HUMAN TOTAL COST OF OWNERSHIP:
MEASURING THE IMPACT OF HUMAN FACTORS ON SYSTEM ENGINEERING

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Abstract
The procurement process often results in information systems that are of limited usefulness, usability and understandability. A focus on short-term cost of acquisition, as a main driving force in procurement, always comes with a hefty price that weighs most heavily on the shoulders of those who have to conduct cognitive work using the new technologies. Procurement that is driven primarily by Designer-Centered Design and the goal of reducing immediate cost fails because it does not recognize the value of the human component. Zachary et al. (2007) proposed a new family of measures for use in procurement, referred to collectively as Human Total Cost of Ownership (HTCO). HTCO might be defined in a number of ways, and from the conceptual definitions one might generate a number of operational definitions of how to actually calculate metrics. Panelists will address the overarching questions of HTCO measures and their integration into the acquisition and development process, current obstacles to Human-Centered Design, ways in which HTCO might gain entry into the procurement process, and alternative approaches to creating specific HTCO measurables.

PANEL SUMMARY
People have needs, goals, and aspirations, such as acquiring the expertise needed to do their jobs and expanding the range of that expertise. People prefer an information/work environment that is sensitive to what they need (and how they need it) to perform their jobs in a satisfying and gratifying way. Meeting such needs is essential to achieving the ultimate goals of "the system" (or organization). Conversely, not meeting human needs and goals is almost a sure way to not achieve the overall goals in the long run, i.e., to not get the desired work performance. If some new human-machine system is to succeed, the human costs must be paid, whether they are considered in the procurement process or not. Yet procurement in both government and business seems fixated on the cost of the hardware/software being bought, and only on the immediate cost of those. (Surprisingly often, it ignores even the predictable costs of replacements, upgrades, and maintenance over the full lifetime of the artifacts.) Human costs, the costs of failing to meet the goal of human-centering, are ignored. Some of the human costs of ownership are summarized in Table 1.
Table 1. Total Human Cost of Ownership factors make bad design effects visible to procurement.

<table>
<thead>
<tr>
<th>HUMAN FACTOR</th>
<th>DESIGN PROBLEMS</th>
<th>FINANCIAL FOOTPRINT</th>
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<tbody>
<tr>
<td>Training</td>
<td>Poor designs are harder to learn.</td>
<td>Training takes longer and may increases ‘wash outs.’</td>
</tr>
<tr>
<td>Frustration</td>
<td>People’s engagement with their work is decreased by tools that are not usable, useful, and understandable.</td>
<td>Work output falls and worker attrition increases, leading to need for more people (and their attendant costs).</td>
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<tr>
<td>Recruitment</td>
<td>User frustration and training washouts mean more recruitment.</td>
<td>Recruitment becomes more difficult and takes longer.</td>
</tr>
<tr>
<td>Performance costs</td>
<td>Poor designs increase errors of various kinds.</td>
<td>Error mitigation costs accumulate and increase.</td>
</tr>
<tr>
<td>Opportunity costs</td>
<td>Longer training, recruitment processes result in positions going unfilled for longer times.</td>
<td>Mission goals and/or customer needs are not achieved; competitors may benefit.</td>
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Designs can be created out of a Designer-Centered Design playbook for technology that is cheap to build (even if known to be hard to learn, use, or maintain). The resulting design flaws become training problems, which become operations problems, which become performance problems, which become human error problems, which become (re)training problems, etc. The low cost solution suddenly becomes high cost, and then just a quiet failure. There are many such bodies buried in the hills around procurement offices. In current practice, total cost of ownership (TCO) is taken to be acquisition cost, that is, the cost of system engineering, which does not consider human costs other than the immediate manning level. This definition of cost has allowed the huge impact of user hostile designs to be hidden. The failure to acknowledge the human costs allows the impacts of design on training, recruiting, and even mission-goal achievement to be largely ignored since those costs are institutionally segregated and separated as if they occurred in different universes. And the irony to all this is that when mission-goal achievement is scrutinized, it is reduced to “performance metrics” in a John Henry versus the steam shovel scenario. Such "blaming the victim" never works in the long run.

