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Global drivers, sustainable manufacturing and systems ergonomics

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ABSTRACT

This paper briefly explores the expected impact of the 'Global Drivers' (such as population demographics, food security; energy security; community security and safety), and the role of sustainability engineering in mitigating the potential effects of these Global Drivers. The message of the paper is that sustainability requires a significant input from Ergonomics/Human Factors, but the profession needs some expansion in its thinking in order to make this contribution.

Creating a future sustainable world in which people experience an acceptable way of life will not happen without a large input from manufacturing industry into all the Global Drivers, both in delivering products that meet sustainability criteria (such as durability, reliability, minimised material requirement and low energy consumption), and in developing sustainable processes to deliver products for sustainability (such as minimum waste, minimum emissions and low energy consumption). Appropriate changes are already being implemented in manufacturing industry, including new business models, new jobs and new skills.

Considerable high-level planning around the world is in progress and is bringing about these changes; for example, there is the US 'Advanced Manufacturing National Program' (AMNP)', the German 'Industrie 4.0' plan, the French plan 'la nouvelle France industrielle' and the UK Foresight publications on the 'Future of Manufacturing'.

All of these activities recognise the central part that humans will continue to play in the new manufacturing paradigms; however, they do not discuss many of the issues that systems ergonomics professionals acknowledge. This paper discusses a number of these issues, highlighting the need for some new thinking and knowledge capture by systems ergonomics professionals. Among these are ethical issues, job content and skills issues.

Towards the end, there is a summary of knowledge extensions considered necessary in order that systems ergonomists can be fully effective in this new environment, together with suggestions for the means to acquire and disseminate the knowledge extensions.

1. Introduction

This paper is focused on the domain of manufacturing, and discusses this topic mainly from the perspective of the European Union (EU27), considered as a trading bloc of some 500 million people.

This focus on manufacturing is justified by the argument that on whatever aspect of sustainability one chooses to focus (e.g. food security, energy, water resources, emissions, health care), sustainability implies continuously-necessary, long-term processes. It is also certain that these processes will entrain manufactured products that are both sustainable in themselves, and are manufactured by sustainable processes. Manufacturing can therefore be considered to be fundamental to sustainability. Because of the extensive role of human beings in manufacturing (strategy, knowledge, design, control, resilience, etc.), the Ergonomics/Human Factors profession has a fundamental role in sustainability.

The purpose of the paper is to outline some of the changes that will happen in the manufacturing domain up to 2050, or thereabouts, since this corresponds to the forward view adopted in many other countries as well as the EU27, and to explore what these mean for systems ergonomics professionals. Since all of the countries that have published their thinking about the future of manufacturing have acknowledged the centrality of people, it seems appropriate to

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prepare the ground for the application of appropriate ergonomics/human factors understanding to the changed roles and likely different relationships that will exist in these future scenarios.

The paper is divided into three parts. Part one discusses some of the implications of Global Drivers, indicating their potential effects on society. These effects may be ameliorated by adopting a 'sustainable' economy, minimising the effects of the drivers themselves, and ensuring that there are resources available for future generations in the societies of their time. Part two outlines how manufacturing is likely to adapt to help deliver this sustainable world. We concentrate on manufacturing on the grounds that it is the artefacts of manufacturing that will be used in other domains to achieve sustainability in those domains – the built environment, transport, agriculture, space, etc.

Since current thinking has humans at the heart of future developments, Part three discusses a number of system ergonomics issues pertinent to the new manufacturing environments; issues that go beyond current practice, particularly in the realm of systems of systems (SoS), and increasingly the sub-area of cyber-physical systems (CPS).

2. Part one: 'global drivers' and their likely combined impacts on society

To provide some purchase on the notion of global drivers, we present a list of these drivers, and a table to indicate their potential effects on our societies and the world. Following a suggestion by one of the paper's referees, we point out that the comments in this section are based on forecasts and strategy documents of governments and other national and international organisations.

2.1. An outline of the global drivers

Global drivers as identified in the Sulston report and the Working Group 5th Assessment Reports of the IPCC are considered mostly from a longer-term perspective; the trends are extrapolated to about 2050 in most of the documents.

Based on this perspective, and focusing on the EU27 as a significant global entity, the following inter-related global drivers can be identified:

- Population demographics, including lifestyles, growth and aging
- Food security
- Energy security
- Resource depletion
- Emissions and global climate
- Community security and safety
- Transportation
- Globalisation of economic and social activity

A brief outline of the effects of the global drivers on the EU27 follows, in Table 1.

Fig. 1a and b below indicate some of the high-level interactions between the global drivers, and classes of actions required for mitigation Both diagrams treat population growth as a main driver, following Sulston 2012.

Taking Fig. 1a and b together with Table 1, three conclusions may be drawn about these Global Drivers;

- Each of the Global Drivers, operating on its own, could have very significant effects on the world as a whole, and on the EU27. Together, they pose a significant threat to the health and well-being of all of us on this planet
- Mitigating this set of drivers necessitates a connected, comprehensive approach; it is evident that tackling one, or another, is unlikely to have much impact by itself.
- A combination of political persuasion and technology will be required to reach any satisfactory conclusion; a comprehensive socio-technical solution will be necessary.

However, there is one slightly-hidden observation that can be made; for all interventions producing physical effects on the Drivers (mainly on the right side of Fig. 1b), new devices, systems and networks will be required to remedy, replace and/or extend the functionality we have in place now, in order to address the integrated nature of the Global Drivers. Without these, we are reduced to persuasion and prayer to fix our problems.

3. Part two: sustainability in manufacturing

As argued above, global drivers make a significant case for sustainability in manufacturing, both as a primary means to mitigate the effects of the drivers, and also because of the energy and materials demands that current manufacturing methods and processes require. Fortunately, a number of studies in recent years have addressed these issues, and a resumé of the findings is given below.

The general conclusion is that all nations in the world need to move from a 'Linear Economy' (from extraction of resources to landfill) to a 'Circular Economy' (recycling, with minimal extraction and landfill), coupled to resource efficiency. This applies to all sectors of the economy, and for manufacturing this is represented in Fig. 2 below. It should be noted that other sectors will employ the products of manufacturing to turn their own linear processes into circular ones, too; this is a further justification for the concentration on manufacturing in this paper.

More specifically, recycling/re-use includes the following:

- Re-use – redeploying a product without refurbishment – e.g. reselling mobile phones, 'obsolete' in the developed world in other regions.
- Remanufacturing – restoring a product to its original performance. For example, Caterpillar has a successful engine remanufacturing business (Foresight, 2013; Lavery et al., 2013).
- Cascaded use – using a product for a lower value purpose – e.g. turning used clothes into pillow stuffing (Foresight, 2013).
- Recycling – extracting a product's raw materials and using them for new products – e.g. aluminium and steel are widely recycled.
- Recovery – using a product's materials for a low-value purpose such as road base.

Triage, shown in Fig. 2, is clearly an important process, relatively unexplored at the present time. It depends heavily on design of the product, too; 'design for disassembly' is an important principle, particularly in relation to vehicles and other products where disassembly poses dangers.

As a concrete example of this, consider the Ricoh COMET Circle, shown in Fig. 3 below:

Ricoh has generated new companies and processes, and a new business model in which they charge by the paper copy rather than by the machine (since the copiers they supply may not be 'new'). As a further example, some other companies have claimed that they have been able to reduce waste for landfill to zero (Lavery et al., 2013).

Consider some aspects of Fig. 2 in more detail, to enhance the picture: