexity Science is that only complex systems can operate effectively within a complex environment. Rigid structures of deterministic systems tend to crumble when placed under conditions of complexity. In contrast, complex structures easily adapt to changes and are resilient to attacks.

It follows that manufacturing businesses which operate in a complex environment should be designed to behave as complex adaptive systems.

Since frequency of unpredictable disruptive events in the global market is high, the detection, impact analysis and rescheduling must be done rapidly – in real time – which can be achieved only by employing intelligent and fast decision-making technology, such as complex adaptive technology.

Manufacturing business processes are, in general, connected, therefore the adaptation in one process will cause ripple effects in other processes, which will have to be dealt with. The implication is that business processes in adaptive manufacturing systems will be continuously selforganizing in order to adapt to disruptions.

Intelligent real-time schedulers are capable of cooperating (or competing) with each other, ensuring that manufacturing processes are interacting with each other.

The architecture of an adaptive manufacturing unit scheduled by an intelligent real-time scheduler is depicted in Fig. 1 below.

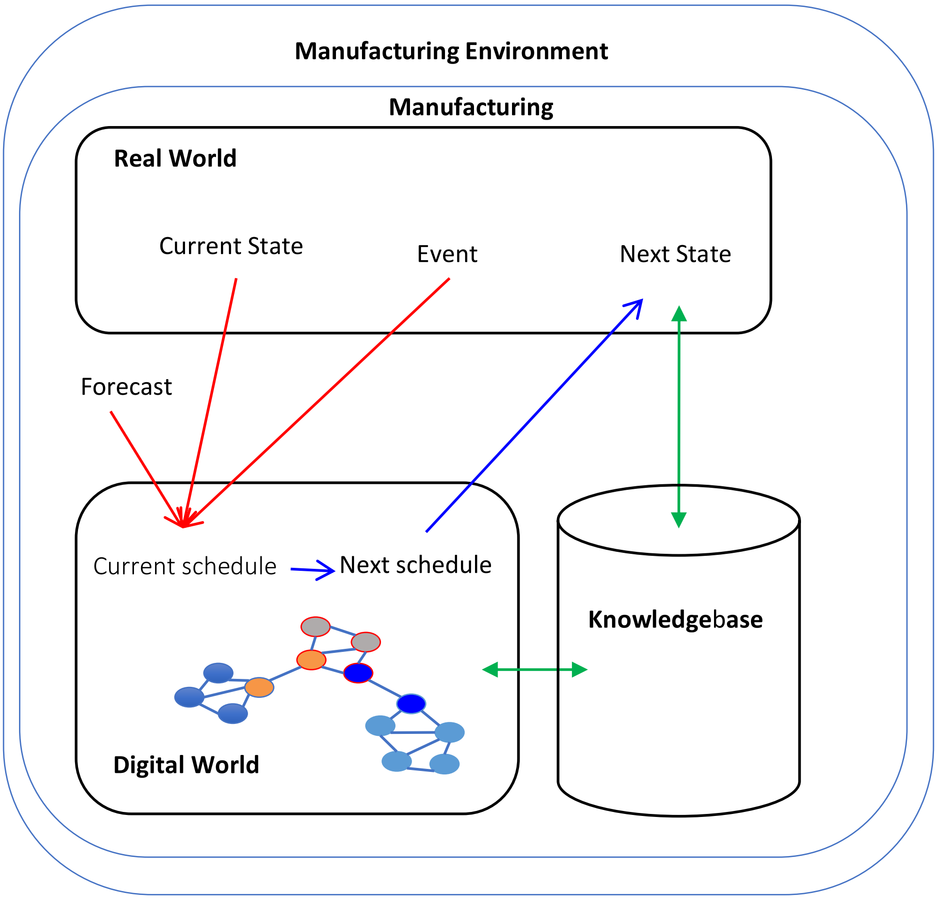

Fig. 1. Architecture of a manufacturing system scheduled by an intelligent real-time scheduler

The system consists of

1. Real-World human and physical resources that perform manufacturing
2. Digital-World agents engaged in real-time scheduling of Real World resources
3. Knowledgebase containing knowledge how to run the manufacturing
4. Interfaces between the two worlds, primarily concerned with the transmission of
    a. information about disruptive events from the Real to Digital World and
    b. instruction how to reschedule human and physical resources, from Digital to Real Word

The process of transformation of a conventional manufacturing to an adaptive manufacturing system could be done with a minimum of disruptions by following an evolutionary transformation methodology [1].

The second step is to turn an adaptive manufacturing system into a versatile. For this, it is necessary for all manufacturing resources (e.g., robots, machine tools, conveyers, transporters, etc.) to be reconfigurable because, normally, every product type within plant portfolio will require a different resource configuration. However, if product types are similar, differences in configurations may be small.

On top of that, it is necessary to build a second layer of selforganization in response to a request for switching from one product type to another, which amounts to (1) instantly detecting whether the requested product type is within system portfolio, (2) rapidly identifying which manufacturing resources are required, and (3) configuring and scheduling required resources.

The author's team has a considerable experience in designing various types of selforganization using in-house developed complex adaptive digital technology.

Conclusions

Building manufacturing facilities at locations remote from points of demand will have to be discontinued.

In the digital age globalization should focus on trading in knowledge rather than goods.

Reinventing manufacturing on a world-wide scale, as described in this paper, would have a huge positive impact on the environment and would help nations to retain certain self-sufficiency which would ensure vital supplies when the global market fails.

However, the probability of changing mindsets of decision makers, which would enable such a project to take off, is minimal.

References

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