INCORPORATING CTEA AS A SCREENING TOOL TO ENHANCE THE PROCESS OF OBTAINING TRAINING EFFECTIVENESS ESTIMATES

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(ABSTRACT)

With the complex nature of many current systems and with the limited time and resources available, more than ever, the emphasis is placed on making sure the training program being developed and implemented is indeed effective. The training program must meets the intended training objectives and be acceptable in terms of cost and effectiveness. Thus, during the planning of training programs, all alternatives need to be explored and evaluated to assure the recommended choice is the preferred training program.

In the evaluation of alternatives to choose a cost-effective training program, the level of effectiveness of each training program needs to be estimated for comparison. The training program effectiveness estimate for each alternative is traditionally obtained by subjecting each alternative to a prototype test. This traditional process calls for all proposed alternatives to be subjected to the prototype testing with no performance of an initial "screening" analysis to identify only potentially effective alternatives for further

prototype testing. As such, the current process is not cost-effective because, by lacking the initial screening analysis, it involves unnecessary added costs, labor, and time to try out alternatives that would have been judged ineffective if screening were initially done.

To address this problem and to make the current process more cost-effective (reducing cost while enhancing the process), an extra screening step needs to be added to the process. The screening is to be done before subjecting alternatives to the prototype testing. An analysis method called Cost and Training Effectiveness Analysis (CTEA) is proposed in this paper to be used as the screening method. CTEA will help training developers identify alternatives with great effectiveness potential which should be further subjected to the prototype testing. This analysis method, developed by the U.S. Army TRADOC, provides the training effectiveness estimate of training programs. CTEA also offers extended utilization of the resulting effectiveness indices such as the determination of the amount of training time required for an individual task and for an entire training program to guide training developers toward developing a cost-effective training program.

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1 INTRODUCTION

Thirty years ago, even when most systems were simple to use, training programs were already emphasized in the system strategic planning process. At the present time, with more advanced technologies and an increasing trend of designing more complex systems (i.e. nuclear power plants, modern ships/aircraft, modern weapon systems...), the necessity of planning and selecting a good training program is not only important but also critical for the system success. Note that the success of the system depends largely on the development of a good training program to train operations personnel to make the system perform its required functions effectively.

In the process of evaluating training program alternatives to select an acceptable training program for implementation, one of the requirements is to assess and to compare the level of effectiveness of each training program alternative with each other. This training program effectiveness is currently obtained by setting up a prototype testing of training materials for each alternative. During this testing, the level of effectiveness of each training program alternative is estimated by assessing the resulting proficiency level of graduated trainees after receiving the training. With this current process, all proposed alternatives are required to go through prototype testing without any initial analysis to further screening and identifying the potentially effective alternatives among the proposed ones. Thus, the current process lacks the screening step to be initially used to analyze all proposed alternatives. If this screening analysis is added, it provides an early-on visibility into the effectiveness of each alternative, thereby minimizing the risk of picking a less-than-effective training program to be developed and implemented. It also helps to eliminate the extra cost, labor, and time involved as a result of having to test all alternatives (instead of testing only the potential effective alternatives identified through the screening).

To enhance the current process used to obtain the effectiveness estimate of training program alternatives, an analysis method called Cost and Training Effectiveness Analysis (CTEA) is proposed in this paper to be used as a screening tool. CTEA, developed by the U.S. Army TRADOC, provides an analysis method to estimate the training program effectiveness by analyzing the effectiveness of individual tasks to come up with an aggregate effectiveness estimate for the entire program. In effect, the use of CTEA will enable training developers to identify potentially effective alternatives to be further subjected to the prototype testing. CTEA also offers extended utilizations of the resulting effectiveness indices such as the determination of the amount of training time required for an individual task and for an entire training program. Based on this data, adjustments can be made to insure having a program that is both effective and cost saving in the end.

This paper first discusses how the development of training programs can be derived from the system design process and all activities associated with the development. The limitation of the current process used in determining the effectiveness of a training program is noted. Then, the CTEA analysis method is introduced and is proposed to be used as a screening tool to enhance the current process. A detailed description of the CTEA method along with its applications to enhance the current process of estimating the effectiveness of training program alternatives is presented. Benefits of using CTEA and extended uses of resulting data such as assessing training time requirements are also discussed.

2 **TRAINING PROGRAM PLANNING**

The planning of a training program involves need identification, solution generation, solution selection among alternatives and other activities traditionally known as the systems engineering process.

