A system-of systems approach to the development of flexible, cost-effective training environments

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Abstract - *In today's aircrew training context, although there is an abundance of training systems that can enhance training and reduce costs, the challenge for the military training organizations to select the most cost-effective training systems to address their immediate and future needs is unresolved. The urgency of this dilemma is exacerbated by shrinking defense budgets. This paper shows how the systems engineering perspective can help the decision-making process for selecting the training media equipment to construct a cost-effective training media environment. A multidisciplinary approach and systems engineering techniques were used to develop a theoretical model of the Mission Training Environment arrangement . Implications of the approach, such as that the training environment can be viewed as a system of systems and that the choice is based on combination of equipment, will be discussed.*

Keywords: Training System, Training Environment, training media, LVC, decision-making, systems of systems.

1 Introduction

In the aircrew training domain, research has intensified in an effort to provide solutions that will ensure an increase in pilot performance (the new operational equipment and environment is more challenging) while there is also a reduction in costs (make the best of existing systems) without compromising safety (for aircrew and civilians).

Lower safety risks, reduced costs and increased operational readiness are benefits offered by the virtual environments. However, virtual environments come in many forms (from virtual simulation to live simulation) and, furthermore, the importance of training in a live environment cannot be underestimated. Therefore, an obvious direction in research is to explore the Mixed Media Training Environments benefits for aircrew training.

Such Mixed Media environments are rarely used (and even more rarely designed); they are constructed on an ad hoc basis as a bottom-up development for a specific exercise, at a specific location and then torn down when the exercise has finished [1]. This makes them difficult to research.

1.1 Cost and opportunity

Asymmetric warfare and shrinking budgets are demands that influence how the military prepares for its activities. Furthermore, these shape the defense industry in terms of development of products and services that aid the process of preparedness of the military, which has resulted in an abundance of “off the shelf” products ready to be used in training programs. Recent developments in the simulation domain have also resulted in high quality products that offer new possibilities to achieve cost-effective training [2], [3].

However, the lack of measurement techniques to assess the benefit of using particular systems in particular ways pose difficulties when it comes to deciding which is the optimum mix of products and services to be used to deliver a cost-effective training exercise.

1.2 Media and aircrew training

The matter of choosing the right mix of training media equipment to deliver cost-effective aircrew training is a question that, in one form or another, has been researched for some time within various domains and, despite the progress made, there are still some issues that need to be resolved [2].

Besides the lack of measurement techniques highlighted earlier, another issue is that although there is a common understanding of the meaning of Live, Virtual and Constructive (LVC) concepts, such that Live means real people operate real equipment; Virtual means real people operate simulating systems; and Constructive means simulated people are operating simulated systems [4], there is no commonly accepted classification and concomitant definitions of media encompassed within the training systems [2]. As a result, terms such as “blurred boundaries” and “blended technology” [1], [2] are more often used.

There is also the problem of capturing and integrating different types of data, such as qualitative data and tacit knowledge, into a rigorous, objective analysis that can aid the process of selecting the training media (equipment) to create an optimum training environment to deliver a cost-effective training exercise.

1.3 The question

With all this in mind, there is an unresolved question of how to create an optimum training media environment to deliver a cost-effective training exercise. This is the question to be answered within this research.

2 Approach

In trying to address as many issues as possible, in an integrative way for the benefit of the overall solution, a multidisciplinary approach was taken to define the problem space and to search for solutions. Therefore, various views from disciplines, such as, Human Factors, Operational Research and Systems Engineering have been taken into account.

2.1 Systems Engineering perspective

A Systems Engineering approach [5] is usually recommended when the problem has a high degree of complexity and there are systems integration challenges. The approach allows the engineer to deal with the complexity by decomposition of concepts and analysis of smaller problems, whilst maintaining focus on the potential interactions between such problems. Furthermore, it helps to define the environment and the boundaries of a problem [6].

The standards and guidelines for System Engineering are usually directed more towards development of new systems, rather that optimization of extant systems, although in practice they are applied to both new and extant systems. For development of extant systems, other approaches that are more specific to Operational Research domain are recommended.