HTCO would certainly include costs that are ordinarily considered TCO, that is, the cost of acquisition and staffing (i.e., the cost of paying for warm bodies, even if they are only perceived as input or output devices). After that, a number of factors might kick in. There is training cost, including the cost of recruiting, salary during training, and the cost of training support (salaries, travel, etc.). Some procurement processes fold in the cost of human error calculated in terms of error frequency and average cost as a percentage of revenue.

It is immediately obvious to procurement officers that up-front costs will increase if procurement depends on initial cognitive systems engineering activities, which are costs in the design/development phase. Pointing out that other phases (involving operation, maintenance, upgrade, etc.) should have lower long-term human costs if the system is designed in a Human-Centered way from the beginning does not get the Cognitive System Engineer terribly far into the procurement decision making process, even if it is claimed that those additional repercussive costs might dwarf the marginal costs delta in the design/development phase.

Might there be a way to short-circuit to these problems? Zachary et al. (2007) illustrated an HTCO measure using an actual case study of software intended to help in the mortgage closing process. While the immediate cost of acquisition was attractive, the company soon learned that training was time-consuming and effortful, and the software so user hostile that there was a high drop-out rate on the part of trainees (48%). Even a conservative estimate of the costs of training, and re-training to replace the drop-outs, showed that the HTCO was outrageous—a cost of about $110,000 per employee who trained to competency and began creating revenue. There was an additional $115,000 per employee cost to the company because of error and the administrative burden of coping with error (i.e., the software was not Human-Centered).

The purpose of this Panel is for experienced cognitive systems engineers, program managers, and systems engineers to discuss alternative measures within the HTCO family of measures, and explore ways for getting HTCO calculations into actual procurement policies and procedures.

Christopher Hale (SAIC)

The recent introduction of HTCO as a consideration in system acquisition and development fits the growing momentum to have Human-System Integration requirements integrated into procurement from the very beginning of technology development projects (see for example, Pew & Mavor, 2007). This reflects a trend extending back over many years (Bias & Mayhew, 1994; Chapanis, 1991; Mantei & Teorey, 1988). What
measures comprise HTCO? How should these measures be defined and quantified? How should they be communicated to the larger system development process? How should cognitive engineers address issues of risk management, between measures of HTCO and other system concerns, among competing HTCO considerations? How should the effects of HTCO factors be evaluated with respect to their effects on measures of system viability, such as effectiveness? How/where/when should cognitive system engineering and HTCO fit into the larger “flow” of system development? How will concerns about HTCO help to justify the look, feel and operational logic of artifacts created by a system development process? In considering the substance of HTCO and its integration into system development, the CSE community will have to address: (1) content quality and efficacy, (2) communication effectiveness, (3) risk management and (4) traceability.

Alternative HTCO Measures (Mike Drillings, US Army)

What procedures might increase the probability that HTCO will be meaningfully considered? First, one must detail the cost consideration process at very high levels of the military. Why are human cost considerations sometimes acknowledged but often dismissed or ignored? How might we make it easier for top-level acquisition executives to evaluate HTCO? HTCO measures that might serve to get a "foot in the door" could be:

- Safety (considerations of system safety and battlefield survivability)
- Military readiness (how ready are units to perform their military mission?)
- Mission success (the probability that the unit will be successful in their mission).

However, such measures fall at a high level of functionality. Anchoring them in measurables will be difficult, both conceptually and practically. One can start with the question, How is Cost of Ownership estimated (the analysis and assessment process)? How do system designers receive this TCO information, if they receive it at all. What incentives, both positive and negative, permit the analysis of cost of development to be the substitute for cost of ownership?