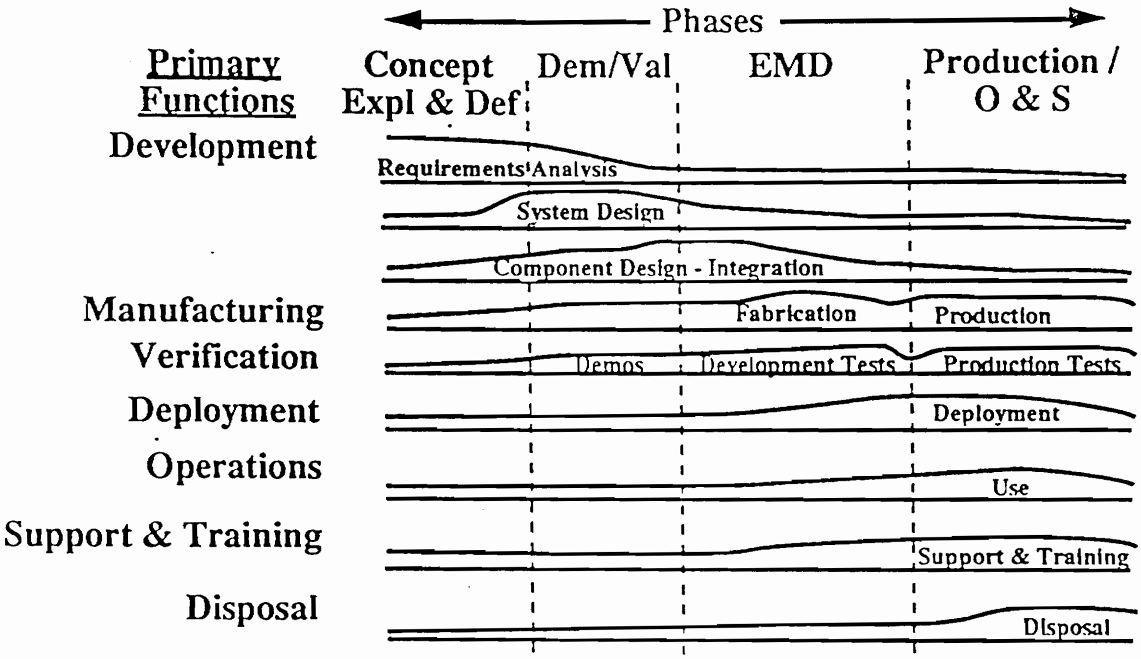
2.1 SYSTEMS ENGINEERING PROCESS

According to the Department of Defense, the systems engineering process is used to: (1) transform validated customer needs and requirements into a life-cycle balanced solution set of system product and process designs, (2) to generate information for decision makers, and (3) to provide information for the next acquisition phase.[13] In order to accomplish all of these, it requires the integration of all appropriate technical disciplines to form a multi-disciplinary team which is responsible for satisfying identified needs. In essence, the scope of the systems engineering process is to integrate technical tasks and all technical effort to yield a single and complete process that focuses all activities on the common objective.[13] It can be concluded that, as stated by Blanchard and Fabrycky, "systems engineering is both a technical process and a management process."[1]

From a technical perspective, to be successful, the analysis and design of a system often requires the knowledge of diverse disciplines to help in integrating and transforming an operational need into an effective total system that will meet cost, schedule, supportability and technical performance objectives. These diverse disciplines generally consist of industrial engineering, human factors engineering, reliability engineering, maintainability engineering, hardware engineering, component engineering, software engineering, test engineering, mechanical engineering, and other appropriate technical areas of expertise. From a management perspective, because of the involvement of many engineering specialties, there is a need for a total integration of efforts from these engineers to make sure the design of a final system forms a single solution and meets all defined objectives.[1,7]

The system life cycle approach is an important concept of the systems engineering process. The system life cycle is the period extending from inception of development activities, based on an identified need or objective, through decommissioning and disposal of the system.[13] This includes concept exploration and definition, demonstration and validation, Engineering and Manufacturing Development (EMD), production, operations and support, and finally, disposal. Designing a system with this life-cycle concept in mind is very important because the customer is interested not only in the acquisition cost of a system, but also in the cost of maintaining that system throughout its required life.

As illustrated in Figure 1, the systems engineering process operates over eight primary system life-cycle functions to define, design and verify the system elements that make up the system products and processes to satisfy customer needs and requirements[1,9]. Also shown in this figure is the relative intensity of activities associated with defining and executing these functions throughout the system life cycle. Basically, the process begins with an analysis of system requirements to produce a baseline for the system design. The system design is then developed from these requirement specifications. This is an iterative, top-down process starting at a conceptual level to identify alternative configurations and evolving toward specific hardware and software designs. Trade studies and evaluations are done between alternatives to compare and to identify the alternative that best meets established system goals. After a configuration is chosen, an analysis of critical components and a detail hardware and software design of system components are accomplished. The system is then integrated and tested to verify specification compliance. Next come the system production, the system deployment and support, the training of end-users, and the system disposal.



Source: Adapt from "Systems Design, Development, and Testing", by Meister in Handbook of Human Factors, 1987

Figure 1. SYSTEM LIFE-CYCLE AND ITS PRIMARY FUNCTIONS

2.2 BASIC APPROACH TO THE DEVELOPMENT OF TRAINING PROGRAMS

The preceding sections have emphasized the role of systems engineers and other engineers in the design of the primary system hardware, software, procedures, and all other job aspects. Systems engineers, along with human factors engineers and training specialists (collectively termed as training developers), also become involved in the planning and development of training programs. The starting point for the planning and development of training programs occurs with the analysis of system requirements to determine personnel and training requirements.[1,5] As shown in Figure 2, the basic approach to the development of training programs generally starts with some form of needs assessment to determine training requirements. Then with the focus on the particular goals and objectives to be achieved as a result of the training program, the general course structure is developed, training program alternatives are generated, evaluated and finally, the most cost-effective training program is selected among alternatives.[3,5,10]

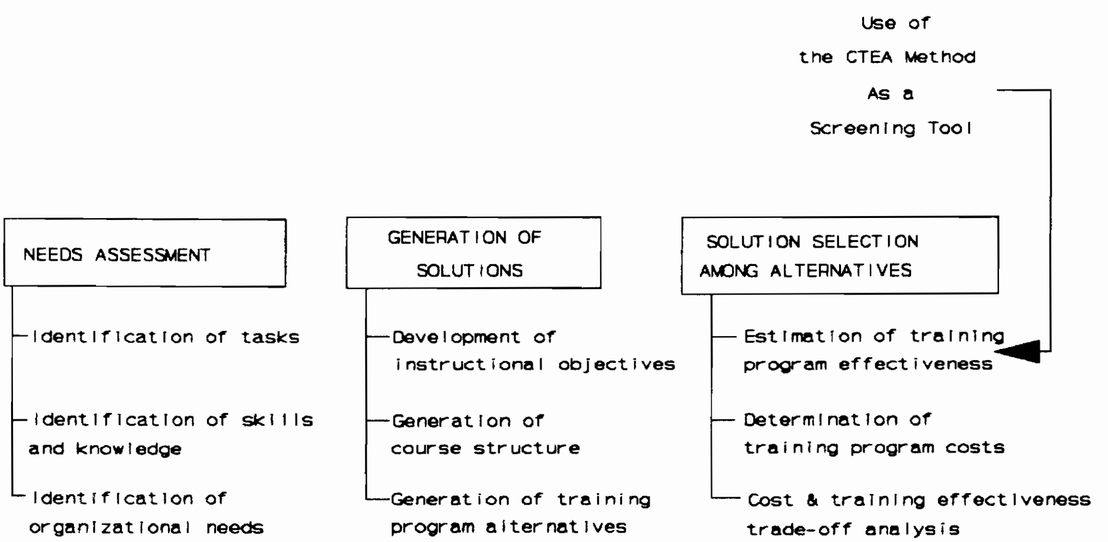


Figure 2. BASIC APPROACH TO TRAINING PROGRAM DEVELOPMENT

2.2.1 Needs assessment

Needs assessment is the first important step because it would attend to the particular goals and objectives to be achieved as a result of the training program. The purpose of this analysis is to define the problem by precisely specifying the training needs which exist and turning them into useful information for training development.