Nevertheless, the inherent holistic thinking and multidisciplinary characteristics of the systems engineering approach makes it ideal to be followed in the present case, as it allows and encourages consideration and integration of multiple perspectives.

2.2 Operational Research

Finding the balance between LVC looks like a straightforward problem to be solved through application of an optimization technique, as such numerical techniques are often used to balance costs against effectiveness [7], [8]. But to be able to apply an optimization technique, certain steps have to be followed and certain criteria have to be satisfied, such as that the problem, the desired solution, the variables, and the dependencies between variables require strict definition [8].

The mathematical optimization models are designed to optimize a specific objective criterion which is subject to a set of constraints and the solution of the model is feasible only if satisfies all the constraints [7]. Therefore, the quality of the solution depends on the completeness of the model through which real-world parameters are reduced or lumped together into assumed real-world parameters. If the abstracted model is incomplete, the solution may not be optimal for the real world system and this raises concerns regarding the adequacy of the mathematical model. This may raise some conflict between the traditional parsimonious modeling approach of finding the simplest model which represents the situation and the SE approach, which focuses on a holistic and integrative view.

Researchers have drawn attention to the fact that human behaviour must also be taken into account when constructing these models to ensure that the solution is adequate and there is no possibility to even fail [8] and that means that human factors data need also to be incorporated and express in these models.

Furthermore, when the context of a system varies greatly, optimization can provide only a short-term advantage and may not be the best solution to make the system more efficient. Fisher [9] also points out that, although optimization is a good technique to increase the efficiency of traditional systems, optimization may undermine adaptability and can become inefficient as the circumstances on which the systems are operating are changing (e.g. increased variability of context = changing training requirements). Users may also be reluctant to repeat the optimization when circumstances change, leading them to rely on inaccurate information.

The application of optimization techniques to solve the problem of finding the balance between LVC for construction of the training media environment for a given training exercise should not be disregarded, but more work is required to fully accommodate all the necessary criteria within the optimization technique for it to be adequate.

2.3 Human Factors and Training Needs Analysis

The purpose of a training exercise, whether it takes place in a live, virtual or mixed media environment is to teach the trainee new knowledge and skills (or develop exiting knowledge or skills). The environment and the method chosen to train have not only to ensure the acquisition and development of skills and knowledge but also to ensure that these skills and knowledge are transferable to real, live situations.

Therefore, two additional variables must be taken into account to decide on the most appropriate arrangement for a training environment. These are degree of transferability of skill and knowledge learned in the training environment, and individual cognitive particularities of trainee.

Distinctions can be drawn between different types of training exercises based on learning stages. Meador [10] makes a distinction between acquisition and retention (or reacquisition), and Frank et. al [1] distinguish between Familiarization, Acquisition, Practice and Validation in their FAPV model. These distinctions have a significant impact on establishing the context of a training exercise and defining the training requirements.

Training requirements are usually derived from the analysis of training needs. Figure 1 shows the TNA (Training Needs Analysis) process. The diagram is an adaptation of the UK MoD TNA Process Diagram depicted in JSP822 report [11], [12].

