Globalization, Networking, and Engineering Technologies

Alexander M. Korsunsky

***Abstract*—In our rapidly shrinking world, countries and affairs that once seemed far away have ever stronger and more profound impact on our lives. This globalization process is undoubtedly technogenic. The first vehicle for this phenomenon is the rise of rapid communications, highlighted by the degree to which the internet and wireless communications permeate our environment, providing email, web, IP telephony, video-conferencing, remote banking and other services. The second important technological contributor is air travel. The volumes of passenger and freight air traffic worldwide continue to grow exponentially, as they have done now over several decades. This growth drives further globalization by accelerating the interchange of people and goods, but questions about the sustainability of such development also become more acute. The third crucial technogenic phenomenon is the globalization of manufacturing, services and engineering development: remarkably, not only engineering technologies create the basis for globalization, but they themselves become involved in the resulting global pattern of research and development activities. What phenomena arise in the context of technology-driven globalization? What is the social and economic impact of globalization? Can organizations and communities suffer or benefit from it?**

***Index Terms*—Globalization, engineering, socio-economic impact, technology.**

I. INTRODUCTION

No-one is surprised today to come across the word "globalization" in a wide variety of contexts, from politics and economy to climate and ecology to issues human and social. It is small wonder, considering how the events happening and decisions made halfway across the world now affect what and how we buy, wear, eat, sing and dream of. In Britain one takes for granted that mutton comes from New Zealand, orange juice from California, and much of the manufactured goods from China. This world that we live in today is a relatively (in fact, historically – very) recent development. We have been able to adjust to this rapid change; it has generally been for the good. It should not be difficult to realize, however, that this may not necessarily last, i.e. that the present state of affairs, or, rather, the present direction of development, may not be sustainable.

As is common in social (and also natural) sciences, in order to begin figuring out what future developments one might expect and how one might best prepare for them, one might try to look back the history – in this case, the history of globalization. That way one might be able to glean answers to some important questions.

How did we get here? Where are we going next?

Manuscript received 8 January, 2010.

Alexander M. Korsunsky is Professor of Engineering Science in the University of Oxford, Department of Engineering Science, Parks Road, Oxford OX1 3PJ, U.K. (tel: +44-1865-273043; fax: +44-1865-273010; e-mail: alexander.korsunsky@eng.ox.ac.uk).

II. GLOBALIZATION HISTORY

The history of globalization is intricately linked with the world's political and economic history. Over the centuries, globalization progressively enveloped trade and economies, finances, manufacturing, ultimately incorporating the globalization of knowledge generally, and engineering design in particular.

A. The establishment of global trading routes

Andrew Sherratt [1] illustrates the development of global trading routes as they became established over the centuries from 3500BC to 1500AD (Fig.1).

An early example provided is of the obsidian trade within western Asian communities that can be traced back to 9th to 6th millennium BC, thus pre-dating the bronze age. Obsidian is a natural black volcanic mineral glass that possesses excellent engineering properties, being both strong and tough, and hence suitable for making cutting tools. It was used to make sharp and strong blades, and was traded in small quantities up to 1000 km away from its sources in the mountains. Since obsidian was traded through gift-exchange, many other valued materials (e.g. plant products used as medicines) probably circulated along the same routes [1].

Sherratt points out how progressive urbanization drives the development of supply chains for goods and foods. Trade connections between the earliest Mesopotamian cities in the fourth millennium BC became extended with the spread of population into the Eastern Mediterranean, the site of the present Turkey and Greece. It is "the greater material wealth of urban communities, with their specialized manufacturing and bulk transport of commodities" that allowed them to draw high-value resources from surrounding countryside, creating and making use of the local exchange cycles [1]. It is readily apparent that the transport of goods was motivated by the increase in wealth it brought to the agents, and was sustained by the know-how possessed by the producers about certain materials and methods, on the one hand, and the knowledge held by the procurers of the utility and use of goods, and the supply and sale channels for them.

Roman Empire integrated the entire basin of the Mediterranean into a single political entity, thus creating a politically integrated economy that promoted stronger trade connections. Under this common umbrella, a more complex network of chains between different parts of the empire could emerge.

ISBN: 978-988-18210-5-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

The development of the interaction between Europe and China becomes evident already in AD1. This trade led to the creating of new trade routes across the Indian Ocean. Centuries later, the discovery of the New World then brought new importance to the Atlantic routes and coastal areas. Fig.1 illustrates the network of global trade routes in AD1500.