According to Goldstein in Handbook of Human Factors, usually this assessment is done through these activities:
(1) "Determine through task analysis and specification of instructional objectives what particular goals the training program is trying to achieve", (2) "Perform a human capability analysis so that the training program is designed to fit the knowledge, skill, and ability characteristics of the trainee population", and (3) Identify organizational needs to tailor the development of training programs to meet the real needs of the organization.[5] Thus, the needs assessment process used to provide the necessary information for input into the design of training programs consists of the identification of tasks, the identification of skills and knowledge, and the identification of organizational needs.

2.2.1.1 Identification of tasks

The identification of tasks is done through a process commonly known as task analysis. Task analysis is a method of describing tasks and listing elements as a preamble to sorting out what learning will need to occur. The first step of this method concerns the specification of job tasks. This activity includes a review of the system requirements and system missions. According to Blanchard and Fabrycky, system missions are defined as "the prime operating mission of the system along with alternative or secondary missions."[1] Missions are then analyzed into functions by performing the functional analysis. Functions are major chunks of mission activities assigned to specific job positions that are required to achieve a given objective. Finally, functions are analyzed into: (1) job operation which is one or more related groups of duties, (2) duty which is a set of related tasks in a job operation, and (3) task which consists of related activities to be performed to implement that particular function[1].

Typically, functions are analyzed with the assistance of subject matter experts (SMEs) such as experienced workers and personnel specialists who have sufficient knowledge and experience to provide responses to questions pertaining to the activities being analyzed.[4,5] These responses are subsequently written as task statements to detail specifically the work to be accomplished on each task. For guidance in writing task statements, please refer to Figure 3 for the general rules regarding writing tasks statements.

1. Use a terse, direct style avoiding long involved sentences that can confuse the organization. The present tense should be used. Words should be avoided that do not give the necessary information.

2. Each sentence should begin with a functional verb that identifies the primary job operation. It is important for the word to describe specifically the work to be accomplished.

3. The statement should describe WHAT the work does, HOW the worker does it, to WHOM/WHAT and WHY the worker does it. The following illustration stems from the job of a secretary:

   WHAT? TO WHOM/WHAT?
   Sorts correspondence, forms and reports
   WHY? HOW?
   in order to facilitate filing them alphabetically.

   The next example comes from the job of a supervisor:

   WHAT? TO WHOM/WHAT? WHY?
   Inform next shift supervisor of departmental status
   HOW?
   through written or verbal reports.

4. The tasks should be stated completely but they should not be detailed that it becomes a time and motion study. For example, a task could be "slides fingertips over machine edges to detect ragged edges and burrs." However, it would not be useful for the identification of tasks to say that the worker raises his or her hand onto table, places fingers on part, presses fingers on part, moves fingers to the right 6 inches, and so on. Rather, each statement should refer to a whole task that makes sense. Usually, the breaking down of the tasks into a sequence of activities is useful when a task is being taught in the training program. However, that step doesn't occur until the total task domain is identified and it is determined which tasks would be taught in the training program. Similarly, trivial tasks such as unlocking the file cabinet or turning out the lights when leaving the office should usually be avoided.

Source: "The Relationship of Training Goals and Training Systems", by Goldstein in Handbook of Human Factors, 1987

Figure 3. RULES IN WRITING TASKS STATEMENTS

2.2.1.2 Identification of skills and knowledge

By definition, the task analysis provides a specification of the required job operations regardless of the individual performing the task. Because a very critical part of the total process, the human being, is left out, a human capability analysis needs to be done to fill this gap. More specifically, (1) the skill and knowledge assessment must be performed after all tasks are specified to find out what must be learned in training, and (2) identifying the human-machine interface relationships that may impact the training.[5,9]

According to Goldstein, skill "refers to the capability to perform job operations with ease and precision" and knowledge "refers to an organized body of knowledge usually of a factual or procedural nature, which, if applied makes adequate job performance possible."[5] Now, with a list of tasks (developed from task analysis), there is a need to do a detail task analysis to identify: (1) functions that are controlled by human, by machine or both, (2) information required for human decision making, (3) any personnel, environmental factors/constraints that can affect human actions, and (4) the human skill level requirements to perform specified actions[1]. In this analysis, questions are asked of SMEs and human factor engineers for each task to determine the specific skills and knowledge required to adequately perform the job. Figure 4 lists the type of questions posed to SMEs during the interview as recommended by Goldstein. In addition, to assure a proper fit of the training program to the trainee population characteristics, these learner characteristics also need to be considered: intellectual and academic background, previous experiences and training, current technical knowledge and abilities, motivations, career orientation, age, sex, physical disabilities and any current or expected job performance deficiencies.[3]

Another step to be done in this analysis is the identification of human-machine interface relationships. In operating the machine, because of the human-machine interaction, how the design of the machine is done may affect the learning and the performance of the operator[9]. These interface relationships need to be identified and considered in both the design of the system and the design of training programs in order not to hamper the performance of the operator during operation and to facilitate the operator's learning to perform that operation during training. As an example, consider a common human-machine interface between the operator and the control panel layout to see how the layout of the control panel impacts the human performance and learning. When the controls and displays are laid out in accordance with the sequence of operation, or when this is not possible because the control/operating procedure is nonsequential, the layout is in accordance with the frequency with which controls must be operated or displays monitored, then it is easier for the operator to learn and perform both during training and real operation. Thus, depending on the design of workstation or panel/display, it can either enhance or hamper the performance of the operators and consequently will make the learning process easier or more difficult during training.

