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JOB DESIGN FOR MANUFACTURING IN AN ERA OF SUSTAINABILITY

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The paper explores the changes that are likely to be necessary as the world moves to a more sustainable way of life. When these changes are added to the development of the Internet of Things, in which it is envisaged that devices with some level of embedded intelligence will communicate with each other, as will intelligent services, it appears that our current ways of conducting job design may be found wanting. The principles of socio-technical design will still apply; how these principles will necessarily be extended is the subject of this paper; how to include aspects of sustainability, the need to train for resilience, etc.

Introduction

This paper explores some likely changes over the next decade to job design as practised by Ergonomists/ Human Factors Engineers. The context for this paper are the foreseeable changes in the manufacturing domain that will be produced by the Global Drivers that require a sustainability response (Allwood, Ashby et al. 2011, Sulston 2012, Lavery, Penell et al. 2013). The paper outlines briefly what these Global drivers are, the likely response of manufacturing, the outlines of which can already be seen, and the implications for job design in manufacturing. These implications are likely to be apparent in other domains as well.

Some global drivers, for the next 35 years

The global drivers are those that are likely to affect the population of the world as a whole, and whose effect, if not addressed, will likely be unpleasant.

Eight drivers are commonly identified:

- Population demographics (estimated to rise by about 60% by 2050, with consequent demand for resources)
- Food security (agricultural land fixed; crops affected by climate change)
- Energy conservation (emissions are a major cause of climate change)
- Water conservation (potable water is limited in many countries)
- Resource depletion (some key minerals will be difficult to access)
- Emissions and global climate (the main cause of climate change)
- Transportation (also contributing to the emissions problem)
- Globalisation (improving living conditions around the world will increase demand for resources)

There are interactions between these drivers, implying that efforts to mitigate their effects will need to be concerted and co-ordinated. Fig. 1a below indicates some of these interactions, and Fig. 1b indicates some countervailing strategies.

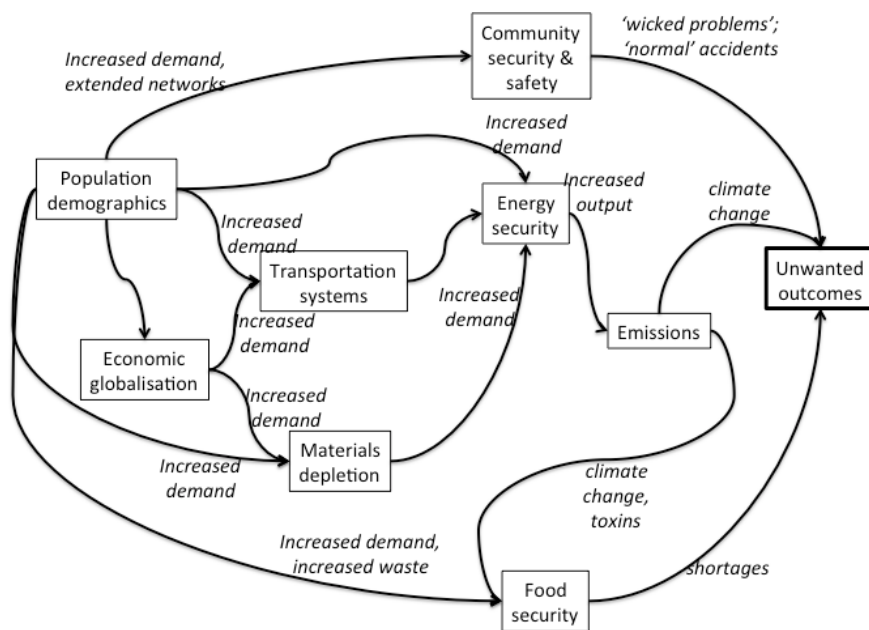


Figure 1a Illustration of the high-level interactions between the Global Drivers, leading to unwanted outcomes. Only a few of the interactions are shown, to assist clarity.

