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DOING MORE WITH FEWER PEOPLE: HUMAN FACTORS CONTRIBUTIONS ON THE ROAD TO EFFICIENCY AND PRODUCTIVITY

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The term 'efficiency' in the context of Human Factors is slightly difficult to operationalise. For example, typical definitions of efficiency include:

'**Efficiency** *n.* The quality or degree of being efficient'

'**Efficient** *a.* …productive of desired effects; especially: productive without waste.' (Webster's Third New International Dictionary).

'Efficiency' is most often, either directly or indirectly, related to cost; 'waste' refers to a waste of time or money. 'Productivity' is highly related to 'efficiency', typically measured in terms of the rate of output per unit input. As a measure of worker efficiency, it is often defined as units per person, per hour. However, measuring system outputs in often not so easily quantified. The underlying theme of this special issue is all about increasing system efficiency (or productivity), either by 'doing the same amount of work with fewer people' or 'doing more work with the same amount of people'. Ideally, the aim is to have the best of both worlds, 'doing more with fewer people'.

Three generic, quasi-antagonistic parameters can be applied to measure the success of any system: safety, performance and cost. The tensions between these aspects can be profound. There is a fine balancing act between them and their equilibrium is dictated by the ultimate philosophy (implicit or explicit) underlying the goals of the system in question. It can be argued that the *ultimate* (but not sole…) consideration underlying all military operations is one of performance. Conversely, in civilian life the regulatory authorities are concerned only with the safety of the design and operation of the systems that they oversee. However, from an organisational perspective commercial operations are required to balance the requirement for safety against both cost and performance considerations. In peacetime, even the military must now place great emphasis on safety (they owe all personnel a duty of care) and in the current economic climate, cost is a significant issue.

In the civilian realm, Human Factors has tended to concentrate almost exclusively on safety aspects. As a result, in many areas Human Factors has become regarded as a 'hygiene factor' – an activity that does not make a positive financial contribution to the organisation, but one where a lack of investment in it may lead to a wide variety of negative outcomes. From the perspective of a manufacturer trying to design, develop, manufacture and ultimately sell equipment, providing a 'better' human-system interface does not 'add value' but on the other hand a failure to provide a user-friendly interface will detract from its saleability (see Harris, 2008); avoiding accidents does not save money – it merely costs the organisation less money. Consequently, it is often difficult to make a convincing cost-based argument for investing heavily in Human Factors research and development.

However, there is a body of evidence beginning to demonstrate that the application of good Human Factors can make significant through life cost savings. The identification of Human Factors issues early in the design and development process can have considerable financial benefits. After the concept design, preliminary design, detailed design and development phases, only approximately 10% of the through life cost monies will have been spent, but effectively over 90% of the committed, locked-in through life costs will have been determined by decisions made by this point.

Analysis of a large number military and aerospace programmes undertaken by Burgess-Limerick (2010) has shown considerable cost savings can be attributed to 'good' Human Factors principles applied during design. Estimates produced varied, but there was usually between a 30 and 66:1 return on investment. Similarly, the US Air Force in their Human Systems Integration handbook (US Air Force 2009) suggests that Human Factors costs are usually between 2-4.2% of an overall development budget but usually produce a return on investment of between 40-60:1 across the operational lifetime of the system.

One of the principal ways in which significant cost savings have been made is by employing fewer personnel. This has been made possible by the increasing levels of automation which have reduced the number of people required to operate a system while still maintaining (or even enhancing) its capability. For example, the common flight deck complement is now that of two pilots: 50 years ago, it was not uncommon for there to be five crew in the cockpit of a civil airliner (two Pilots; Flight Engineer; Navigator and Radio Operator). Now just two pilots, with much increased levels of assistance from the aircraft, accomplish the same tasks once undertaken by five personnel. More extensive crew reductions have been achieved in the maritime context. The last generation of Royal Navy attack submarines (the Trafalgar Class) required 130 crew. The Astute class, a significantly larger and more capable boat, requires a complement of only 98 officers and men. Crew sizes in future generations of warships will be even smaller (e.g. Anderson, Malone and Baker, 1998). Similar reductions in the number of personnel required to operate a system have been observed in many other areas (for example, petrochemical industry; nuclear; manufacturing, etc.). Many urban rail systems (for example the Docklands Light Railway) are now unmanned. Autonomous road vehicles are also being introduced in town centres (e.g. Milton Keynes, Coventry). These reductions in operating personnel have vastly reduced operating costs by increasing efficiency.

The reductions in manning levels have transformed the manner in which systems are operated. Many of the functions once performed by human operators are now wholly (or partially) performed by automation. The emphasis in the role of the operator has changed to that of being a systems manager. Highly automated systems are usually under some form of supervisory control rather than manual control, with the operators now being an outer-loop controller (a setter of high-level goals) and monitor of systems rather than that of an inner loop ('hands on', minute to minute) controller. This has changed dramatically the nature of the operator's control tasks as well as allowing a reduced number of personnel.

The shift towards increasing levels of system autonomy has further changed the nature of the operators' task. Even complex automated systems operate within well-defined parameters. Autonomous systems are more adaptive, with a greater degree of self-governance which allow them to respond (within bounds) to factors in the environment that were not anticipated. However, the flexible and less predictable nature of their responses poses challenges for their testing and certification, and demands a different approach to their management, including the training of their operators. Trust in these systems becomes a key issue.

The aerospace and automotive industries have long been in the vanguard of developing advanced automation and autonomous systems. Several papers are derived from these application areas (Degani, Goldman, Tsimhoni, and Deutsch; Schutte; Huddlestone, Sears and Harris; Lachter, Brandt, Battiste, Matessa and Johnson). Schutte considers the role of the human in the highly automated aircraft: why is the pilot there and how can they best be supported by the automation in a complementary manner? The theme of examining the human-machine role to optimise human performance in considered in the automotive context in the paper by Degani, Goldman, Tsimhoni, and Deutsch). In the commercial aviation context, the Human Factors considerations of reducing the number of pilots to just a single member of flight crew (with support from the ground) is considered in the contributions from Huddlestone, Sears and Harris, and Lachter, Brandt, Battiste, Matessa and Johnson, both of whom adopt a similar approach to this issue. Richards sand Stedmon go even further, considering the display design characteristics for autonomous systems when one operator is responsible for many unmanned aerial systems. Oberhauser and Dreyer also examine issues in interface design, but in this case the efficiencies are achieved in the design process by use of a virtual reality flight simulator.

Many of these contributions are extended and expanded versions of the presentations given during the special session of invited papers on the theme of 'doing more with fewer people' at the HCI International Conference in Los Angeles (2-7 August 2015). We are grateful to all the authors for their efforts in producing these papers for this special issue.

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Coventry University, June 2017

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