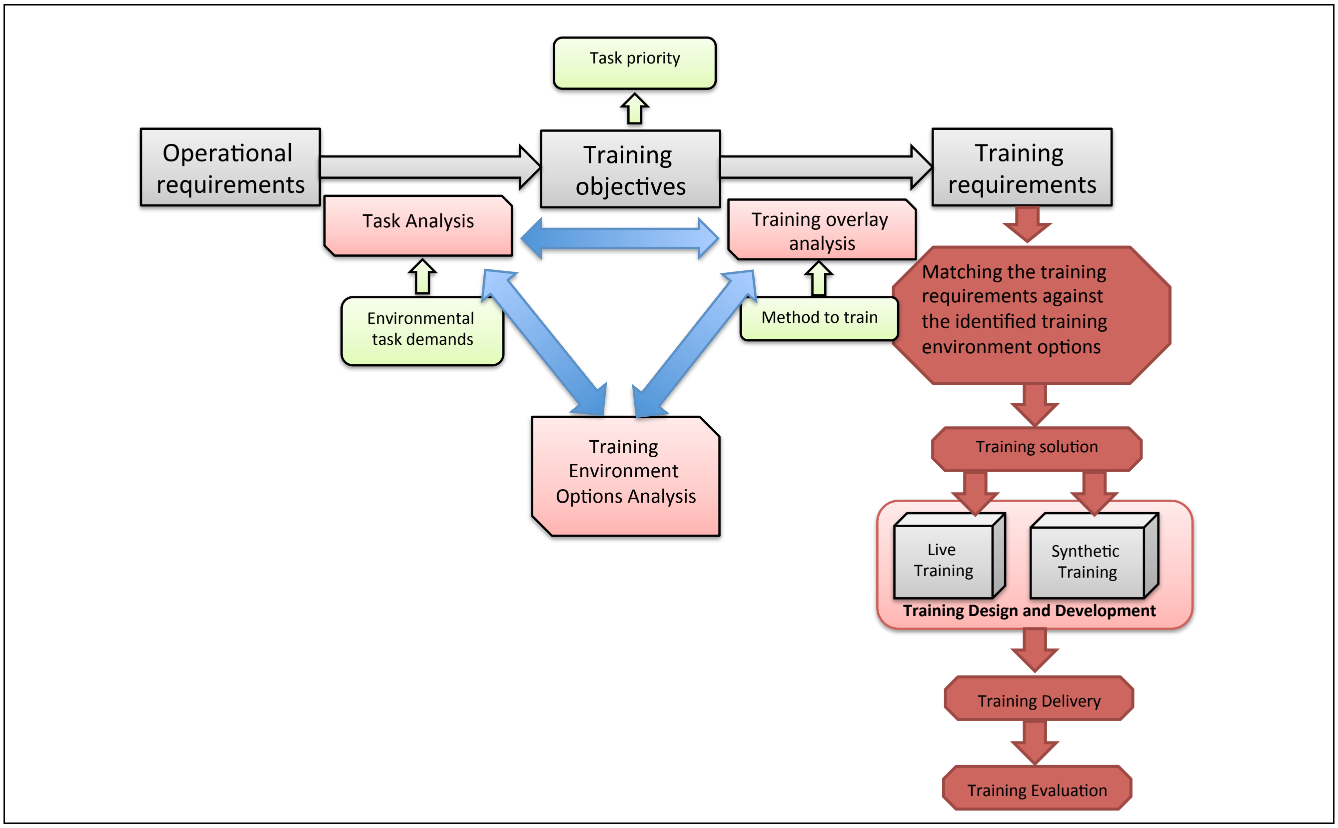

Figure 1. TNA Process Diagram

As can be observed from Figure 1, human factors particularities are captured at the training needs analysis stage that precedes the design and development phase of a training exercise. Furthermore, the training media environment system is decided based on the training requirements resulting from previous analyses.

However, this process is very restrictive. It is a major deficiency that such a process only allows the selection of one training environment system per exercise; it does not allow the possibility of choosing a combination of training systems to create a training environment. A combination may prove to be more cost-effective because it will maximize the usefulness of the available resources. Furthermore, the process of Figure 1 does not take into consideration factors such as schedule, maintenance, cost and other variables that impact the cost-effectiveness of a given training environment.

3 Method

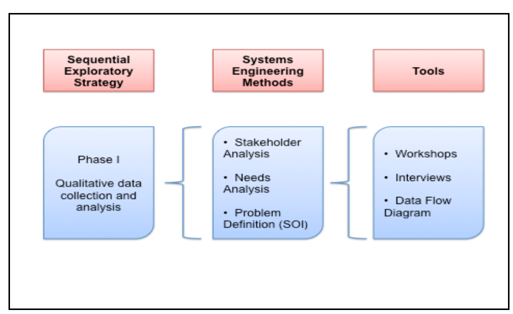

Figure 2. Applied methodology, methods and tools

Because of the high importance of defining and representing the problem through as accurate a model as possible, and because of the issues with this, such as the need to integrate quantitative and qualitative information into the model, a *mixed methods methodology (sequential exploratory strategy)* [13] was used in parallel with *systems engineering methods* to develop a Theoretical Model of Media Environment arrangement for the Mission Training Scenario. The methodology, and the process of methods and tools that was followed are presented in Figure 2.

