Human Factors Program Cost Estimation- Potential Approaches

A Concept Paper

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Table of Contents

List of Illustrations

Tables

Figure

Human Factors Program Cost Estimation- Potential Approaches
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1. Introduction

1.1 Objective

The objective of this concept paper is to develop possible approaches for estimating human factors cost for a NAS modernization program.

The intent of this document is not to validate these approaches, but to define them. These approaches will need to be validated and refined as they are applied to cost estimation situations.

1.2 Background

Human factors researchers, managers, and sponsors often face a difficult question of estimating human factors costs for a given National Airspace System (NAS) modernization program. The scope and level of human factors efforts vary according to the type of the program. Generally, the modernization program that aims to achieve a positive change can be categorized as:

- Development of decision support tools (e.g., Traffic Management Advisor),
- Procedural changes (e.g., Reduced Vertical Separation Minima),
- Advanced concepts (e.g., Dynamic Resectorization),
- New software/hardware (e.g., Standard Terminal Automation Replacement System, Display System Replacement), and
- Advanced technology (e.g., Global Positioning System).

All of the above types of programs typically affect either operational users and/or maintenance staff. Therefore, the user needs and their characteristics must be considered at the onset of any program.

Often, sponsors, researchers, and practitioners ask what should be included in the human factors cost. At times, the answer is not very straightforward. If human performance data is collected from a study, then all costs are included as a part of human factors cost. If human performance data is not collected (e.g., stability testing of an equipment, Developmental Test and Evaluation of an equipment), then the study cost is not considered a part of human factors cost. For the purposes of this document, the following types of costs are assumed to fall under human factors costs, if the study involves human performance assessment:

1. Designer cost,
2. Programmer cost,
3. Human factors staff cost,
4. Laboratory cost,

5. Participant cost,
6. Subject matter expert cost,
7. User needs assessment cost,
8. Concept studies cost,
9. Prototype and usability assessment costs,
10. Modeling and fast-time simulations cost,
11. Real-time human-in-the-loop simulation cost,
12. Experiment/study plan development cost,
13. Scenario development cost,
14. Scenario shakedown cost,
15. Final simulation cost,
16. Data collection cost,
17. Data analysis cost, and
18. Final report development cost.

Generally, any time human performance data is collected or estimated in a study, experiment, or test, all of the costs affiliated with that data should be considered as a part of human factors cost.

Cost estimation, particularly in the early stages of acquisition or program development, is more of an art, rather than a science. Traditionally, historical data is the primary source of such estimation (FAA-iCMM, page 227, 1997). However, historical data may not completely represent the current conditions and cost drivers.

1.3 Scope

A single approach to cost estimation may not be appropriate to all NAS modernization programs and to all the different stages of acquisition management. Therefore, multiple approaches have been proposed in this paper. The following acquisition management stages are considered:

1. Mission analysis,
2. Investment analysis,
3. Solution implementation,
4. In-service management, and
5. Service life extension.

The authors reviewed the best practices in cost estimation approaches in sawmill industries, software engineering, manufacturing and chemical industries. Based on the review, the following sections identify potential approaches for human factors cost estimation in a NAS modernization program.

2. Human Factors Cost Estimation Approaches

2.1 Expert Judgment Approach

Developing a cost work breakdown structure and then estimating human factors cost requires considerable information regarding the modernization program. Sufficient information may not be available in the early stages of acquisition process. Additionally, developing such work breakdowns could take considerable amounts of time. Therefore, depending upon how much human factors information is known, the estimation of costs might use one of the expert judgment methods identified below.

2.1.1 Method 1 - Cost Estimation Committee

Historically, the human factors budget in a NAS modernization program is generally decided ad hoc. Utilizing a group of human factors practitioners to estimate the cost may provide a more consistent result. This committee would review any new modernization effort to assess its impact. As appropriate, the committee would identify the benefits and feasibility studies that need to be conducted. Then, the committee would develop cost estimates and a budget for the human factors activities and would propose a high-level human factors plan.