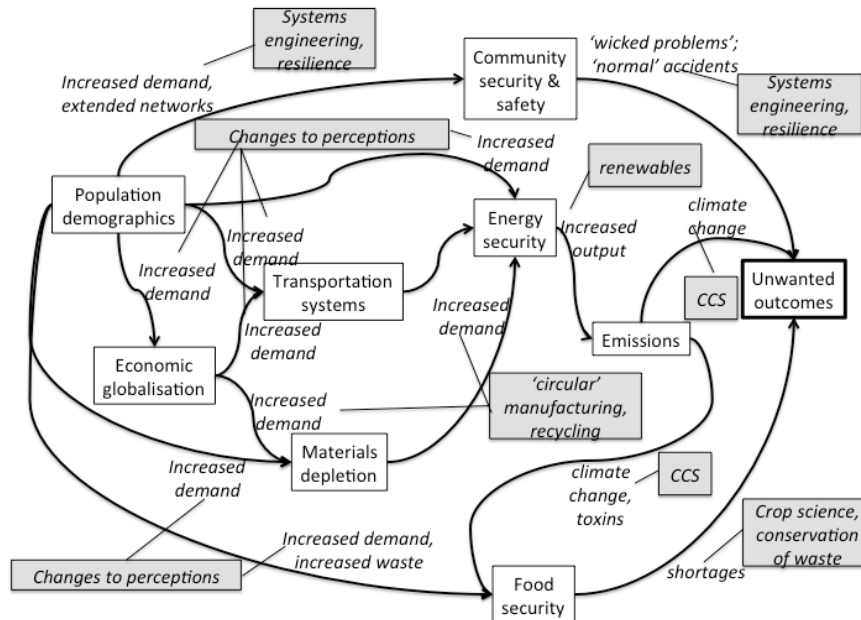


Figure 1b Global Drivers, including approaches to mitigate the unwanted outcomes that could accrue from the harmful interactions of the Global Drivers (CCS = Carbon capture and storage.)

Fig 1b includes approaches to mitigate the unwanted outcomes that could accrue from the harmful interactions among the Global Drivers (CCS = Carbon capture and storage.)

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. 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.

Turning now to manufacturing, it is clear that this domain has a massive part to play in reaching a sustainable state:

- Manufacturing creates the main demand for the exploitation of resources, and is a major producer of emissions and of landfill.
- Manufacturing will create the devices and the processes that will enable the world to reach a sustainable state.

- Re-engineering manufacturing processes to be more efficient will be necessary to reduce the emissions and other waste. “Circular manufacturing” will have to become a dominant philosophy (Kagermann, Wahlster et al. 2013, Lavery/Penell 2014).
- Re-engineering the products of manufacturing to minimise waste and to enable the recycling implicit in Circular Manufacturing will have to become a necessity. Legislation is already providing manufacturing push; for example in the UK there are the End-of-Life Vehicles (ELVs) Regulations 2003 and the ELVs (Producer Responsibility) Regulations 2005; in the EU27 there is the ECODESIGN Directive 2009/125/EC, and in Japan the ‘Top-runner’ scheme has been in existence for many years (Siderius and Nakagami 2007).

Many new jobs will be created by a move to a circular economy, replacing those lost in the extractive industries, and most manufacturing jobs will require some degree of redesign; the latter caused by the re-engineering points listed above.

The re-engineering of manufacturing

The philosophy of manufacturing is changing markedly. Some trends are already evident, as is indicated below:

- Manufacturing is moving from a major-plant-centric view to a networked view, as exemplified in the ‘Industrie 4.0’ agenda adopted by the German government; first there was the introduction of steam and mechanical production (a technical revolution), followed by the move to standardised parts, mass production and task specialisation (an organisational revolution), then the introduction of IT (technical again), to be followed by the 4th, networking revolution (organisational again), involving the ‘Internet of Things’ (IoT) which includes data, services and cyber-physical systems (e.g. robots and other devices with embedded intelligence), including intelligent machine-to-machine communications, perhaps with significant autonomy. The network, not the factory, becomes the core of manufacturing.
- The demands of Circular Manufacturing imply change to materials, machines, products and processes; all of which will impact job design
- Because of the interlinked nature of the Global Drivers and their impact on local communities and the manufacturing organisations within these communities, issues such as local ecology/biodiversity and corporate social responsibility are intertwined with more traditional manufacturing concerns. This is for two reasons; legislative push, and wide recognition that governments and the tax-payer by themselves cannot produce the mitigations required.