4 Results

A Theoretical Model of Training Environment arrangement that is presented in Figure 3, has been developed based on the analysis of the information captured from Subject Matter Experts (SME's). The theoretical model is represented by a data flow diagram.

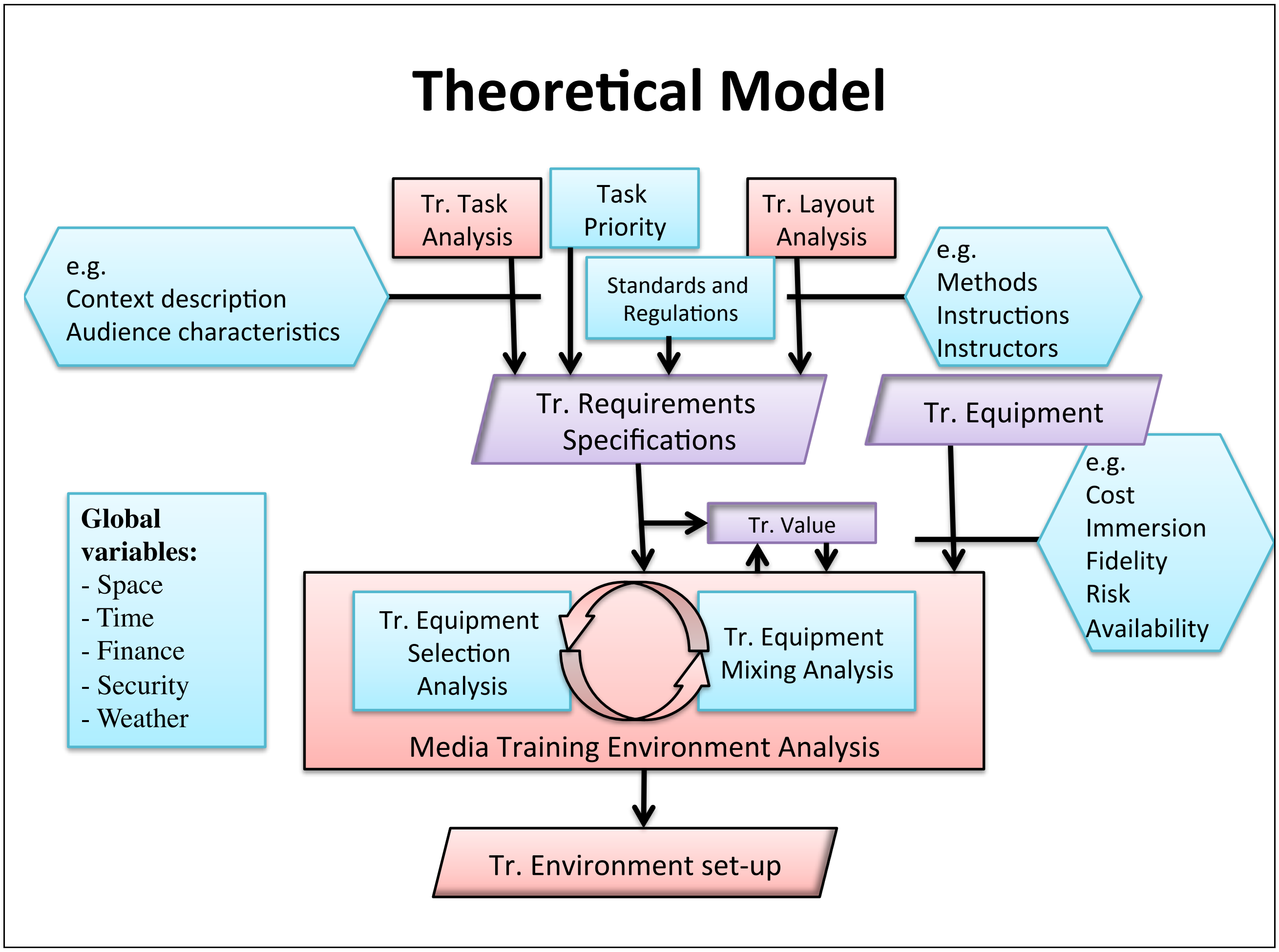

Figure 3. Theoretical Model of Training Environment arrangement

The model presents the System of Interest (SoI), which is the "Training Media Environment Analysis", and the Wider System of Interest (WSoI), which is represented by the factors that influence the behaviour of the SoI.