This approach is similar to those used in other industries in which an intuitive method is used to estimate the costs. The benefit of a committee is that it would incorporate more views in a consistent way.

There are two ways to estimate human factors cost by a committee. In the first approach, the human factors budget is estimated (absolute judgement) using prior knowledge and experience rather than a systematic approach. In the second approach, the committee uses a structured method for estimation.

Committee structure- The committee would consist of three to four human factors practitioners. The committee would be engaged in the human factors cost estimation as soon as costs were required to be identified for a NAS modernization program baseline.

Advantages- Since the same committee members would estimate human factors costs, the approach would offer consistency in estimations. Over time, the committee would be able to estimate costs more accurately due to lessons learned and refinement of techniques employed.

Disadvantages- The committee would need information and guidance about the program and about the levels of human factors effort and their cost estimate. This guidance may be undefined in the early days of this committee. The committee approach entails the use of multiple human factors resources from a limited source.

2.2 Parametric Cost Estimation Approach

Using a parametric cost estimation approach, the human factors budget is estimated based on certain parameters of a NAS modernization program. The parametric cost estimation method is used in software engineering (e.g., lines of code) and chemical plants.

For human factors cost estimation, three different parametric cost estimation methods could be used, as follows:

1. Parametric cost estimation based on the type of changes a NAS modernization program would generate.
2. Parametric cost estimation based on the type of human factors activities that must be performed to demonstrate the feasibility and benefits of a NAS modernization program.
3. Parametric cost estimation based on a combination of the above two approaches.

2.2.1 Method 2 - Parametric Cost Estimation Based on Type of Human Factors Impact

In order to estimate the human factors budget to examine the potential impact on the above factors, the following steps could be used:

Step 1 – Identify which of the factors outlined in Table 1 that may impact (or be impacted by) a NAS modernization program.

Step 2 – Identify the level of impact (no impact, very low impact, low impact, medium impact, high impact or very high impact) for each factor.

Step 3 – For each potential impact, provide an estimated cost for conducting human factors analysis based on the severity of the impact (using Table 2).

Step 4- Identify total human factors cost, which would be the sum of all costs identified in step 3 for each potential impact.

Table 1: Types of Human Factors Impact

The following is a list of factors that could impact (or be impacted by) the NAS modernization program (FAA Human Factors Job Aid, 1999):

1. **Workload:** Operator and maintainer task performance and workload.
2. **Training:** Minimized need for operator and maintainer training.
3. **Functional Design:** Equipment design for simplicity, consistency with the desired human-system interface functions, and compatibility with the expected operation and maintenance concepts.
4. **CHI:** Standardization of computer-human interface (to address common functions employ similar user dialogues, interfaces, and procedures).
5. **Staffing:** Accommodation of constraints and opportunities on staffing levels and organizational structures.
6. **Safety and Health:** Prevention of operator and maintainer exposure to safety and health hazards.
7. **Special Skills and Tools:** Considerations to minimize the need for special or unique operator or maintainer skills, abilities, tools, or characteristics.
8. **Work Space:** Adequacy of work space for personnel and their tools and equipment, and sufficient space for the movements and actions they perform during operational and maintenance tasks under normal, adverse, and emergency conditions.
9. **Displays and Controls:** Design and arrangement of displays and controls (to be consistent with the operator's and maintainer's natural sequence of operational actions).
10. **Information Requirements:** Availability of information needed by the operator and maintainer for a specific task when it is needed and in the appropriate sequence.
11. **Display Presentation:** Ability of labels, symbols, colors, terms, acronyms, abbreviations, formats, and data fields to be consistent across the display sets, and enhance operator and maintainer performance.
12. **Visual/Aural Alerts:** Design of visual and auditory alerts (including error messages) to invoke the necessary operator and maintainer response.
13. **I/O Devices:** Capability of input and output devices and methods for performing the task quickly and accurately, especially critical tasks.
14. **Communications:** System design considerations to enhance required user communications and teamwork.
15. **Procedures:** Design of operation and maintenance procedures for simplicity and consistency with the desired human-system interface functions.
16. **Anthropometrics:** System design accommodation of personnel (e.g., from the 5th through 95th percentile levels of the human physical characteristics) represented in the user population.
17. **Documentation:** Preparation of user documentation and technical manuals (including any electronic HELP functions) in a suitable format of information presentation, at the appropriate reading level, and with the required degree of technical sophistication and clarity.
18. **Environment:** Accommodation of environmental factors (including extremes) to which it will be subjected and their effects on human-system performance.