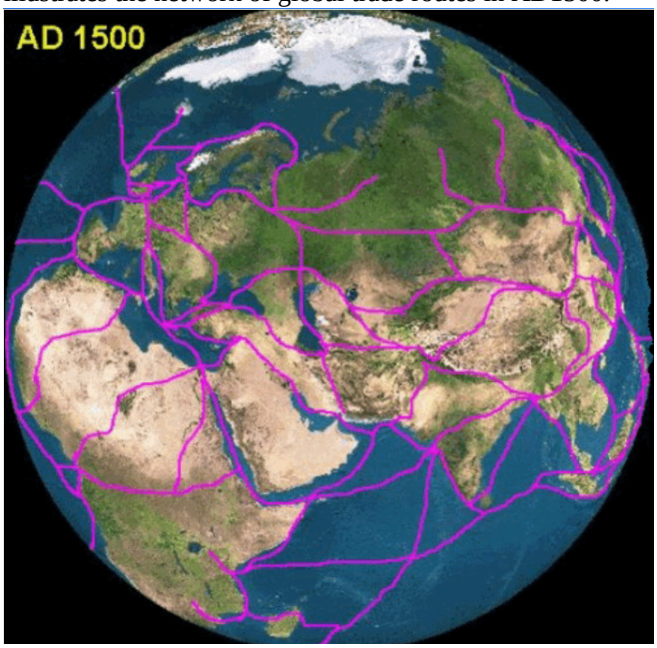

Fig.1. Global trade roots in AD1500 (from [1]).

B. *The emergence of global economy*

While originally the trade routes served the principal purpose of facilitating the exchange of goods, their development naturally brought with it the transport of ideas, wealth and influence. In the context of the emergence of a global economy, the British Empire played a pivotal role. Britain became the world's foremost power in the 18th century. The following century of *Pax Britannica* was characterized by the increase of wealth across the globe. The British East India company that ruled the subcontinent before the mutiny, had by 1850 acquired the wealth and turnover that exceeded that of Britain itself. The presence of the imperial trading and administrative outposts ensured that the dissemination and uptake of technological advances across the world proceeded at an unprecedented rate. The global market emerged under the political umbrella of the British Crown, similarly to the way that the Roman Empire in its time unified the then known world both politically and economically. The global penetration of common methods of trading, accounting, construction and manufacturing, together with the coverage of a third of the world's land mass (with influence evident in every part of the globe) resulted in the emergence of an integrated economic system that for the first time could be called global.

It is interesting to note the debate that arose in recent years regarding the relationship between investment and return within the British imperial system. Some have argued that the net flow of wealth within the British empire was outwards, from the metropolis to the colonies. While making a definitive judgment on such a complex matter remains a challenge, it is probably correct to observe, at least qualitatively, that the engineered products of industrialized Britain at the time had little substitute or competitors anywhere in the world. This makes it difficult or impossible to assess their true value by comparison with equivalents, but suggests that it should be placed appropriately high. One should not also neglect the future benefits of economic and financial integration and the development of local structures and organizations – some of these advantages became apparent in economies such as India and China many decades later.

Avner Offer [2] opens his review on the subject with the question; "Was the British empire an asset or a liability?" He continues with the quotation from Adam Smith, who thought the "the American colonies were an asset, but… the effort to govern them from London was a folly". These observations place into context the earlier comments about the full spectrum of benefits of the globalized market, and lead us to the subject of the emergence and effects of the globalized financial institutions.

C. *Global finance*

By the start of the 20th century, a global financial system was in place. Its existence was necessitated by the fact that large scale engineering projects were undertaken in places far removed from the investors, be it individuals or organizations. The scale of the projects, such as the construction of major canals, required the involvement of multiple investors, and that, in turn, motivated the creation of financial market with instruments such as shares and bonds. Information was also required by the investors to allow them to make qualified judgments about the value of projects, commitments, etc.

An important role in international trade and finance is played by the national currencies and their exchange rates. Fixing these rates with respect to some reference provides stability for the currency market, as e.g. pre-1914 due to the classic gold standard, and during the twenty-five-year period following World War II, when a system of fixed exchange rates pegged to the dollar prevailed [3]. The modern de-regularized world offers greater flexibility and flow of funds, but sometimes at the expense of massive swings of exchange rates, as seen in the late 20th and early 21st centuries. Although this introduces additional uncertainties for companies operating globally, it also increases the room for maneuver, as far as planning and operations are concerned.

D. *Globalized manufacturing*

In the course of the 20th century the world witnessed the progressive involvement of new territories and populations in the global economic process. This expansion was driven by the relentless requirement to reduce costs and improve competitiveness. Recognizing situations when labor costs constitute a substantial fraction of the total manufacturing expenditure, large and small companies sought the possibilities of moving some of their production to locations where labor was cheap and readily available. The longer term consequences of such activities were profound and manifold. On the one hand, this brought to the poor regions not only jobs, but eventually also the increase in the wealth of the local population. Ultimately this inevitably resulted in higher salaries, and served to undermine the original motivation for moving the manufacturing facility at a particular locale: the labor was no longer cheap. On the other hand, the increase in

ISBN: 978-988-18210-5-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

wealth led to the emergence of a local consumer market, opening up the possibilities for sales and further wealth creation.

Gradually the new consumer markets became more diversified and sophisticated. Ultimately such markets demanded the development of new bespoke products. This laid down the foundations for the globalization of the engineering process itself. In the next section I discuss some of the drivers and trends in this new dimension of globalization.

E. Globalization of engineering design in the 21st century

As a consequence of the developments in the global trade, markets and finance, by the end of the 20th century the world arrived at a fundamentally new junction. For the first time the globalization process became applied now to the very source of wealth creation: the intellectual activity that creates added value by inventing, designing, manufacturing and marketing new products. Lynn and Salzman [4] describe this transition and introduce the concept of the 'new globalization of engineering'.

Lynn and Salzman [4] start by pointing out that in the second half of the 20th century, "the typical multinational (MNE) was vertically integrated and hierarchically organized. Key functions were headquartered in one of the triad economies of the U.S., Japan or Europe. In the case of technology development, for example, more basic R&D work might be conducted by central research laboratories, with more applied work done at triad production facilities. Some engineering activities were conducted in emerging economies, but these had little to do with the core engineering programs of the firm."

Of course, some engineering design activities necessarily took place locally. However, the nature of such activities was peculiar and restricted. Lynn and Salzman [4] give the example of a Whirlpool facility in India, where "washing machines were redesigned to keep out rats, to survive shipment on bad roads, and to cope with power ebbs and surges in electrical current". They further assert that engineering managers at an electronics firm in India "did not consider doing work on their more advanced technologies at a site in India because, until recently, there was no market in India for products based on the newer technologies, and no sense that India provided a viable export platform." The situation meant that "engineering teams in the emerging economies worked in relative isolation from their counterparts at triad facilities and provided little that was useful in the triad economies."

The fundamental shift took place around the turn of the century, when "the geography of technology development has undergone profound shifts as multinationals disperse core activities, "unlocking" them from longstanding forms of organizational integration. Geographic embeddedness that, only a few years ago, seemed to confer unassailable advantages to areas such as Silicon Valley must be examined anew now that the "developing countries" are developing some of the world's leading-edge technology. Triad multinationals are racing to shift cutting-edge work on cellular telephones and other aspects of telecommunications to China. They are moving software development and some pharmaceutical research to India. Advanced aerospace work is being done in Brazil." [4]

The authors call this emerging pattern of activities in technology development 'the new globalization of engineering'. They summarized the nature and the significance of the transition as follows: "The reduction of international trade barriers and the development of new technologies allowing globally dispersed work on engineering have coincided with the push by firms to cut costs by dispersing engineering activities globally and the pull of growth markets in the emerging economies that requires new engineering and technology development, and offers the availability of highly skilled human resources. The result has been a massive transfer of technological capacity to the emerging economies." Importantly, the authors also note that "the transition is not yet complete, and its full ramifications are as yet poorly understood." Some aspects of this change give particular concern to Lynn and Salzman, e.g. analyzing the possibilities and threats posed by this evolving pattern, and whether "boundaries might exist between change that is adaptive and change that risks the loss of control over essential functions."

Against the backdrop of this adaptive development of the world engineering activities, other significant drivers for change exist. Camuffo [5] focuses his attention on the automotive industry. More specifically, the author carries out a case study of the concept of the Fiat Palio - the "world car", i.e. "a car that involves absolute cross-country identity of interior/exterior design, parts, and quality standards."