With a list of the tasks (developed from the task analysis), the following type of questions are recommended to be asked to SMEs to find out what skills and knowledge are required of trainees to adequately perform the job:

- Describe the characteristics of good and poor employees on (*name of task*).
- Think of someone you know who is better than anyone else at (*name of task*). What is the reason they do it so well?
- What does a person need to know in order to (*name of task*)?
- Recall concrete examples of effective or ineffective performance. [Then lead a discussion to explain causes or reasons.]
- If you are going to hire a person to perform (*name of task*), what kind of skills and knowledge would you want that person to have?
- What do you expect a person to learn in training that would make him/her effective at (*name of task*)?

Source: "The Relationship of Training Goals and Training Systems," by Goldstein in Handbook of Human Factors, 1987

Figure 4. RECOMMENDED QUESTIONS TO BE ASKED TO IDENTIFY REQUIRED SKILLS AND KNOWLEDGE

2.2.1.3 Identification of organizational needs

Organizational needs are perhaps the most nebulous to assess because they are usually so global in nature. "Improve productivity," "boost morale," "be a leader in the marketplace" are some examples of organizational priorities or mission statements. Nevertheless, identifying organizational goals and needs through organizational analysis is an important part of a needs assessment because these needs can affect decisions about which personnel get trained, which jobs are subjects of training development and the availability of personnel and resources to get the development job done.[5] In short, accomplishing an organizational analysis provides a perspective for the rest of the training development process.

2.2.2 Generation of solutions

The second phase in the development of training programs is to generate solutions or create a concept of the products or services to be delivered which, in this case, is a cost-effective training program. This phase helps identify not only what the training programs will look like, but also how they will be strategically aligned with decisions made and information gathered earlier during the needs assessment[3,10]. The training program concept should be a direct outgrowth of the data collected in the previous analyses.

According to Crawford, the generation of training programs generally encompasses these three activities:[3]

(1) Development of instructional objectives,

(2) Generation of course structure, and

(3) Generation of training program alternatives.

2.2.2.1 Development of instructional objectives

Before the development of instructional objectives, tasks are further analyzed with the operational sequence analysis and the error and safety analysis. The objective of the operational sequence analysis is to show the operational flow and the relationship of functions and human and equipment actions in time. During this analysis, a sequence of major phases or events of operation are described, the starting and ending conditions of each task are defined, major events or phases that require functions to be invoked are listed, and the human and equipment actions are identified such as the operator control movement and the information feedback of the machine via readouts, displays, etc. When performing the error and safety analysis, the main concern is to identify areas where faults and hazards might be introduced to the system by the human being in order to alert the operators to pay close attention and to take preventive measures.

Through previous analyses, each task listed should already come with a description of initiating and terminating conditions, the actions required, the relevant controls and displays (if exist), the description of the stimulus-response (S/R) conditions involved for each type of control and display, and the conditions under which the S/R descriptions apply (i.e., external constraints, malfunctions, performance parameters)[5]. Based on this information and other factors being asked, as mentioned by Goldstein, such as what are the performance standards, what are the required skills to perform the task, are these tasks associated with unusual job conditions, what stimuli to look for during task performance, etc., SMEs then review and evaluate all tasks and jobs to determine performance objectives and learning objectives. Next, instructional objectives are developed as statements of the intent of the training and serve as a bridge between the need for training and the training itself. These objectives are specified in observable and measurable terms, describing exactly the end-of-training behaviors that the trainees must demonstrate as proof of mastery of the course content. These objectives will ultimately serve as the foundation for specifying functional learning requirements and for determining the form of the instructional delivery system later on[10].

2.2.2.2 Generation of course structure

With the specified instructional objectives and the identification of the skill level requirements serving as the framework to generate the course structure, now tasks must be analyzed to select tasks to be included for training. In other words, the major issues here are the selection of tasks to be trained and the level of training required to accomplish the training program's objectives[5].

The selection of tasks and necessary training level requires a more detailed analysis of specific tasks. Normally, tasks that are not important, not frequently performed, and are easily learned on the job need not be included in the training program. Similarly, tasks that are frequently performed, easy to learn on the job but are not very important should be given less attention than the infrequent but critical tasks that are difficult to learn. Thus, the criteria and judgments used in selecting tasks for training and specifying the level of training need to be analyzed carefully to assure all tasks chosen are useful to the design of a training program. Since decisions are made on the basis of the criticality of each task, task criticality ratings are listed below to help in the decision process. With the help of human factor engineers and SMEs, task criticality ratings are assigned on the basis of eight factors using guidelines adapted from Goldstein:[5]

1. Learning difficulty
2. Performance difficulty
3. Time delay tolerance
4. Accuracy requirements
5. Immediacy of performance
6. Location to learn task (on the job vs. in training)
7. Task importance (level of effect on the failure or success of system missions)
8. Frequency of performance

After each task is assessed on each factor using a scale from low to high, all scores for that particular task are added together to obtain one total criticality score. Next, depending on the nature of each task, it is then evaluated and classified into one of the following categories using a logical sorting procedure:[3,5]

1. Requires certification training
2. Requires qualification training
3. Requires refresher training
4. Can be considered for on-the-job training
5. Requires maintenance of proficiency training
6. Can be considered for reduced training time
7. Can be considered for elimination from training

The rationale behind the classification is that tasks with high criticality scores should require certification or qualification training while tasks with low criticality scores can be considered for reduced training time or elimination from training. For tasks with criticality scores around the average range, classification is obtained with a consensus of judgments from SMEs and human factor engineers.

These activities of rating and classifying tasks should lead training developers to be more sensitive to the implications of including or deleting tasks. In addition, as Goldstein explains, they are necessary because not only do they provide the data necessary for required training decisions, they also serve as a basis for performance measurement and consequently the selection of media and methods of deliveries.[5]

It should be noted that the information collected in the process of selecting tasks for training is also useful for decisions that extend beyond the training program[3]. For example, tasks that are categorized under category 7 and are excluded from the training program should not be simply ignored. Instead, if this information is used, it will help people doing the personnel selection to know that they ***must*** look for individuals with ***prior*** knowledge of how to perform those specific tasks.

