Some implications of the drive for sustainability for the Human Factors Engineering discipline

Murray Sinclair[1], Michael Henshaw[1], Stephanie Henshaw[2]

[1]Loughborough University, [2]Westminster University

ABSTRACT

Unless we are able to create sustainable communities, the future for humanity and the living world is bleak. Consequently, as a profession dedicated to humanity's interaction with the world, we have a duty to help deliver sustainable communities. This paper explores some implications for Human Factors Engineering (HFE) professionals of responding to this duty. The problem is to construct our way to a sustainable future, while accommodating the disruption to our current styles of living and working and without lowering our current levels of social justice. First, there is a discussion of the drivers of change addressing sustainability, and some implications of these. Then there is a discussion of the communities that will undergo these changes, and the problems that change management must face. The final part of the article addresses the importance of the user experience to make the changes palatable for all citizens.

Introduction to change

While there is a loud argument within some parts of the political world and in social media about whether there is a real problem of sustainability and if so, what to do about it, there is a parallel scientific and financial case for building sustainable solutions, and a growing momentum towards reaching globally-sustainable lifestyles. Firstly, there has been the wide-spread adoption by nations of the United Nations (UN) Sustainable Development Goals, together with their metrics, tools and objectives (Kanuri, Revi et al. 2016, UN-SDG-19 2019), with measurable progress in many countries around the globe. Secondly, the domain of finance and banking is moving with increasing speed towards the adoption of investment policies with a strong commitment to Environment, Sustainability and Governance (ESG) requirements, together with many of the world's big organisations also adopting ESG policies - even the oil majors such as BP, Conoco-Phillips and Shell are moving in this direction. It has been noticed by the finance industry that investments in firms that have adopted ESG principles, such as Unilever ad Apple, have produced better investment returns than the rest. This has resulted in a wave of investment products built around ESG demands and proof of compliance becoming available. The 'Moral Money' newsletter from the Financial Times provides evidence.

It is this latter trend that has most significance for the drive to sustainable living and hence for the Human Factors Engineering (HFE) profession. In the 1990s the UN set up the United Nations Environment Programme - Finance Initiative (UNEP-FI) which, aided and abetted by the G20 and other bodies, set up the Task force on Climate-related Financial Disclosures (TCFD) which, together with the Sustainability Accounting Standards Board (SASB) and the Greenhouse Gas protocol (GGP) have created an investment framework that, for example, has led to banks refusing loans for fossil fuel developments. Similarly, the European Union (EU) has developed and now promulgated the Sustainability Financial Disclosure Regulation (SFDR) and its associated taxonomy to enable its implementation, both of which came into effect this year (EU-Sustainability-20 2020, EU-Taxonomy-20 2020).

How will organisations respond? First and foremost, by moderating their energy requirements, to reduce greenhouse gas emissions and reduce global warming, followed by other steps such as reductions in waste. In the field of energy conservation, governments and regulators around the world seem to be converging on the Greenhouse Gas Protocol and the ISO 14064 family of standards. Distilling these documents down to the basics, there is a requirement for organisations to respond to three Scopes. In the words of the US Environment Protection Agency (EPA-17 2017):

- Scope 1 Greenhouse Gas (GHG) emissions are direct emissions from sources that are owned or controlled by the Agency. Includes on-site fossil fuel combustion and fleet fuel consumption.
- Scope 2 GHG emissions are indirect emissions from sources that are owned or controlled by the Agency. Includes emissions that result from the generation of electricity, heat or steam purchased by the Agency from a utility provider.
- Scope 3 GHG emissions are from sources not owned or directly controlled by EPA but related to Agency activities. Includes employee travel and commuting; also includes emissions associated with contracted solid waste disposal and wastewater treatment.