One of the questions of major concern to the author is the relationship between globalization, modularization and outsourcing in the auto industry. In line with the general trend identified above of globalized manufacturing following the market expansion, in the 1990's most automotive OEMs "pursued a 'produce-where-you-sell' strategy, opening up new plants in foreign countries and asking some suppliers to follow them with direct investment". Camuffo [5] writes: "More generally, assemblers have employed a series of measures to lower the minimum scale of vehicle assembly plant in order to reduce the investment risk, respond more flexibly to volume changes, speed up models turnover, facilitate equipment upgrading, minimize job impact and social cost in case of crisis. Financial considerations are especially critical given the enormous amount of money required by foreign direct investment strategies and the uncertainty of their rate of return and payback time."

These important organization and management developments present the background against which the changes in engineering design practice took place. The very relationship between automotive OEMs and suppliers became re-adjusted for the new situation, so that "suppliers play a larger role in terms of parts' design, technology development and sometimes even assembly, while OEMs focus on their [core] activities, narrowing the scope of the operations they carry on."

Another important observation made by Camuffo concerns the crucial role played in this process by networking and the information technology. He notes that "new (especially Internet related) technologies are facilitating knowledge codification (Nonaka and Takeuchi, [6]), reductions in

ISBN: 978-988-18210-5-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

information costs, and evolution towards mass customization and build-to-order (Helper and Mac Duffie, [7])".

This is a junction where the different threads and concepts that appear in the title of the present study come together. The most important (for the purpose of the present study) consequence of the globalization process, the emergence of distributed and outsourced engineering activities, only becomes possible with ubiquitous spread of networking and data interchange. Distributed engineering relies on the availability of highly sophisticated, detailed and robust technical data formats, as well as the software capable of handling large data volumes of this type.

Camuffo [5] continues that "in the new global auto industry, there have been (and, to a certain extent, there still are) incentives to transfer component design/manufacturing responsibility to suppliers. This has entailed, from the OEM perspective, more outsourcing, and determined a power shift in favor of suppliers." He concludes that "within a global strategy, modularization and outsourcing, though remaining conceptually distinct, tend to become, in practice, increasingly inseparable. The modularization of design, production and organization is intimately related to how, while trying to save costs, reduce risky investment, and manage the institutional constraints deriving from globalization, OEMs and suppliers partition their tasks, defining a new international division of labor."

The general thrust of these processes is toward increasing *complexity* in design, technology, management and operations. Camuffo [5] observes that "*modularization* is one possible way to address this issue and reduce complexity. Modularization means that, in the future, vehicles will probably result from the integration of a series of self-contained functional units with standardized interfaces within one or more standardized product architectures, units conceived, manufactured or supplied, and assembled as autonomous 'modules' [8]."

The best known example of such modularized car manufacture is the MCC plant located in France (Hambach), that is "a joint venture between Mercedes Benz and Swatch (Swiss watch producer), that assembles a two-seater "minicar" (named Smart). A small group of suppliers, defined as "system partners", located nearby the MCC plant, build and deliver complete modules like doors and cockpits directly to MCC final assembly line." Camuffo [5] continues to consider the effects that modularity in manufacturing has on the organizational modularity of companies and manufacturing networks, taking up "a typical organizational meaning and mingling with those of standardization, scalability and replication", with each "organizational module" also corresponding to a "design module".

In the context of design globalization, it is interesting to note also that "international rules (trade barriers, local contents, etc.), regional/national institutions, and cross-country cost differentials impact on the transfer of component design/manufacturing responsibility to suppliers and, as a consequence, on the degree of decomposability and information partitioning into visible design rules of new and existing products (Schilling [9]).

To conclude this section of the present paper, it is convenient to draw on the points made by Rycroft [10], who asserts that globalization "can be said to have *co-evolved* with rapid and pervasive technological innovation. By this it is meant that changes in technological advancement appear to have helped create increasingly global markets and other institutions, and these ever more global political and economic institutions appear to modify emerging technological innovations." Rycroft [10] goes on to ask the question about the major indicators of the "globalization/technology co-evolutionary process". He identifies several dimensions, or groups of indicators of technological globalization, namely, *technological exploitation*, *technological generation*, and *technological collaboration*. The author then chooses to focus his attention on innovation networks as organizations that can help provide insight and measure the depth of technological globalization processes.