For converting the potential impact into actual dollars, the relationships in Table 2 are proposed. These cost estimate methods may not be best suited for all situations and may change in the future, however the relationship serves as a starting point. As more data is available, the actual dollar values would change.

Table 2: Potential Impact of Change and Associated Human Factors Cost

Cost Method	Level of Impact of Each Item[1]					
	No[2]	**Very Low**	**Low**	**Medium[2]**	**High**	**Very High [2]**
Direct Cost (in $, FY02)	$10,000	$100,000	$200,000	$300,000	$400,000	$500,000
Percentage of Developmental Budget	0%	0.11% per change. For all 18 very low impact changes, a total of 2%.	0.22% per change. For all 18 low impact changes, a total of 4%	0.33% per change. For all 18 medium impact changes, a total of 6%.	0.44% per change. For all 18 high impact changes a total of 8%.	0.55% per change. For all 18 very high changes a total of 10%.

NOTES: Not all factors identified in Table 1 will be impacted equally. Therefore, the total percentage would be a combination of different levels of impacts. For example, if there are two very low impact items, one low impact item, two medium impact items, one high impact items, and two very high impact items then the human factors budget would be 2.64% of the total budget (=2*0.11 + 1*0.22 + 2*0.33 + 1*0.44+ 2*55 = 2.64%). For a $100 million program, the HF cost might be $2.64 million. Alternatively (using the Direct Cost Method), the total human factors cost estimate would be $1.9 million. In case of differences, select the estimate that is larger.

If all 18 items have a very high impact, then the total human factors budget would be $9 million, or 10% of the total program developmental costs. If all 18 items have very low impact on severity of a change, then the total human factors budget would be $1.8 million, or 2% of the total program costs.

Disadvantage- The cost estimates may not be the same for different NAS modernization programs. Also, the cost estimates need to be validated using historical data and future program development experience. These estimation approaches will take time to mature due to its reliance on historical data (currently unavailable).

Advantage- Once the approach has matured, it will be straightforward to apply. This approach is particularly useful in the early stages of program planning when there is a lack of information for many factors that may affect cost.

[1] The indicated costs of very low, low, medium, high and very high impacts are for each factor that is likely to get impacted. So, if multiple factors are affected, then the cost will increase accordingly.
[2] It can be argued that if there is no impact, there may be no human factors cost. Usually, in order to determine if there is any human factors impact, some preliminary studies or discussions need to be conducted. The estimated budget of such activity is provided here.

2.2.2 Method 3 - Parametric Cost Estimation Based on the Type of Studies

This method describes the cost estimation based on the type of studies that need to be performed to demonstrate the feasibility and benefits of a NAS modernization program. This approach is similar to above described approach, except that the costs would be estimated by the different types or categories (see Table 3) of studies to be performed to investigate the feasibility and benefits. The following list provides the role of human factors in different stages of acquisition (Operational Concept Validation Plan, FAA ACT-540; FAA iCMM, 1997).