Some Scope 3 emissions can also result from transportation and distribution (T&D) losses associated with purchased electricity: In other words, first, you must control your own emission of greenhouse gases. Then you must control the emissions that arise from your demand for external energy. Then you must clean up you upstream and downstream supply chains. This will bring emphasis on recycling and the Circular Economy with the energy savings that these bring, but with increased emphasis on standards, co-ordination and control. This in turn creates extra demands for sensors, Big Data, and AI-based analytics for decision support, which from a Human Agency and HFE control perspective, bring issues of transparency, explicability and trust. Resilience becomes a fundamental requirement too, as these networks are not likely to be fully reliable (Woods and Branlat 2010, Schätz, Törngren et al. 2015, Engell, Paulen et al. 2016).

Note that ‘Agency’ in these Scopes includes HFE Consultancies, and compliance is involved. The SFDR (EU-Sustainability-20 2020) and the SASB sustainability accounting standards (SASB-17 2017, SASB-20 2020) both require that in accepting a financial loan, you must declare what action you propose to take on sustainability, both this year and in subsequent years, and how you will measure and report progress. There may be get-out clauses for small companies, but there will be a push for compliance. Note that there is an implication that HFE consultants carrying out work for companies will need to show that their improvements deliver sustainability improvements as well. HFE Consultants should expect to show competence in sustainability as a marketing USP.

Of course, this applies to HFE clients, too, and it is here where there may be big contributions that the HFE discipline can make. Consider, for example the effects of the three Scopes for manufacturing. As Toyota (among other auto companies) demonstrated, their requirement that suppliers show a 3% year-on-year improvement in productivity (either cost reduction or improved performance of their products), means that in the near term this can be delivered by incremental improvement exercises, tweaking the existing processes. But this is not a sustainable approach for the supplier, within three years or so there will be no more tweaks available for the current processes and the supplier necessarily must carry out a major overhaul of the processes, else fail. The best strategy is to plan for the major overhaul immediately, and introduce the changes incrementally, with regard to annual affordability.

Fairly swiftly, manufacturing organisations will have to embrace recycling; a circular economy is far more energy-efficient than a linear economy (Allwood, Ashby et al. 2011, Allwood, Dunant et al. 2019), implying changes to supply chains and the characteristics of the products that pass through them (new processes = new opportunities to upgrade products and to alter their performance. There may be downstream unexpected consequences of these opportunities). There will be a strong impetus towards the adoption of Industry 4.0 technologies such as changing the

business model to 'Manufacturing as a Service' (MaaS), creating subsidiary recycling businesses, and adopting a model-based systems philosophy for the whole organization, to improve overall control and resilience (there are dangers in this, too; care is required). In particular, there will be a strong push for automation and software-based control of these processes both to deliver precision of effects, to minimize waste and GHGs and to become more responsive to the marketplace and competition and deliver sustainability benefits as well. Then there is the upheaval in knowledge, expertise, and organisational procedures, systems, and culture caused by the adoption of model-based control (e.g. the 'digital twin' concept (ATI-digital 2017)), and the need for control by changing model parameters, rather than by physical interaction (Schätz 2014). All of these, and more, will present competence challenges to the HFE profession in delivering well-designed solutions.

There is clearly a significant change implied in the nature of jobs; many more will be computer-intermediated, implying job losses, job displacements and job reconfigurations. Leaving aside the implications of these for the economy and for communities, there will be a massive requirement for retraining, re-acculturation, the reconstruction and redistribution of responsibilities and the acquisition of expertise for the new environment. The requirement and scope for HFE knowledge and expertise appears endless, as long as we are properly prepared for this new environment (your exam question: in your current project, how will you report on its improvements to GHG emissions and sustainability?)