The model shows the input data necessary for the system, the needed transformation functions and the required output. Furthermore, some specific and global variables upon which the decision making of selection relies are highlighted.

5 Discussions

The idea put forward by the model is that, if the properties exhibited by the relationship between training equipment and LVC technology, Media, Training Equipment and Training Environment are investigated, the following may be concluded:

Media ⊃ Training Equipment

And,

Training Equipment = Training Environment

And as,

Training Equipment = Training System

Then,

Training Environment = Training System

However, this relationship is true only in the case when (after the decision that was made on the selection of the training equipment) the result is to use only one training equipment to deliver the training exercise (for example, a ground base simulator).

If the decision is to use more than one training equipment to deliver a training exercise, then the following can be concluded:

Media ⊃ Training Equipment ⊃ Training Environment

Then if,

Training Equipment = Training System

Training Environment = Training System

Means that,

Training Environment Sub-system = Training Equipment Systems

Furthermore, if we look at the developments made in the synthetic training domain it can be observed that there is an abundance of off the shelf products that are cheaper than bespoke ones and highly efficient in delivering cost-effective training. But these training systems have not necessarily been designed to be used alongside other training systems.

Because of this interoperability particularity, we propose that the Training Media Environment should be considered to be a Training System of Systems rather than a Training System. Therefore, it can be considered that the setting up of a training media environment is not only a matter of identifying and selecting a cost-effective training system but rather a matter of constructing and managing a System of Systems Training Environment that comprises a mix of LVC technologies.

Furthermore, as the emergent behavior of a system depends on the interactive behavior of its components, the decision of selecting the components of a system is, or should be, directly influenced by the effect resulting from the combination of different components. This means that, the decision making process of selection of the training media equipment to construct a training media environment should be tightly coupled with the training systems mixing analysis.

The developed Theoretical Model of Training Environment Set-up that is proposed in this paper is the first step in a research project the aim of which is to develop a tool to help decision makers in selecting the most appropriate blend of training media to construct a cost-effective training environment for aircrew training. By bringing together, data resulted from training needs analyses and training equipment analyses, coupled with the overall context variables, a more comprehensive tool to aid the decision making process can be built.

This theoretical framework will help the development of a tool that will integrate quantitative as well as qualitative data in its analyses. This will also be beneficial in capturing tacit knowledge that is usually lost when the experts that are making the decisions retire. Furthermore, this model will contribute towards making cost-effective decisions, because it promotes the idea of making the most out of the available resources.

6 Limitations

Although, the proposed theoretical model has been validated at the conceptual level, with the help of military aviation domain SME's, the verification process has not been carried out at this stage. The scope of model applicability is limited to the particular training application associated with mission training scenarios. Although, it is possible that it could be extended to other training applications and domains, there has been no attempt, so far, to validate it more widely.

Further development of the theoretical model may yield additional main variables that have not so far been captured; this will be tested during the next development phase.

7 Conclusions

In answering the question of how to create an optimum training media environment to deliver a cost effective exercise, this research proposes a novel, multidisciplinary approach to be taken forward.

The theoretical model that was developed at this stage represents a first step into integrating multiple types of data into an analysis that will help decision makers, in their process of building an optimum media training environment, to deliver a cost-effective training. The model comprises variables linked with human characteristics as well as with equipment characteristics. Furthermore, it incorporates some global variables that have usually been missed so far. The scope of the model is to address the more complex training needs of the future, and takes a wider perspective of the solution; hence may also generate more cost-effective solutions of greater flexibility.

Furthermore, significantly and explicitly the model includes consideration of human issues and because of this characteristic it could be applied to complex civilian roles as well (e.g. emergency response).

The approach that is put forward in this paper has its limitations, however, it offers an alternative, integrative way to explore the phenomenon of constructing Mixed Media Environments for the benefit of the next generation of aircrew training.

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