Table 3: Human Factors Activities in System/Life-Cycle Development

Activity Stage	Human Factors Effort	Human Factors Methods
Identification of the purpose of the change (either decision support tools, new procedures, new concept/operational improvement, new hardware/software, and new technology).	Identify ways in which the change will impact- procedural requirements, human factors performance (workload, situation awareness, accuracy, speed, etc.), training, maintenance monitoring, workstation layout, shift schedule, etc.	Literature review, interviews with SME, analysis.
Mission Needs analysis (using literature, current data, SME interviews- include both operational as well as maintenance needs).	Identify: 1. Information needs 2. Human-computer interaction needs 3. Hardware needs 4. Software needs 5. Procedural needs 6. Airspace needs	Literature review, interviews with SME, design, analysis, etc.
User identification and user analysis (using literature, current data, SME interviews- operational as well as maintenance).	Identify current and future user population and their characteristics	Literature review, interviews, analysis, studies.
Feasibility and benefits assessment (depending on the purpose of change).	Identify impact on human performance using: 1. Concept studies (task analysis, functional decomposition, etc.) 2. Prototyping 3. Fast-time simulation 4. Real-time human-in-the-loop simulation (part task, full-task)	Concept studies, fast time simulation/ modeling, rapid prototypes, analysis, real-time simulation human-in-the-loop simulation (HITLS).
Development of system/concept requirements and specifications.	Provide system requirements from human factors perspective by: 1. Prototyping 2. Concept studies 3. Literature reviews 4. Interviews	Interviews, group discussions, studies, analysis, prototypes, etc.
Development of system/change	Identify if user needs are met and	HITLS, user trials/usability

Activity Stage	Human Factors Effort	Human Factors Methods
facilitator (involvement of users, human factors experts, SME, engineers, etc.).	human performance is improved or not affected negatively by: 1. User trials 2. Human-in-the-loop simulations- assessment of human performance 3. Usability assessments 4. Iterative development	assessments, prototyping, design, data collection.
Validation and verification.	Identify that the developed system indeed meets user needs and specifications by: 1. HITL simulations 2. Test and evaluations (developmental testing, engineering testing, operational test and evaluations) 3. Assessment of human performance, benefits and feasibility	HITLS, user trials/usability, Test and Evaluations, data collection.
Training.	Identify training needs: 1. Develop training protocols 2. Test training 3. Develop training material 4. Validate training material 5. Evaluate training material 6. Computer based training 7. System training	Usability of training system, data collection, and actual training implementation.
Shadow mode testing and initial field implementation.	Gather further information to ensure that the system indeed meets user needs and does not adversely affect performance (or improve performance) in the field 1. User feedback 2. Human performance data collection	Surveys, interviews, observations, data collection.
Implementation.	Gather user feedback.	Surveys, interviews, observations, analysis, data collection.

Based on the phases listed above, a detailed analysis of human factors effort, as categorized by different types of studies, can be conducted.

*Cost estimate = a1X1 + a2X2 + a3X3 + a4X4 + a5X5 + a6X6 + a7X7

Where a1, a2, a3, a4, a5, a6, and a7 are constants, and

- X1 = number of user needs assessment studies that need to be performed.
- X2 = number of concept studies that need to be performed.
- X3 = number of fast-time simulation studies that need to be performed.
- X4 = number of prototyping studies that need to be performed.

- X5 = number of real-time human-in-the-loop simulation studies that need to be performed.
- X6 = number of test and evaluation/validation studies that need to be performed.
- X7 = number of hours of training required by each user.

Table 4 provides values of constants based on fidelity of a study.

Table 4: Values of Constants (Points) by Fidelity Requirements[3]

Constants	Initial Constant Values (Low Fidelity)	Initial Constant Values (Medium Fidelity)	Initial Constant Values (High Fidelity)
a1	1	1	1
a2	1	N/A	N/A
a3	2	4	6
a4	7	9	11
a5	12	14	16
a6	12	14	16
a7	$75/Hr	$150/Hr	$200/Hr

These points are currently chosen based on intuition and are not yet validated. However, a conversion between the points and dollars can be made when historical data is obtained. (e.g., *1 point = $40,000*).

Disadvantage- The challenge in this approach is to determine the values of the constants. However, as more historical human factors cost data becomes available, these constants can be determined more easily. This estimation approach will take some time to mature due to its reliance on historical data.

Advantage- Once the approach has matured, it will be straightforward to apply.

****Note-*** The cost estimate could be in terms of dollars or as a percentage of total budget of a NAS modernization program.