Figure 2 below is an illustration of what is meant by Circular Manufacturing.

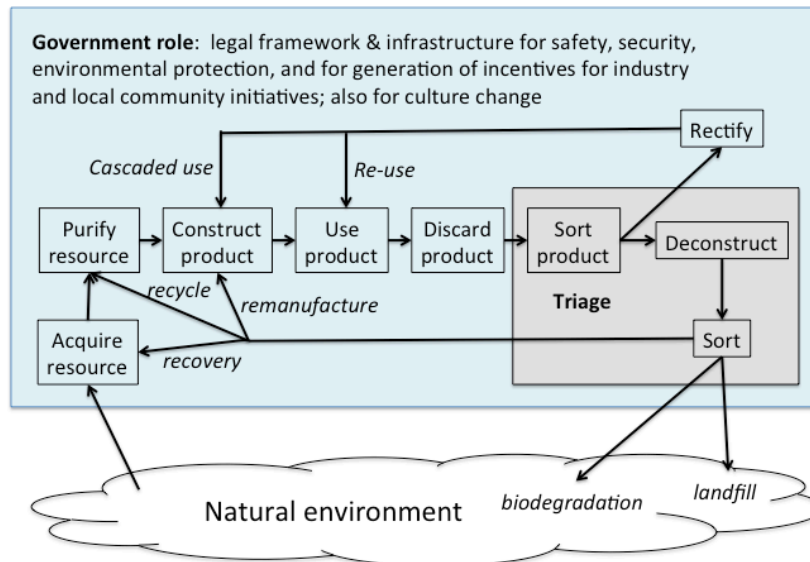


Figure 2: Illustration of 'Circular Manufacturing', as an instance of the 'Circular Economy'. Note that the 'use product' box may involve considerable iterated re-use by a sequence of owners.

These trends have implication for an organisation's policies, and their decomposition into jobs. This is shown, for example, by Nestlé™, a major company in the food industry, which has adopted six policy principles within their 'New Accelerated Model', in addition to the usual 'faster, better, cheaper' mantra, widespread in manufacturing (NMR/2deg 2014):

- Energy – transition to low energy sites
- Water – optimised water withdrawal & use across sites
- Waste – transition to low waste sites
- Biodiversity – recognised for promoting & developing biodiversity
- Value chain – reduction in environmental impact across the value chain
- Community & people – recognised as a 'good corporate citizen' and adding value to local communities

At a site where these principles were first piloted, the company has been able to achieve, over a period of 6 years, savings of about 22% in green-house gas (GHG) emissions, about 30% in energy consumption, and about 22% in water usage per tonne of product. This site has become a 'zero waste' site (implying the creation of a value chain for waste) and has made contributions to 'butterfly meadows'.

Similarly, Toyota™ in their UK operations over a period of 20years have reductions per vehicle of 74% for energy, 69% for water, and 60% for waste. Both of these companies have emphasised that these improvements necessitated the interpretation of these principles into the jobs that their employees do,

accompanied by continuous efforts to gain acceptance, not just acquiescence, of these re-defined roles and responsibilities.

Re-emphases for job design in manufacturing

The first point to make is that the core, socio-technical principles for the design of human jobs and roles within organisations as enunciated for example by Cherns (Cherns 1976, Cherns 1987) and subsequently elaborated by Eason, Clegg and Doherty (Eason 1988, Clegg 2000, Doherty 2014) remain the same. As an aside, as cyber-physical systems within the IoT become more intelligent with more autonomy, these principles (adapted) may be necessary for them, too.