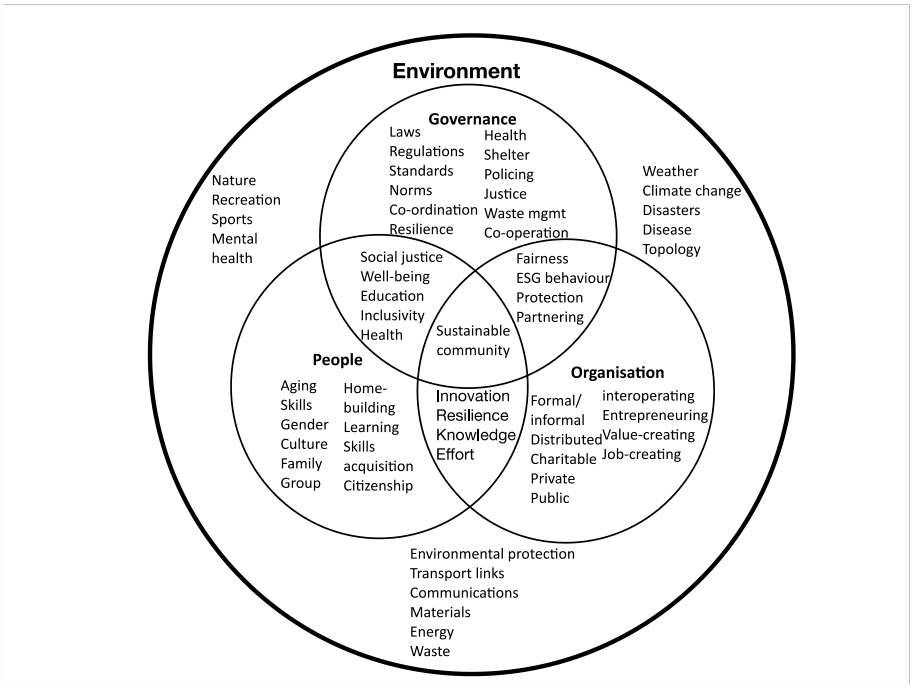
We may expect these classes of change to spread into other domains of the economy; transport, agriculture, health and so on. Inevitably, there will be implications for Health and Safety legislation and practice, due to the adoption of new materials and processes, but also due to the greater integration caused by the circular economy; for example, if we adopt the Precautionary Principle (Anon 2000) and consider customer protection, who is the end-user? Where does liability end? If the software components of a robot comes from 20 different suppliers, to whom do we assign liability in the case of an accident?

It seems obvious that the HFE profession, and the CIEHF in particular, will need to be prepared for these changes. Mostly, the changes will pick up speed towards the 2030s, and thereafter. There is time, but not much. Are our curricula appropriate for this new HFE working environment? In all of the domains where change will happen? Are our practitioners pivoting towards these new demands?

The complexities of communities

And what of the people who will be caught up in this wave of change? It is time to shift our perspective from the change process above to the implications for communities. Very briefly, and compressing complexity and variety ruthlessly, communities come in different sizes, from hamlets (four houses at a cross-roads) to mega-cities such as Shanghai. They comprise three essential entities (organisations, municipal governance and people) existing on an environmental surface. Organisations provide the basis of trade, both external and internal, and provide the jobs, pay and self-worth for the community. Municipal governance provides the law and order framework for the community and its organisations as delegated by parliament (or equivalent) as well as assuring the delivery of utilities. People provide knowledge, expertise, effort, culture, drive and resilience to both the organisations and the governance functions to deliver a sustainable community, within its environmental topography. Together, these three entities form a triad providing the core of future sustainability for the community. A host of networks, personal, virtual and physical, of varying duration operate in parallel within the community and beyond, supporting the communications and interoperabilities necessary for the community to continue to exist and prosper. These networks are vital; modern communities rely on trade and other transfers between communities, between rural and urban enterprises and between different cultures for their prosperity and, in some cases, for their survival. The Venn diagram in Figure 1 below is an attempt to show the range and variety of

the interoperabilities involved within the community, albeit it does not show the myriad of networks required to support these communications and interoperations. Note that because of knowledge limitations, parochialism and lack of access, most communities are unaware of how complex and



interdependent they really are.