2.3 Cost Estimation Based on a Heuristics Approach

A heuristic approach can also be developed to estimate the cost. With the knowledge of NAS modernization programs, human factors effects of NAS modernization programs, and human factors evaluation methods, a systematic procedure could be used to generate cost estimates.

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[3] These are chosen as best-guess estimates at this point. These points will have to be correlated with a dollar amount. When historical data becomes available, more accurate conversion will be possible.

2.3.1 Method 4 - Human Factors Cost Estimation based on Heuristics

In this approach, a number of questions are posed to gather a preliminary assessment of a NAS modernization program's impact. Based on the appropriate response, a flow chart will be used to determine the types of studies that are needed. The number of YES responses, the types of studies, and the total points are counted. The hypothesis is that the more total points, the more human factors cost requirements. Such a hypothesis can be tested using the historical data. The conversion between points to dollars (or % of the total budget) can also be performed using historical data. The heuristic approach is explained below.

For each of the 18 items provided in Section 1, the following process is adopted:

- Step 1 - Identify if there is a change in procedure, technology, decision support tools, hardware, software, and/or operational concept.
- Step 2 - Identify the potential user population(s) that will be impacted by this change. The potential user populations include:
    - En route controllers (R and/or D side),
    - Terminal controllers,
    - Oceanic controllers,
    - Flight service station specialists,
    - Traffic management unit specialists,
    - Administrators/managers,
    - Supervisors, and
    - Airways facilities personnel.
- Step 3 - For each of the users identified in the Step 2, identify applicable potential types of human factors impact from Table 1 (what type of impact and how severe).
- Step 4 - For every potential change (Step 1), identify the types of studies (and how many of each type) need to be conducted to examine the effects of potential changes using the flowchart provided in Figure 1.
- Step 5 - For each study, identify the number of points from Table 5 based on the fidelity level requirements of each study.
- Step 6 - Identify total points for each applicable item (out of 18 items) for the selected user. Compute the total points for all applicable items for each affected user.
- Step 7 - Compute the total points for all affected users.
- Step 8 - Convert the total number of points to either dollars or percentage of the total budget.

The above process is repeated for each change type (e.g., procedures, technology, software/hardware, concept of operations, and decision support tool).

Using the flow chart (see Figure 1), a user of this approach can determine the type of studies that need to be done. The user must also determine if more than one study is necessary of each type (e.g., more than one real-time simulation study). In order to differentiate the fidelity requirements of studies, different points are assigned based on fidelity.