But networking manufacturing via the IoT will bring some important changes to jobs; firstly, there are cultural implications; while large assembly plants will still exist (because physical components must be brought into contact to create products), much of the manufacturing of components, particularly components that can exist as software, will be in different, smaller enterprises that may be widely distributed. 'Company culture' may become local, with enterprise culture becoming more of a mosaic, predicated on trust in performance and with an emphasis on 'good citizenship', built into job design and support.

Security and confidentiality issues are already prevalent in the Internet. However, it brings a number of issues with it, as outlined below:

- 'Informed Consent'; for example, you give consent to a request from the network to use your current location data. It is unlikely that you know, or ever could know, who or what has access to that data, what meaning(s) will be inferred from the data, for how long this access will be enabled, how your data will be combined with other data, and so on. Solutions are not immediately evident.
- 'Informed Command', as given, for instance, by a human controller involved in a networked process in which some devices may have some degree of behavioural autonomy. The UK Ministry of Defence has a rule of for this; summarised as 'whoever gives the last command is responsible for the outcomes.' This is also embodied in International Humanitarian Law. The implication is that whoever gives a command must be able to anticipate the likely outcomes and side-effects of any command. Again, solutions are not immediately evident; nevertheless, this problem sits at the heart of systems of systems/SoS ergonomics.
- Identity. As a Foresight document has pointed out, each of us has many identities, and some of these are not constructed by us but exist on the internet (Foresight-FFI 2013). There is a question of who owns and who can use these identities and for what purpose, especially those we have not constructed ourselves. This has implications for the notions on informed Consent and Informed Command, above, especially if some of these identities have been created or utilised with criminal intent.
- Autonomy and learning. Not all cyber-physical systems need to be given the capability to learn, though some must; robots, for instance. Current thinking suggests that autonomy should be constrained to level

6 or below on Sheridan's scale (Parasuraman, Sheridan et al. 2000): 'The [robot] allows the human a restricted time to veto before automatic execution'; however, this returns the problem to 'Informed Consent' and 'Informed Command'; the rule assumes that the command-giver is in an appropriate 'informed' state.

However these issues are resolved, there are a few things of which we may be sure; networked manufacturing will produce unexpected problems of varying extent and severity on a frequent basis, both in 'normal' operations and when changes are introduced. These will need to be solved by those involved (as implied by Clegg and other authors), but over the network; an important part of job design will be problem-solving via the network, involving an understanding of how the IoT works and can be fixed, how cultures interact, and the chances of miscommunication across cultures, disciplines, ontologies and legal frameworks.

Secondly, there must be concentration on training and education for resilience; this may obviate some of the problems above, and will certainly improve local operations, both with regard to speed and reliability.

Thirdly, the IoT and the networking of processes may result in a much more labile approach to jobs; there may be much more redefinition of jobs and roles, leading to more churning of jobs and hence of people who do these jobs. This raises issues of training for employability and for career progression; issues well-addressed by Zink in his recent review paper (Zink 2013).

Finally, there is the necessity of turning the Nestlé™ principles (for example) into the tasks and roles that people undertake. Firstly, the principles must be translated into Key Performance Indicators (KPIs) appropriate to the performance of the organisation in relation to these policies, and then cascading these down into the activities (i.e. Activity Performance Indicators – APIs) that people undertake within their roles; for example, they may have to become part of the Minimal Critical Specification for a role, following Cherns and others. Given this, the role-holder will require training and authority over resources to be able to achieve these APIs. Given the range that these APIs may take – consider support in the job for biodiversity, for example – the organisation may well have to have very good links into local education and training facilities, professional services and the like in order to fulfil its obligations to the role-holder.

Conclusions regarding Ergonomics/ Human Factors Engineering

As things stand, it is difficult to see how an Ergonomist/ Human Factors Engineer would be able to design jobs for this new, networking model of manufacturing within the constraints and imperatives of a sustainable world, based on current approaches such as Cognitive Work Analysis, Hierarchical Task Analysis and Situation Awareness. There appears to be a knowledge gap, requiring some effort to fill. Einstein's famous quotation is relevant here:

“The world as we have created it is a process of our thinking. It cannot be changed without changing our thinking.”

We have some work to do.

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