Figure 1 A Venn diagram to show the interactions necessary to support a sustainable community. Networks are omitted. As an HFE professional, you might want to contemplate where in this diagram your professional competences fit; similarly for your parent organisation.

It is in this context that the changes discussed above must happen, often in parallel, again. Of course, further changes must be added to this milieu; climate change, other environmental effects, and disasters happen, sometimes unexpectedly, and requiring time, effort and resources for their amelioration. Bringing these different factors together – friction in and between networks, the unawareness of the complexities in communities, the changes coming in parallel on different timescales, the intrusions of unexpected events, the problems of access to resources and their allocation – and compressing them together ruthlessly again, we arrive at the Planner's Triangle (Campbell 2016), shown in Figure 2 below, summarizing the inevitable conflicts that arise.

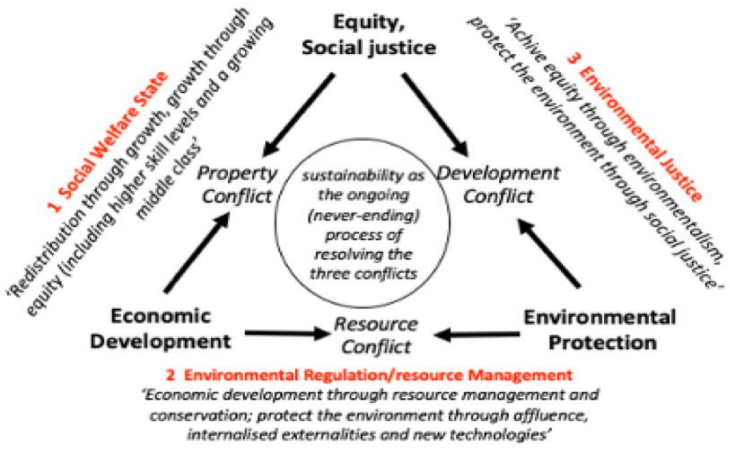


Figure 2 The Planner's Triangle, summarizing the conflicts that arise in communities, from the perspective of town planning (Campbell 2016).

It is a fairly recent development (since about 1992) for the HFE community to focus on sustainability, and uncommon for the focus to be on communities as a whole. Examples are In the first paragraph above it was stated: "… as a profession dedicated to humanity's interaction with the world, we have a duty to help deliver sustainable communities."; there is a need for the HFE community to develop a knowledge base and technological competence to ensure the benefits of our discipline deliver desirable change across the triad to achieve beneficially-changed communities. It is not evident that an informed, solid base exists, though some excellent papers are informative; for example 'Macroergonomics' (Hendricks and Kleiner 2001) and particularly the chapter on 'Community Ergonomics' (Smith, Cohen et al. 2002)); Patorniti et al (Patorniti, Stevens et al. 2017); a series by Thatcher et al., (Thatcher and Yeow 2018, Thatcher and Yeow 2019, Thatcher, Nayak et al. 2020); Knowles et al. (Knowles, Bates et al. 2018) and Guimaraes (Guimarães 2012); Salmon et al., (Salmon, Stanton et al. 2019) and (Wallensteen 2015), the latter because in community projects conflicts will be present.

Next, given the lability of communities and their networks, it would be wise to treat projects as 'wicked problems' (Rittel and Webber 1973, Vicente, Burns et al. 1997, Daw 2004, Siemieniuch and Sinclair 2014). Lessons from experience, (Williams 2005, Williams 2007) are:

- Managers of change projects need to be flexible orchestrators, entrepreneurs, knowledge managers, networkers, and ambassadors. In other words, they must demonstrate flexibility while maintaining the purpose.
- Trust is critical and relies on having long-term relationships beyond individual projects. Scan horizons continuously, and sign flexible contracts. Internal project relationships must also be based on trust and handshakes.
- It is important to maintain continuous, ruthless concentration on go/no-go decisions. Develop strategies, but plan in detail only to next decision point, and test rapidly and continuously.