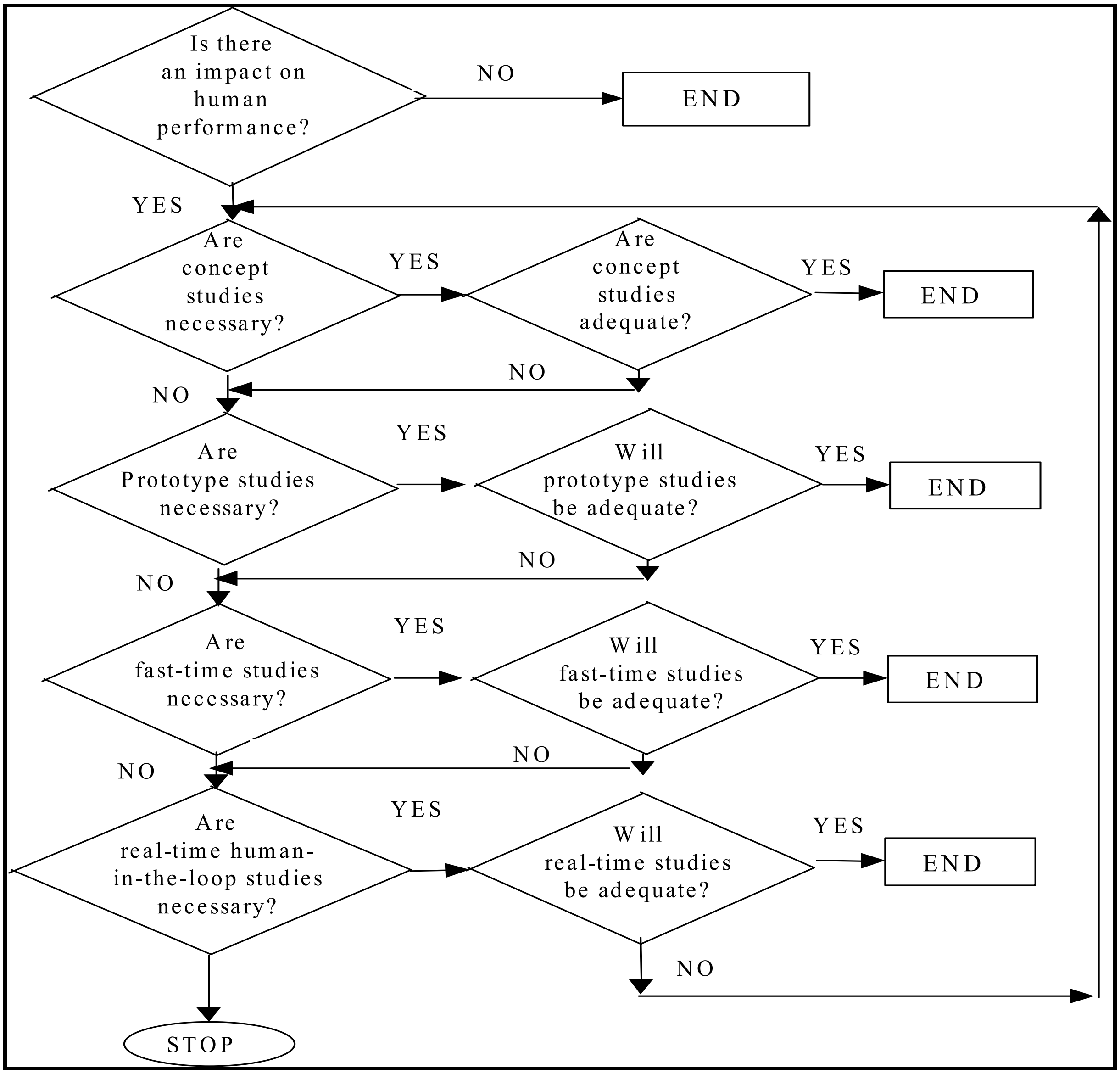

Figure 1: Identification of Necessary Studies[4]

[4] A study is considered adequate if it addresses the objectives and no further human factors evaluation is necessary.

Table 5 provides these point estimates. These points are currently based on intuition and are not validated. However, a conversion between the points and dollars can be made when historical data is obtained (e.g., *1 point = $40,000*).

Table 5: Points by Study Type and Fidelity Requirements

Generic Study Type	Low Fidelity	Medium Fidelity	High Fidelity
Concept study	1	A concept study is only low fidelity	
Fast-time simulation	2	4	6
Prototyping	7	9	11
Real-time human-in-the-loop simulation	12	14	16
Test and evaluation	12	14	16

The aforementioned studies can be subdivided further (e.g., a concept study into requirement studies, interviews, surveys, etc). However, the generic study types are the general classes of studies that are typically conducted for validating new concepts or acquiring new systems (Operational Concept Validation Plan, 1999). A detailed breakdown of the different types of studies at the early stages of program development may not be possible. Prototyping, fast-time simulation, and real-time human-in-the-loop simulation (HITLS) could be performed using different fidelity levels, as appropriate. These fidelity levels need be identified early in the program since low, medium, and high fidelity simulators have different costs.