At this stage, by taking all available information into consideration, the skeleton of an ideal course structure is derived. However, in reality, constraints usually exist which may require this preliminary ideal course structure to be modified. Constraints, in this sense, are any issues that can have an impact upon the design, delivery, or management of a course. Thus, after taking constraints into consideration and after necessary modifications, the final outcome is the general course structure. The general course structure usually provides specifications of the training program in three major areas: strategies, materials, and tests. In these specifications, all applicable choices proposed in each area that will enable the training program to meet its objectives need to be listed for trade-off analysis[10]. These specifications are necessary because they serve as the foundation from which all training program alternatives will be derived and compared.

Test specifications are determined from an analysis of the instructional objectives. This assures the trainees are evaluated on behaviors related to their learning and performance needs. Considerations as to when to test, how often to test, choices of applicable testing format (i.e., performance, pencil-paper, etc.), level of job-like simulation, choices of equipment/simulators, test time and student achievement criteria are noted in the test specifications.

Materials specifications list applicable choices of media, textbooks, workbooks, training/job aids and required instructor materials. Preliminary outlines for scripts, basic sketches of media, preliminary student-oriented exercises and overall teaching schedules are also specified.

Instructional strategy details how the training will be delivered. All applicable choices (instructor-led, group-paced, individualized...) that will enable the training program to meet its objectives should be listed for trade-off analysis. Additional decisions about the type of questions to pose to trainees and the degree of difficulty or challenge which should be incorporated into the course must also be made here.

2.2.2.3 Generation of training program alternatives

Once a general course structure has been developed, the next step is to specify several training program alternatives that can be used to meet training objectives. Variables that are considered in this regard are the instructional delivery system (method/media), training time, logistical support, types of simulators used, facilities, number of instructors, etc.[3,10]. A point to focus on here is to identify variables with great impact on ***cost*** and ***effectiveness*** to be included in and proposed as alternatives.

As a result of this analysis, each training program alternative generated should give a detailed conceptualization of the program's format that will enable training objectives to be met.

2.2.3 Solution selection among alternatives

The last of the training program development activities involves the selection of the one best training program among alternatives specified above. This final best selection is a result of a culmination of evaluations from associated activities such as the estimation of training effectiveness, the determination of training program costs, and the trade-off analysis of cost and training effectiveness.[2]

Evaluation done while still in the development phase is very critical since it will enable training developers to revise programs before spending a lot of money on final production.

2.2.3.1 Estimation of training program effectiveness

The concern of this analysis is to estimate the degree to which trainees, after experiencing a given tryout of each training program, are able to meet the specified training objectives. The proficiency level of graduated trainees determines the estimated degree of effectiveness of the training program. Traditionally, training program effectiveness of each alternative is estimated empirically by setting up a prototype of each training program alternative and then running the programs in parallel during the conduct of the prototype testing while observing the results[11]. Through this prototype testing, the training materials for each training program alternative are tested to determine if they work as intended. The testing involves review by instructional experts as well as tryouts with small groups of intended trainees. Such testing for effectiveness is concerned with the relevance, accuracy, completeness, ease of use, ease of understanding and instructional effectiveness of training materials and methods. Other measures of training program effectiveness also include indices like time to learn, percent of trainees reaching criterion within allowed time limits, and performance test scores.

This prototype testing for effectiveness from each training program alternative is done to allow training developers to easily pick out alternatives with better potential to be effective for further analysis. Currently, in order to pick out these potential alternatives, all alternatives are tried out during the prototype testing to obtain the training effectiveness estimate of each alternative. This process calls for all alternatives to be subjected to the prototype testing without performing any initial "screening" analysis to identify only potential effective alternatives to be followed through with the prototype testing. Without the added step of performing the screening analysis, the current process is not very cost-effective. Because of the possibility of having to go through unneeded tryout testings of some alternatives that otherwise would be eliminated if a screening analysis were initially done, this indicates that, as a result of using this process, there are unnecessary added costs in terms of extra labor and extra time spent. In addition, these unnecessary added costs may not be the final one-time added costs.

Consider a scenario where there is a need to update the system requirements a number of times during the system development. This will consequently entail, among the review of data and alternatives, the re-doing of the prototype testing of all alternatives to provide the estimated training effectiveness data for the trade-off analysis. This scenario shows that, until the system requirements are fixed, these unnecessary added costs will continue to accumulate each time there are changes in the system requirements.

So, to address these problems and to make the current process more cost-effective (reducing cost while enhancing the process), there is a need to add an extra screening step to the process. With this extra step, instead of subjecting all alternatives to prototype testing, training developers can initially use a screening analysis method to help them identifying the potential effective alternatives among all proposed alternatives. Then, with results from the screening, only those alternatives with an acceptable level of estimated effectiveness are chosen to be further subjected to the prototype testing. Thus, by applying this screening step to the current method, the number of alternatives that have to go through with the prototype testing may be reduced, thereby helping to eliminate the unnecessary added cost, time and labor that traditionally incurred otherwise.

The screening method proposed to be used with the added screening step is the CTEA analysis method. CTEA provides training developers a pencil-and-paper analysis method to estimate the effectiveness of each alternative. Because the effectiveness of all alternatives can be estimated early before the prototype testing, CTEA can serve as a screening tool to help training developers picking out potential effective alternatives for further testing. The CTEA analysis method will be discussed later in more details.

2.2.3.2 Determination of training program costs

While the effectiveness analysis is being conducted, life-cycle cost estimates for each training program alternative are also determined. The life-cycle cost estimates should state what each training program alternative will cost to develop, operate, and maintain over the anticipated service life of the system[13]. The cost analysis done in this phase primarily concerned with identifying general classes of resources required and their anticipated levels. Resources generally include the time taken to develop the training program, the cost of developing, maintaining, and disposing it.