Where wicked problems are concerned, it is wise to remember the following comment: "Complexity is all the stuff we leave out when we think we understand what is going on".

Addressing sustainable community problems

This entails three questions; 'What are we confronting?', 'Where to start?' and 'What to do?'. These are questions to be addressed by HFE experts when addressing sustainability issues in projects whose main focus may be on people or organisations or municipal governance, or all three.

What are we confronting? This implies measurement at the immediate problem level and at the wider community level. HFE expertise provides answers at the problem level; at the community level there is help from the UN's Sustainable Development Goals and the support and advice that is provided to meet them (Kanuri, Revi et al. 2016, UN-SDG-19 2019). In particular, there are numerous indices available to provide initial assessment of community issues. Two problems; firstly, these are for use at City level, and may need some adjustment for smaller communities. Secondly, there is a reliance on proxy variables and care must be taken in interpretation.

Where to start? What does matter about these indices is that they all rely on scores for observable variables and proxy variables, and hence are history-oriented perspectives on observable conditions. These observable conditions are manifestations of problems, but the problems themselves will need to be elucidated with the aid of experience and knowledge (Kitchin, Lauriault et al. 2015). Problem elucidation is perhaps best approached by problem structuring methods, developed in Operations Research. Exemplars are the Cynefin approach (Kurtz and Snowden 2003, Snowden and Boone 2007), Soft Systems Methodology (Checkland and Scholes 1990, Checkland 1995), and Strategic

Options Development and Analysis (Rosenhead 2013). All of these approaches embrace the management style above and are collaborative in operation involving the community. It has been pointed out that collaboration is necessary; involvement of the community must include ownership of the problem leading to a negotiated agreement about the identity of the problem, it's casting into a systems perspective and a possible way forward. Two useful support documents are BS PAS 440:2020 'Responsible innovation - Guide' based on the EU's 'Precautionary principle' (Anon 2000) and ISO 26000 'Guidance on social responsibility' (ISO26000 2010).

What to do? Methods to decompose a wicked problem include Accimap, STAMP and Cognitive Work Analysis, discussed in some depth in Thatcher et al. (Thatcher, Nayak et al. 2020), together with some other tools. Accimap (Svedung and Rasmussen 2002) is an accident analysis tool based on Rasmussen's risk management framework (Rasmussen 1997). STAMP (Systems-Theoretic Accident Model and Processes) was developed to explore systems control, and was also based on Rasmussen 1997. Cognitive Work Analysis has been developed from Vicente's original ideas (Vicente 1999) and has become a sequential toolset. Other relevant approaches include community cluster detection (Fortunato and Hric 2016), potential system vulnerabilities analysis (PReMISTS) (Clegg, M. Robinson et al. 2017) and the Psychodynamics of work (Dejours and Deranty 2010, Brunoro, Bolis et al. 2019). After these, normal HFE knowledge and expertise becomes relevant. However, bearing in mind the comment about complexity, an approach that is collaborative and co-operative with relevant stakeholders will be essential.

A summary

- There is a big scope for HFE applications – new processes, new workstations, etc
- But skills must be added – software control, pervasive IT&C-based workstations, etc
- How to assess GHG, energy and recycling benefits from interventions
- The CIEHF must provide support for HFE professionals – education, skills, marketing
- Initial HFE education will require some refurbishment to equip people with additional skills
- Communities are complex and ever-changing; persuasion skills are important
- All of this is a bolt-on to what we already do.

References

Allwood, J. M., M. F. Ashby, T. G. Gutowski and E. Worrell (2011). "Material efficiency: a white paper." Resources, Conservation and Recycling 55: 362-381.