The following pseudo-code summarizes the procedure.

```
Line 0   Start
Line 1       For each userDO (out of 8)
Line 2       IF this user's performance affected by a change THEN goto Line 3
Line 3           For each item DO (out of 18)
Line 4               Identify type of studies to address impact of each applicable item
                     (from Figure 1)
Line 5               Identify how many studies of each type are necessary
Line 6               Identify points for that item (from Table 4)
Line 7           If all 18 items are considered THEN goto Line 9, ELSE goto Line 2
Line 8           Consider next item
Line 9           Repeat Lines 3-5
Line 10          Compute total points for all items for that user
Line 11      If all users are considered THEN goto Line 14, ELSE goto Line 12
Line 12      Consider next user
Line 13          Repeat steps from Lines 3-11
Line 14          Sum all points for all users
Line 15      Convert total points to percentage budget or total cost
Line 16  End
```

3. Use of Different Methods

The use and accuracy of approaches may be different at different phases of acquisition. Table 6 provides a summary of how these approaches are applicable in various phases of acquisition.

Table 6: Use of Different Methods

Cost Estimation Approach	Acquisition Phase				
	Mission Analysis	Investment Analysis	Solution Implementation	In-service Management	Service Life Extension
1-Cost committee	✓			✓	
2-Parametric cost estimation (based on impact)		✓	✓		
3-Parametric cost estimation (based on type of studies)		✓	✓	✓	✓
4-Heuristic based	✓	✓	✓	✓	

4. Initial Criteria for Determining Human Factors Costs or Percentage of Budget

Based on a best guess, it can be estimated that 1 point will be approximately equal to $40,000 (in FY2001 dollars). It is often speculated that the human factors budget is approximately 2-7% of the total budget of a program. This estimate is gathered from informal discussions with international and domestic researchers, sponsors, and practitioners. One expert's estimate indicates that in the U.K., approximately 3-5% of the budget is spent on the human factors. A similar estimate in the U.S. is also speculated. However, these estimates may be as old as 10 years. In recent years, the awareness, importance, and role of human factors (including the human-system interface and integration) have increased. Therefore, the authors estimate that the human factors budget can be as high as 10% of a program. The best-guess median estimate is about 7%. The best-guess lowest estimate is about 2%. It is estimated that the total number of points for a typical NAS modernization program will be about 100. Therefore, for a typical modernization program, 1 point will be approximately equal to 0.07%. Table 7 summarizes the cost and percentage budget conversions for the proposed methods.

Table 7: Cost and Percentage Budget Conversion

Method	Output	Percentage budget conversion	Cost conversion
1-Cost estimation committee	Either cost or % of budget	N/A	N/A
2-Parametric-based on type of change (Costs are	Very low impact	0.11% per change	$100,000 per change

Method	Output	Percentage budget conversion	Cost conversion
type of change (Costs are represented as percentage of the total program budget or actual dollars)	Low impact	0.22% per change	$200,00 per change
	Medium impact	0.33% per change	$300,000 per change
	High impact	0.44% per change	$400,000 per change
	Very high impact	0.55% per change	$500,00 per change
3-Parametric-based on type of studies	Points	1 point = 0.07%	1 point = $40,000
4-Heuristic based	Points	1 point = 0.07%	1 point = $40,000

5. Effects of Macroscopic Factors

The above methods focus on microscopic factors that affect human factors costs. However, there are some overarching macroscopic cost drivers. These macroscopic factors include:

1. *Pace of program (e.g., aggressive, normal, slow)*- As the program schedule becomes more aggressive, more resources are needed, and the cost increases in a shorter period.
2. *Safety and security considerations (e.g., higher security, or normal security)*- As the safety and security requirements for equipment, technology, procedures, or decision support tools increase, more developmental activities and investigations need to be conducted to meet the safety standards. This leads to higher cost.
3. *Collaboration with international or domestic organizations for standardization and other reasons*- Early collaboration with international and domestic partners increases the likelihood of ensuring that all requirements are taken into consideration. However, increased collaboration increases the cost of a program due to higher travel costs, increased requirements, and increased communications costs.
4. *Organizational culture*- The climate of an organization plays a role in determining how easily the new changes will be implemented. Some changes are easier to implement than others due to their perceived or actual acceptability. The changes that face resistance become costly since part of the cost goes towards ensuing that the resistance is managed. Nature of relationships among management, user and provider unions, industry, and other stakeholders plays an important element in accepting these changes. Often, a concept or technology offers differing benefits (or losses) to different stakeholders even though, on the average, they are beneficial to the NAS. Under such circumstances, time and cost need to be devoted to gain mutual consensus. Such processes increase the cost.
5. *The complexity of the human-system integration*– The complexity of the integration between the user/maintainer and the system (including the human-system interface such as that reflected in the display design) may increase the developmental, and evaluations costs.