In developing the training program, the majority of the cost is in the development of training materials.[6] So, to help in predicting the cost of developing training materials, in "Predicting the Costs of Training," Hassett suggests that two things be done.[6] First, before the cost range can be estimated, there is a need to predict the complexity of the training program based on three broad factors of content, experience, and design. A guideline to determine training program complexity is provided in Table 1. Then, based on the complexity of the training program, the time and cost of developing training materials can be estimated by using some rules of thumb as presented in Table 2.

However, Hassett only suggests a method for estimating the initial development cost. Depending on the anticipated usage period of the training program, the overall estimated support cost along with the phaseout cost should also be figured in to derive at the total life-cycle cost estimate (initial development cost & maintenance cost & disposing cost). Besides the complexity of the training program, some other factors that can greatly influence costs are: travel and lodging, type and number of proposed equipments, training simulators and facilities to be maintained, the number of instructors to be involved, etc.[6]

Table 1. PREDICTING THE COMPLEXITY OF TRAINING PROJECTS

	Simple Projects	**Complex Projects**
Content	Straightforward, stable, and not controversial	Intellectually challenging or not well specified or understood
Experience	Both developers and subject matter experts have developed training previously	Developers or subject matter experts are not familiar with the course development process
Design	No complicated design features or special requirements	Elaborate or sophisticated requirements

Source: "Predicting the Costs of Training" by Hassett in Training & Development, Nov. 1992

Table 2. RULES OF THUMB FOR ESTIMATING TIME AND COST OF DEVELOPING TRAINING MATERIALS

	Simple projects	**Complex projects**
Instructor-led courses		
Developer hours per training hour	40	100
Total cost, at $____ per developer hour	$_____	$_____
Self-study courses		
Developer hours per training hour	80	200
Total cost, at $____ per developer hour	$_____	$_____
Computer-Based Training		
Developer hours per training hour	100	400
Total cost, at $____ per developer hour	$_____	$_____
Video		
Cost per finished minute	$2,000	$10,000

Source: "Predicting the Costs of Training" by Hassett in Training & Development, Nov. 1992

2.2.3.3 <u>Cost and Training Effectiveness trade-off analysis</u>

With the available estimated data on the cost and training effectiveness for each training program alternative, the final step is to do a trade-off analysis to choose one best, cost-effective training program among many available alternatives.

A cost-effective training program can be defined as a designed sequence of controlled learning events that will ultimately deliver a mission competence result with the least costs.[2] So there is a general trade-off between efficiency in the learning process (the effectiveness of training program) and the instructional cost. This means that usually a high rate of learning would call for high instructional costs. Thus, in the trade-off analysis, the good decision is the one that finds an optimum balance between the inflection of the benefits curve and the inflection of the costs curve.

The selection of a preferred alternative is done in accord with accepted cost-effectiveness analysis guidelines[13] to help minimizing the probability of making a poor choice in terms of a preferred training program alternative. With the objective of identifying the most <u>effective</u> training program alternative from among those that are judged <u>affordable</u>, this analysis basically consists of two steps as described below:

STEP 1: Select a preferred training program alternative based on effectiveness score

To select a preferred training program alternative, there is a need to partition the available alternatives into two sets, designated *acceptable* and *unacceptable*, on the basis of their effectiveness scores. The level of acceptable effectiveness score is set depending on specified goals and objectives of each organization and thus is varied from case to case. Once this acceptable level is set, unacceptable training program alternatives with scores lower than expected are then eliminated from consideration.

STEP 2: Evaluate acceptable training program alternatives based on life-cycle costs

In the second step, all alternatives judged acceptable in terms of their estimated effectiveness are evaluated on the basis of their life cycle costs. Again, two groups of alternatives are designated: acceptable (*affordable*) and unacceptable (*unaffordable*). Affordable means that the total cost of the training program, if realized, will be within the available resources allocated for this specific purpose. Any alternative with cost over the limit is considered unaffordable. At this stage, elimination has been made to systematically choose only alternatives that are both acceptable and affordable. These alternatives are then subjected to additional analysis following standard cost-effectiveness procedure to select the preferred training program. Note that the analysis is now restricted to a range of alternatives judged both acceptable and affordable.

3 USE OF THE CTEA ANALYSIS METHOD AS A SCREENING TOOL

As discussed above, in choosing a cost-effective training program, the analysis and evaluation is done on two main factors: the instructional cost and the effectiveness of the training program. While cost can be estimated rather accurately and efficiently using the method suggested by Hassett, training effectiveness estimates are currently obtained rather inefficiently. As previously discussed, besides the unnecessary added cost and extra time and labor involved, the current process used to obtain the effectiveness estimates of alternatives lacks the initial screening analysis method to serve as a tool to guide training developers toward picking only potential effective alternatives for further subjection to prototype testing.

To address these problems and to enhance the current process of conducting the estimated training effectiveness analysis with an added screening step, an analysis method called Cost and Training Effectiveness Analysis (CTEA) is proposed to be used as a screening tool. CTEA is discussed in detail below along with its background and benefits. Also, in conjunction with assessing the estimated training effectiveness using CTEA, training developers can use the result of this estimation to determine and to adjust accordingly the amount of required training time for each task within a training program and for the entire training program in order to meet specified training objectives.

3.1 BACKGROUND OF CTEA

Prior to 1975, there already existed a Training Effectiveness Analysis (TEA) used by the U.S. Army. TEA is the evaluation of properly conducted training methods research and training development efforts. A TEA system involves assessment of training development products by independent interdisciplinary evaluation teams to determine training effectiveness and costs, and training impacts on organization mission effectiveness.[12]

However, with increasing costs of training and training resources, long hardware system development cycles, and increasing complexity of hardware systems, the Commander of the U.S. Army Training and Doctrine Command (TRADOC) directed service school commandants to undertake more comprehensive analyses of costs and training effectiveness to assess the training impacts and the effectiveness of Army training programs in preparing the soldier for modern battlefield operations. Thus, based on those analyses and the earlier Army's TEA, a formal TRADOC's TEA System was established in

1979 to produce assessments of Army training effectiveness to support combat development processes and to provide data for training decision maker use.[12]

There are five types of studies in the TRADOC 's TEA system, and CTEA is one of those five. CTEA is developed specifically to fulfill two of TEA's objectives: (1) "Assess training-related and trainability issues associated with developmental systems to insure cost and training effective training subsystems are available at fielding", and (2) "Insure proposed and developmental training subsystems and training equipment are cost and training effective if implemented or acquired."[12] It is developed with the intent to offer training developers with an analysis method to estimate the effectiveness of training programs.