Allwood, J. M., C. F. Dunant, R. C. Lupton, C. J. Cleaver, A. C. H. Serrenho, J. M. C. Azevedo, P. M. Horton, G. Clare, H. Low, I. Horrocks, J. Murray, J. Lin, J. M. Cullen, M. Ward, M. Salamati, T. Felin, T. Ibell, W. Zho and W. Hawkins (2019). Absolute zero. Cambridge, UK, UK FIRE.

Anon (2000). Communication from the Commission on the precautionary principle. Brussels, Commission of the European Community.

ATI-digital (2017). Digital transformation. London UK, Arospace Technology Istitute. 01.

Brunoro, C. M., I. Bolis, B. C. Kawasaki, R. Giannini and L. I. Sznelwar (2019). HFE and the Global Sustainable Development Goals. Human factors for sustainability: theoretical perspectives and global applications. A. Thatcher, K. J. Zink and K. Fischer. Boca Raton, CRC Press: 75-95.

Campbell, S. D. (2016). "The planner's triangle revisited: sustainability and the evolution of a planning ideal that can't stand still." Journal of the American Planning Association 82(4): 3898-3397.

Checkland, P. B. (1995). Soft systems methodology and its relevance to the development of information systems. Information systems provision: the contribution of soft systems methodology. F. A. Stowell. Maidenhead, McGraw-Hill: 1-17.

Checkland, P. B. and J. Scholes (1990). Soft systems methodology in action. Chichester, UK, J.Wiley & Sons.

Clegg, C., M. Robinson, M. Davis, L. Bolton, R. Pieniazek and A. McKay (2017). "Applying organizational psychology as a design science: a method for predicting malfunctions in socio-technical systems (PreMiSTS)." Design Science 3(e6).

Daw, A. (2004). On Delivering Capability. Systems Engineering Conference, Loughborough University, BAE SYSTEMS.

Dejours, C. and J.-P. Deranty (2010). "The centrality of work." Critical Horizons 11(2): 167-180.

Engell, S., R. Paulen, C. Sonntag, H. Thompson, M. Reniers, S. Klessova and B. Copigneaux (2016). Proposal of a European research and innovation agenda on cyber-physical systems of systems 2016-2025 Dortmund, FRG, CPSoS Consortium.

EPA-17 (2017). Greenhouse gases at EPA. Washington DC, Environmental Protection Agency.

EU-Sustainability-20 (2020). Sustainability-related disclosures in the financial services sector PE/87/2019/REV/1. E. Commission. Brussels, BE, EU Commission. PE/87/2019/REV/1.

EU-Taxonomy-20 (2020). Framework to facilitate sustainable invesment (Taxonomy regulation). EU 2020/0852. European Union, Technical Expert Group. EU 2020/852.

Fortunato, S. and D. Hric (2016). "Community detection in networks: a user guide." arXiv(arXiv:1608.00163v2).

Guimarães, L. B. d. M. (2012). "Sustainability and cities: a proposal for implementation of a sustainable town." Work 41: 2160-2168.

Hendricks, H. W. and B. Kleiner, Eds. (2001). Macroergonomics: theory, methods and applications. Boca Raton, CRC Press.

Kanuri, C., A. Revi, J. Espey and H. Kuhle (2016). Getting started with the SDGs in cities.

Kitchin, R., T. P. Lauriault and G. McArdle (2015). "Knowing and governing cities through urban indicators, city benchmarking and real-time dashboards." Regional Studies, Regional Science 2(1): 6-28.

Knowles, B., O. Bates and M. Håkansson (2018). This changes Sustainable HCI. CHI Conference, 2019. Montréal, QC, Canada.

Kurtz, C. F. and D. J. Snowden (2003). "The new dynamics of strategy: sense-making in a complex and complicated world." IBM Systems Journal 42(3): 462-483.

Patorniti, N. P., N. J. Stevens and P. M. Salmon (2017). "A systems approach to city design: exploring the compatibility of sociotechnical systems." Habitat International 66(August): 42-48.

Rasmussen, J. (1997). "Risk management in a dynamic society: a modelling problem." Safety Science 27: 183-213.