The New Challenge for Human Factors in Systems Acquisition (John Burns, US Navy)

In July of 2006, the Joint Readiness Oversight Council (JROC) approved the implementation of a mandatory Sustainment Key Performance Parameter while in March of 2007, the Deputy Undersecretary of Defense for Logistics and Material Readiness put out a memo establishing Life Cycle Sustainment outcome metrics for all major DoD programs. These actions, coupled with the ongoing development of supporting policy, have enormous potential implications for Cognitive Systems Engineers and, indeed, for all of those in systems acquisition whose focus is on human performance.

Heretofore, human costs and contributions have been viewed as the result of system design—not as factors to be incorporated into conceptualization and design. The challenge before us now lies in bringing our human performance expertise to bear early in the systems acquisition process. In particular, the following issues will be discussed:

- Methods and tools for integrating human performance considerations during concept exploration
- The role of standards—For whom? At what point? Are those that address humans and human performance adequate?

Over 50 years ago, human factors engineering arose out of a specific context and a specific set of needs. Today, the DoD has once again put out the call for a strong infusion of psychological science. This presentation will attempt to sketch out the context of this environment, identify some key constraints, and suggest some potential avenues of exploration that might enable the behavioral sciences community to have a visible and meaningful impacts early in acquisition.

The Distribution of Human Total Cost of Ownership (Michael Linegang, FAA)

The TCO decision process is highly distributed. While the procurement organization is often closely associated with the organization that will operate the system, the procurement and operations organizations rarely have direct control over the design decisions that will ultimately impact the cost of ownership. Many organizations develop core systems and technologies that are then tailored to meet the needs of multiple procurement and operations customers. Some, and possibly many, of the HTCO characteristics are built into the core systems and technologies long before any one specific procurement effort begins. The aviation industry provides numerous examples of this
customizable core technology approach. Major aircraft manufacturers invest in the development of new airframes and avionic systems long before the detailed requirements are specified for any given procurement effort; the design and development investments are based on broad market projections; many of the system's characteristics were locked in place during the development of the core technology.

Human factors principles suggest that the more customized solution should lead to a lower HTCO. But the up-front cost of complete customization (and the schedule and cost risks associated with building systems from the ground-up) will almost always favor the procurement of customized core technologies over ground-up development. So a significant portion of the answer to HTCO does and always will reside in the design decisions made when developing core technologies. How can HTCO costs be minimized in core technology systems, long before the specific users and operators for those systems are identified?

HTCO discussions have identified "performance" and "training" as examples of costs that are impacted by poor human factors. Recent treatments have expanded to recognize costs such as "recruitment," "frustration," and "opportunity" costs (Zachary et. al. 2007). It is important to recognize that the cost concerns will vary based on the industry, the project, and the role of the organization in the system engineering process. In the civil aviation domain, the aircraft or avionic system manufacturer has primary responsibility for design decisions and bears most of the investment risk during system development. New civil aircraft or avionic systems rarely have one single target procurement organization or operators. Instead, an aircraft or system may be procured by any number of airlines, corporations, or private individuals, and each of those groups has its own set of requirements for the aircraft or system. Few if any of those groups are directly involved with the design decisions. In this situation, performance and training costs are certainly relevant to the TCO, but the manufacturer passes those costs on to the customer. The manufacturer is responsible for "schedule" (meeting a scheduled delivery date or bringing the product to market before a competitor), for "manufacturing" (minimizing time and complexity required to mass-producing a given design), for "marketing" (positioning the product relative to competitors), for "regulatory compliance" (meeting minimum standards for safety), for "reliability" (minimizing repairs and redesigns required after product delivery), and for "safety" (minimizing the negative impacts resulting from an unsafe product).

If manufacturers have no responsibility for the primary drivers of HTCO, there is little hope that they will minimize those costs on their own accord. Why should manufacturers seek to minimize HTCO? One answer may lie in answering a different question: In what ways can HTCO be felt by a manufacturer? To have an impact on industries like civil aviation, HTCO measures need to be defined in a manner that allows manufacturers to recognize benefits from minimizing HTCO.

REFERENCES