Even though CTEA is designed primarily for the Army's use in the estimation of training effectiveness and the evaluation of its training systems, the CTEA concept is general enough that it also applies to the outside industry. The following is a discussion of the proposed use of CTEA as a screening analysis method. It is to be used initially to estimate the training program effectiveness of all alternatives in order to screen and eliminate alternatives judged to be ineffective from undergoing the prototype testing. In addition, extended use of the resulting data obtained from the CTEA analysis method (i.e. the determination of adequate training time) can serve to aid the training developers to make necessary adjustments so that the resulting training program will be both effective and less costly.

3.2 DESCRIPTION OF CTEA

CTEA basically consists of: (1) an analysis process to estimate the effectiveness of a training program, and (2) a process to determine adequate training time for each training program and each task within it.[12]

3.2.1 Estimate the effectiveness of training programs

To estimate the effectiveness of each training program alternative, the analysis is based on a technology called MultiAttribute Utility Measurement (MAUM).[8] The objective of MAUM is to establish a functional relationship among the various factors characterizing a training program and the eventual effectiveness of that program. This functional relationship defines an explicit value structure that can serve as a basis for decisions concerning training program alternatives.

The MAUM based approach consists of three steps as described below:

STEP 1: Determine each task training worth estimate

The first step involves determining the worth of training each task selected for inclusion in the training program. These task training worth estimates are used, along with estimates of training effectiveness, to form a figure of merit for each training program alternative.

To begin the process of determining worth for training, a subset of the eight task criticality factors noted earlier (in section 2.2.1.4) are selected to define the bases of training worth. Then, each of the criticality factors, j, is assigned a number (j = 1 to n) and a relative importance weight, called R_j. The R_j are scaled to fall in the interval zero to one and to sum to unity as summarized below.

$$\sum_{j=1}^{n} R_j = 1 \quad , \quad 0 < R_j < 1$$

Next, each of the SME's responses to each criticality factor is assigned a utility rating in the interval zero to one. The resulting utility values for each task, i, are called U_{ij}. Finally, task utility values are multiplied by their respective importance weights to obtain task training worth indices, called W_i.

$$W_i = \sum_{j=1}^{n} U_{ij} R_j \qquad (1)$$

where: j = criticality factor # from 1 to n
i = task # among tasks selected for training

W_i = training worth of i^{th} task

U_{ij} = utility value for i^{th} task associated with criticality factor j

R_j = relative importance weight of criticality factor j

As an example, the following subset of criticality factors is chosen to define training worth for each task of each training program alternative:

Criticality factor # j		Relative importance weight R_j	Utility value for task 1 (i=1) U_{1j}
1	Consequences of inadequate performance	0.3	0.6
2	Task importance	0.4	0.75
3	Frequency of performance	0.2	0.5
4	Learning difficulty	0.1	0.3

		1.0	

According to equation (1), the resulting training worth value, W_1, for task 1 is:

$$W_1 = \sum_{j=1}^{4} U_{1j} R_j$$

$$= (0.6)(0.3)+(0.75)(0.4)+(0.5)(0.2)+(0.3)(0.1)$$

$$= 0.61$$

STEP 2: Determine effectiveness estimate of each training program alternative in training each task

In the second step, effectiveness estimates are obtained by requiring a group of training specialists or SMEs to reach a consensus regarding the percentage of trainees that can be expected to reach criterion on each task with each training program alternative[11]. In the process of determining the training effectiveness estimates and to reach such consensus, SMEs need to review and consider all aspects of each training program alternative such as proposed media and methods, training time allocation, provisions for practice, student characteristics, and the like. The resulting training effectiveness estimates are called E_{ki}, where the subscripts k and i represent the specific training program alternative and the task to be trained, respectively.

STEP 3: Determine an estimate of the aggregate effectiveness of each training program alternative

To determine the aggregate effectiveness estimates for each training program alternative, the product of each task-level training effectiveness estimates, E_{ki}, and the indices of training worth estimates of each task, W_i, are summed up as expressed in equation (2) below:

$$TPE_k = \sum_{i=1}^{n} W_i \, E_{ki} \qquad (2)$$

where:

- k = Training program alternative #
- i = task # from 1 to n number of tasks selected for training
- W_i = training worth rating of the i^{th} task
- E_{ki} = estimated effectiveness of the k^{th} training program alternative in training the i^{th} task
- TPE_k = estimated effectiveness of the k^{th} training program alternative

Since the W_i are scaled to fall in the interval from 0 to 1, and since the E_{ki} fall in the interval from 0 to 100, TPE_k will occur in the interval from 0 to 100.

3.2.2 Determine adequate training time for each training program alternative

To determine whether more or less training time is required for each training program alternative to meet training standards on all tasks, training developers need to examine the results obtained from step 2 of the training effectiveness estimation process and perform further analysis:[12]

STEP 1: Determine training time increments and decrements on each task with each training program alternative

Following the estimation of the effectiveness of each training program alternative in training each task, the SMEs are asked to consider again those tasks for which the E_{ki} are either under standard or over standard. Typically, standard means that 90 percent of trainees meet the standard stated in the performance objective.[8] In the case of tasks where the E_{ki} are under standard, SMEs are asked to estimate the amount of training time required to raise trainees to standard. Similarly, for tasks in which the E_{ki} are over standard, SMEs are asked to estimate how much time could be cut from the planned training program and still meet the standard. These time increments and decrements are denoted t^+ and t^-, respectively.