Rittel, H. W. J. and M. M. Webber (1973). "Dilemmas in a general theory of planning." Policy Sciences 4: 155-169.

Rosenhead, J. (2013). Problem structuring methods. Encyclopedia of operations research and management science. S. I. Gass and M. C. Fu. New York, Springer Verlag: 1162–1172.

Salmon, P. M., N. A. Stanton, G. J. M. Read, G. H. Walker, N. J. Stevens and P. A. Hancock (2019). From systems ergonomics to global ergonomics: the world as a socio-ecological-technical system. Contemorary Ergonomics and Human Factors. R. Charles and D. Golightly. London, UK.

SASB-17 (2017). SASB conceptual framework. San Francisco, Sustainability Accounting Standards Board.

SASB-20 (2020). Content moderation taxonomy: a foundation for standard setting on the issue of content moderation. San Francisco, US, Sustainability Accounting Standards Board.

Schätz, B. (2014). The role of models in engineering of cyber-physical systems – challenges and possibilities. CPS20: CPS 20 years from now - visions and challenges. Berlin.

Schätz, B., M. Törngren, S. Bensalem, M. V. Cengarle, H. Pfeifer, J. McDermid, R. Passerone and A. Sangiovanni-Vincentelli (2015). CyPhERS - research agenda and recommendations for action. München, Germany, CyPHERS consortium.

Siemieniuch, C. E. and M. A. Sinclair (2014). "Extending systems ergonomics thinking to accommodate the socio-technical issues of Systems of Systems." Applied Ergonomics 45(1): 85-98.

Smith, J. H., W. J. Cohen, F. T. Conway, P. Carayon, A. D. Bayeh and M. J. Smith (2002). Community ergonomics. Macroergonomics: theory, methods and applications. H. W. Hendrick and B. j. Kleiner. Mahwah NJ, L. Erlbaum & Associates.

Snowden, D. J. and M. E. Boone (2007). "A leader's framework for decision making." Harvard Business Review 85(11): 68-76, 149.

Svedung, I. and J. Rasmussen (2002). "Graphic representation of accident scenarios: mapping system structure and the causation of accidents." Safety Science 40: 397-417.

Thatcher, A., R. Nayak and P. Waterson (2020). "Human factors and ergonomics systems-based tools for understanding and addressing global problems of the twenty-first century." Ergonomics 63(3): 367-387.

Thatcher, A. and P. H. P. Yeow (2018). "Sustainability and resilience: using the sustainable system-of- systems model for ergonomics interventions." Ergonomics SA 30(1): 1-16.

Thatcher, A. and P. H. P. Yeow (2019). Factors to consider in the application of the sustainable system- of-systems odel for human factors and ergonomics interventions. Human Factors for Sustainability: Theoretical Perspectives and Global Applications. A. Thatcher, K. J. Zink and K. Fischer. Boca Raton, CRC Press: 213-232.

UN-SDG-19 (2019). Sustainable Development Goals.

Vicente, K. J. (1999). Cognitive work analysis: towards safe, productive and healthy computer-based work, Lawrence Erlbaum & Associates.

Vicente, K. J., C. M. Burns and W. S. Pawlak (1997). "Muddling through wicked design problems." Ergonomics in Design 5(1): 25-30.

Wallensteen, P. (2015). Understanding conflict resolution. Los Angeles, SAGE Publications.

Williams, T. M. (2005). "Assessing and moving on from the dominant project management discourse in the light of project over-runs." IEEE Transactions on Engineering Management 52(4): 497-508.

Williams, T. M. (2007). "How do organisations learn lessons from projects - and do they?" IEEE Transactions on Engineering Management 55(2): 248-266.

Woods, D. D. and M. Branlat (2010). "Hollnagel's test: being 'in control' of highly interdependent multi-layered networked systems." Cognition, Technology and Work 12(2): 95-101.