III. THE COMPLEX SYSTEM OF WORLD ECONOMY

The dimension of globalization that concerns technology and engineering design is played out against the backdrop of company level and national and international level economic realities. The world economy is one of the most important and well-studied complex systems of great significance to the vast proportion of global population. Yet, as past and recent experiences show, despite extensive research effort and investment, all attempts at predicting or controlling this system appear to enjoy very limited success.

Of particular significance in the rapidly developing world are the issues of global capital flows and their impact on the wealth of nations. Of note here must be the work of Paul Krugman [11] on the New Trade Theory. This approach criticizes international free trade, asserting that using protectionist measures in certain countries may allow the build up of a strong industrial base in certain industries that will then allow these sectors to dominate the world market. As an example, it is argued that this was the pattern that allowed the development of the Japanese automotive industries in the middle of the 20th century, when companies were allowed and encouraged to import production technology from abroad, but nevertheless required to produce 90% of components locally.

Modern computer simulation tools may help shed some light on the processes that take place in complex systems, by carrying out increasingly large scale agent-based simulations. In these simulations, agents must represent businesses that interact with each other, and also with the "landscape" that represents the world. The test of the validity of the model is obviously its ability to predict financial and economic situations that are observed in practice. Notable attempts to develop such agent-based, complex systems models of global wealth flows have been reported [12].

IV. OUTLOOK AND CONCLUSIONS

The different aspects of globalization touched upon in the brief outline presented here stand in complex, interactive relationships with each other. The size and complexity of the modern global economy, finance, manufacturing and engineering design present a great challenge to politicians, economists and engineers alike. Under the umbrella of such

ISBN: 978-988-18210-5-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

complex systems, decisions made by significant players may have effects that are profound and often difficult to predict. Therefore, particularly well-placed would seem the efforts aimed at identifying and developing network metrics, e.g. measures of impact of particular decisions on the global system.

REFERENCES

[1] A. Sherratt (2004), "Trade Routes: the Growth of Global Trade", ArchAtlas, January 2008, Edition 3, http://www.archatlas.org/Trade/Trade.php, January 2010.
[2] A. Offer, "*The British empire, 1870-1914: a waste of money?*", Economic History Review, XLVI, 1993.
[3] M. Flandreau, C.-L. Holtfrerich, and H. James. *International Financial History in the Twentieth Century: System and Anarchy*. Cambridge: Cambridge University Press, 2003, 278 pp.
[4] L. Lynn, H. Salzman, "The 'New' Globalization of Engineering: How the Offshoring of Advanced Engineering Affects Competitiveness and Development", 21st European Group for Organizational Studies (EGOS) Colloquium, Berlin, 2005.
[5] A. Camuffo, "Rolling Out a "World Car": Globalization, Outsourcing and Modularity in the Auto Industry", to be published.
[6] I. Nonaka, H. Takeuchi H., *The knowledge creating company*, Oxford: Oxford University Press, 1995.
[7] S. Helper, J.P. MacDuffie, "E-volving the auto industry: E-business effects on Consumer and Supplier Relationships, paper prepared for E-business and the Changing Terms of Competition: A View From Within the Sectors", The Fischer Center on the Strategic Use of Information Technology, Haas School of Business, UC Berkeley, 2000.
[8] S. Helper, J.P. MacDuffie, F. Pil, M. Sako, A. Takeishi, M. Warburton, "Project Report: Modularization and Outsourcing: Implications for the Future of Automotive Assembly", IMVP Annual Forum, MIT, Boston, 1999.
[9] M.A. Schilling, "Toward a General Modular Systems Theory and Its Application to Interfirm Product Modularity", Academy of Management Review, 25, 312-334, 2000.
[10] R. Rycroft, "Technology-Based Globalization Indicators: The Centrality of Innovation Network Data", Occasional Paper Series, GW Center for the Study of Globalization, 2002.
[11] P. Krugman, "*Rethinking International Trade*", Boston: The MIT Press, 1994.
[12] R.-C. Damaceanu, "An agent-based computational study of wealth distribution in function of resource growth interval using NetLogo", Applied Mathematics and Computation 201, 371–377, 2008.

ISBN: 978-988-18210-5-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)