STEP 2: Determine total training time for each training program alternative

Now with the available t^+ and t^- estimates provided earlier by SMEs for each task within each training program alternative, the total "slack" time in the training program can be determined by obtaining the sum as follows:

$$TS_{ki} = \sum_{i=1}^{n} t_{ki} D_{ki}$$

where: t_{ki} = the t^+ or the t^- value for the i^{th} task on the k^{th} training program alternative

and,

$$D_{ki} = \begin{cases} 1 & \text{if more training time is required} \\ -1 & \text{if less training time is required} \end{cases}$$

If TS_{ki} is greater than zero, $TS_{ki} > 0$, then more training time is required for the k^{th} training program alternative to meet standard on all tasks. When $TS_{ki} < 0$ then less training time is required to meet the objectives of the training program. With help from SMEs and the assessed t^+ or t^- for each task, training developers can decide later how to allocate additional or less training times across tasks.

4 BENEFITS OF USING CTEA

There are many benefits associated with the use of CTEA as a screening analysis method to aid in the training program selection process.

The first area where CTEA can help is in estimating the effectiveness of the training programs to screen alternatives for the prototype testing. By using the MAUM-based approach to estimate, training developers are systematically guided toward obtaining a rather valid effectiveness estimates. This ability to assess the best estimate of training program effectiveness at the early stage of the development phase is of great help because it enables the training developers to identify the potential effective training programs to be further tested during the prototype testing. Through this screening analysis, only alternatives judged to be effective are further tested. In effect, by assessing the effectiveness estimate twice, during the screening analysis and the prototype testing, these two estimates can be used to cross-check to help training developers making more confident decision and thereby, minimizing the risk of mistakenly selecting an ineffective training program and reducing the impact of time and cost involved in fixing the deficiencies, if needed, to meet the training objectives. Note that fixing the deficiencies while still in the development phase is less costly compared to doing the same once the program has been realized and implemented.

The effects on cost factor when an ineffective training program is implemented mistakenly are examined next. Instead of having an effective training program with minimum and minor deficiencies, now we have a less than effective program that does not meet the training objectives and contains many deficiencies in which some are major. Now it is too late to do anything but implement a series of training fixes designed to correct the most obvious deficiencies. Furthermore, decisions concerning training facilities and training devices already have been realized in the form of training areas, buildings, and training equipment. Thus, at this point, allocated training resources have been expanded and little can be done to redress mistakes or deficiencies in these areas, except to spend more money and time to correct the problems. These problems and the involved costs clearly represent a very undesirable situation. Thus, through this illustration, one can see the importance of obtaining the best valid estimate at the early stage to initially base the selection of training program on, and indeed, this is an area where using CTEA can be beneficial.

In addition, as a result of using this screening step in the current process, the total cost of doing the prototype testing will be reduced in terms of time and labor involved since there is a reduced number of alternatives that eventually would have to undergo the prototype testing (after the screening, only potential effective alternatives among all proposed will be further tried out).

Another area where CTEA can be of great help is in the determination of adequate training time. Since the unneeded time costs extra money and the under-estimated time impacts the effectiveness of the program, the determination of just the right amount of training time is very important. Through the iterative process of adding or subtracting the "slack" training time evaluated individually on each task within the program, the result is a training program that is both cost saving and effective in that there are just enough training time incorporated to satisfactorily meet the training objectives. In this context, CTEA can be used to tightly control the training time (thus, maximize the cost saving) of the training program and at the same time insure that the effectiveness of the training program is still achieved.

5 SUMMARY AND CONCLUSION

As presented in the paper, the development of a training program mainly consists of activities that include (1) identifying training needs and organizational needs, (2) identifying and describing all job tasks necessary for operation and maintenance, (3) establishing required level of knowledge and skills, learning objectives, performance measures, and instructional objectives, (4) identifying those tasks for which training is necessary, (5) generating a general course structure to serve as a basis for developing training program alternatives to choose from, and lastly, (6) evaluating these alternatives to select a preferred training program that is both effective and affordable.

During the needs assessment process, notice the extensive use of detailed job and task analysis procedures prior to entering the evaluation phase of the analysis. The organizational needs and the learner needs are also assessed thoroughly to determine precise training needs that serve as inputs to the design and development of training program.

During the process of generating solutions, care must be taken in preparing an overall training strategy and a general course structure for accomplishing all of the required training tasks because this is the foundation where several alternatives of training program will be based upon.

Entering the evaluation phase in which a training program is selected among all viable alternatives, the emphasis is now placed on the approach and the criteria used in the trade-off analysis. Alternatives are evaluated based on the cost-effectiveness guidelines which involve the trade-off of cost and training effectiveness within each program and the comparison of these factors among alternatives.

In obtaining the effectiveness estimates of training program alternatives, the proposed use of CTEA as a screening tool to be added to the existing process can serve to provide training developers with many benefits. Because CTEA can be initially used to estimate the training program effectiveness of all alternatives, this screening analysis method provides training developers the early-on visibility into the effectiveness of each alternative, thereby minimizing the risk of mistakenly picking the "wrong" training program alternative to be developed and implemented. Thus, this added screening step will enable training decision makers to select a preferred alternative with more confidence. Also, the use of the screening tool enables training developers to reduce the number of alternatives to be subjected to the prototype testing, thus eliminating the unnecessary added costs that normally incurred if no initial screening were done. In addition, CTEA can be used to assess the required training time for either an individual task or the entire training program so that adjustments can be made accordingly to make the resulting program both effective and less costly.

In summary, because CTEA can possibly help training developers to (1) estimate the effectiveness of training programs to initially identify potentially effective alternatives for further testing, (2) minimize the risk of selecting the "wrong" alternative by providing needed data to be cross-checked to substantiate the selection of a preferred alternative, and (3) reduce the cost, labor, and time involved in doing the prototype testing, it is recommended to be used as a screening analysis tool to supplement and enhance the existing process of obtaining the training program effectiveness.

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7 GLOSSARY OF TERMS

CTEA	- Cost and Training Effectiveness Analysis
EMD	- Engineering and Manufacturing Development
MAUM	- MultiAttribute Utility Measurement
SME	- Subject Matter Expert
S/R	- Stimulus-Response
TEA	- Training Effectiveness Analysis
USA TRADOC	- U.S. Army Training and Doctrine Command