Table 8 captures the impact of these cost drivers. The factors would be rated for their impact on the costs based on the descriptors provided. Once the rating is gathered from subject matter experts, the costs derived by the any of the above five methods would be modified based on the parameters provided in Table 8. These parameters will be used to multiply the costs derived from any of the above five methods. These baseline estimates are provided based on prior experience and best guess. These parameter values will be modified as more experience is gained and data becomes available.

The following assumptions are made:

1. The relationship between costs and different levels of each factor (e.g., pace of program factor has very slow, slow, normal, aggressive, and very aggressive as levels) is linear.
2. The effect of one factor is independent of another. If a dependency-between factor is identified for a specific program, then cost factors could be modified.

Table 8: Multipliers to Capture Effects of Macroscopic Factors

Factors	Attributes	Implications					
Program Pace	Descriptors	N/A[5]	Very Slow	Slow	Normal	Aggressive	Very aggressive
	Cost Multipliers	***1***	***0.60***	***0.80***	***1***	***1.20***	***1.60***
Safety and Security	Descriptors	N/A	Very Low	Low	Moderate	High	Very High
	Cost Multipliers	***1***	***1.05***	***1.10***	***1.15***	***1.20***	***1.25***
International collaboration	Descriptors	N/A	Very Low	Low	Moderate	High	Very High
	Cost Multipliers	***1***	***1.03***	***1.06***	***1.09***	***1.12***	***1.15***
Organizational Culture	Descriptors	N/A	Very Conducive	Conducive	Moderate	Resistant	Very Resistant
	Cost Multipliers	***1***	***1***	***1.1***	***1.2***	***1.3***	***1.5***
Human-System Integration complexity	Descriptors	N/A	Very Low	Low	Moderate	High	Very High
	Cost Multipliers	***1***	***1***	***1.02***	***1.03***	***1.04***	***1.05***

[5] N/A represents not applicable.

6. General Considerations

No matter what approach is used for cost estimation, having a human factors cost estimation committee is desirable. The committee would offer a standard and consistent approach in estimating the human factors budget for different NAS modernization programs. The committee may vary the approaches proposed in this concept paper.

The process that is used to estimate budget can also be used to determine the schedule and overall resource requirements for human factors activities. The approaches presented here can also be used to gain a better understanding of the required duration for human factors activities. Usually, the schedule and costs are correlated therefore; estimating both simultaneously would be beneficial.

7. Next Steps

The following activities should be considered in order to establish a mechanism for estimating human factors costs:

- There is a need to begin recording, and archiving historical human factors costs in a database. Such a database should include the description of the human factors activities, their costs, total human factors costs, schedule, and lessons learned.
- Validation of cost estimation methods is necessary. Face validity can be obtained by gathering feedback from human factors practitioners. However, more accurate validity can only be assessed using historical data and application of these approaches.
- It may be useful to develop a software module that will aid in determining the cost estimates. With such a software tool, the user will be asked a series of questions based on the above methods, and the module will perform the cost estimation.

8. Conclusions

It is essential to develop a viable human factors cost estimation mechanism for early program cost estimation. Such a mechanism will help baseline and plan the human factors budget for modernization programs. To date, scant data is available (at least at one place) to provide human factors costs. Therefore, it is necessary to start collecting such data. Historical data also needs to be examined and used for future programs. This concept paper provides approaches to estimate the human factors costs. These approaches provide a framework and consistent representation of human factors effort for NAS modernization programs, but are premature at this time; rather, as initial steps, these approaches will need validation before their routine use. However, establishing a human factors cost estimation committee would be a good starting point to examine the utility of identified approaches.

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