DOCUMENT RESUME

ED 310 731 IR 013 920

AUTHOR	Fletcher, John D.; Orlansky, Jesse
TITLE	Recent Studies on the Cost-Effectiveness of Military Training in TTCP Countries.
INSTITUTION	Institute for Defense Analysis, Arlington, Va.
REPORT NO	IDA-P-1896
PUB DATE	Jan 89
CONTRACT	MDA-903-84-C-0031
NOTE	45p.; For related papers, see IR 013 918-919.
PUB TYPE	Information Analyses (070) -- Reports - Evaluative/Feasibility (142)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Computer Simulation; *Cost Effectiveness; Evaluation Methods; *Flight Training; Foreign Countries; Intermode Differences; Military Training; Postsecondary Education; *Resource Allocation; Slides; *Technical Education; *Transfer of Training
IDENTIFIERS	Australia; Canada; New Zealand; Technical Cooperation Program; United Kingdom; United States

ABSTRACT

This report summarizes 22 recent empirical studies on the cost-effectiveness of military training reported by countries that participate in The Technical Cooperation Program (TTCP), i.e., Australia, Canada, New Zealand, the United Kingdom, and the United States. A discussion of the methodology used to summarize the studies is followed by a description of the results and conclusions about the effectiveness, costs, and cost-effectiveness of the types of training that were investigated. The studies show an almost exclusive interest in simulation that extends from full-task, highly realistic simulators to part-task, lower cost simulators. The data show that simulator-based training is effective in developing performance proficiency; some transfer from simulator-based training to performance on actual equipment occurred in every case. Speed of performance was initially slower on maintenance tasks for simulator-trained students than for those trained with actual equipment. As expected, simulator training was found to cost less than training with actual equipment. The types of cost and effectiveness data collected in these studies do not permit an examination of trade-offs between cost and effectiveness. Future studies of training should examine functional relationships between effectiveness and cost and include sensitivity analyses of key variables that determine the cost-effectiveness of alternative training approaches. (27 references and 5 tables) (Author/GL)

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IDA PAPER P-1896

RECENT STUDIES ON THE COST-EFFECTIVENESS OF MILITARY TRAINING IN TTCP COUNTRIES

John D. Fletcher
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January 1989

Prepared for

Office of the Under Secretary of Defense for Acquisition
(Research and Advanced Technology)

INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311-1772

IDA Log No. HQ 88-[illegible]

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT Distribution limited to DoD and DoD contractors only; Foreign Information, 2/27/89. Other requests must be referred to ODDDR&E(R&AT), Room 3D129, The Pentagon, Washington, DC 20301.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) IDA Paper P-1896	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Institute for Defense Analyses 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION DoD-IDA Management Office, OUSD(A)
6c. ADDRESS (City, State, and Zip Code) 1801 N. Beauregard Street Alexandria, VA 22311	7b. ADDRESS (CITY, STATE, AND ZIP CODE) 1801 N. Beauregard Street Alexandria, VA 22311
8a. NAME OF FUNDING/SPONSORING ORGANIZATION ODDDR&E/R&AT 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER MDA 903 84 C 0031
8c. ADDRESS (City, State, and Zip Code) Room 3D129 The Pentagon Washington, DC 20301	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT: — ; PROJECT NO.: — ; TASK NO.: T-D2-310 ; WORK UNIT ACCESSION NO.: —

11. TITLE (Include Security Classification)
Recent Studies on the Cost-Effectiveness of Military Training in TTCP Countries

12. PERSONAL AUTHOR(S)
John D. Fletcher and Jesse Orlansky

13. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM 10/87 TO 12/87	January 1989	35

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17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	The Technical Cooperation Program, empirical studies, military training, cost effectiveness, simulators, simulator training, training, simulation, computer-based instruction, transfer effectiveness

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This paper summarizes twenty-two recent, empirical studies on the cost-effectiveness of military training reported by countries that participate in The Technical Cooperation Program. The studies show an almost exclusive interest in simulation that extends from full-task, highly realistic simulators to part-task, lower cost simulators. The data show that simulator-based training is effective in developing performance proficiency; some transfer from simulator-based training to performance on actual equipment occurred in every case. Speed of performance was initially slower on maintenance tasks for simulator-trained students than for those trained with actual equipment. As expected, simulator training was found to cost less than actual equipment training. Simulator training was found to be more cost-effective than training with actual equipment. The types of cost and effectiveness data collected in these studies do not permit examination of trade-offs between cost and effectiveness.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL John D. Fletcher	22b. TELEPHONE (Include Area Code) (703) 578-2837 22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR   83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

IDA PAPER P-1896

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INSTITUTE FOR DEFENSE ANALYSES

Contract MDA 903 84 C 0031
Task T-D2-310

SUMMARY

This paper summarizes twenty-two recent, empirical studies on the cost-effectiveness of military training reported by countries that participate in The Technical Cooperation Program. The studies show an almost exclusive interest in simulation that extends from full-task, highly realistic simulators to part-task, lower cost simulators. The data show that simulator-based training is effective in developing performance proficiency; some transfer from simulator-based training to performance on actual equipment occurred in every case. Speed of performance was initially slower on maintenance tasks for simulator-trained students than for those trained with actual equipment. As expected, simulator training was found to cost less than actual equipment training. Simulator training was found to be more cost-effective than training with actual equipment. The types of cost and effectiveness data collected in these studies do not permit us to examine trade-offs between cost and effectiveness. Future studies of training should examine functional relationships between effectiveness and cost and include sensitivity analyses of key variables that determine the cost-effectiveness of alternative training approaches.

ACKNOWLEDGMENTS

We acknowledge the contributions of data and information provided by members of the TTCP countries without which this paper could not have been prepared. The reviews and comments offered by our colleagues and friends in the TTCP countries on an early draft were especially valuable. Any failure to follow their advice reflects only on us.

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CONTENTS

TABLES

ABBREVIATIONS

TTCP	The Technical Cooperation Program
UTP-2	Technical Panel on Training Technology
TER	Transfer Effectiveness Ratio
TCR	Training Cost Ratio
CER	Cost-Effectiveness Ratio

I. INTRODUCTION

This paper summarizes recent studies on the cost-effectiveness of training performed in member countries of The Technical Cooperation Program (TTCP): Australia, Canada, New Zealand, United Kingdom, and United States. It is intended to update an earlier TTCP report on the same topic (Chatelier, Harvey, and Orlansky, 1982). The present studies, limited primarily to analytic and/or empirical comparisons of new with existing methods of training, were provided by members of the Technical Panel on Training Technology (UTP-2), TTCP. This paper discusses issues, data, and conclusions presented in the studies. It is not a complete review of all cost-effectiveness studies that might be found by a more comprehensive search in the five TTCP countries.

This paper includes the following:

(1) Discussion of the methodology used in this paper to summarize the empirical studies;

(2) Results summarized from the studies;

(3) Discussion of the studies;

(4) Conclusions regarding the effectiveness, costs, and cost-effectiveness of the types of training that were investigated;

(5) Recommendations based on these studies.

II. METHODOLOGY

This paper considers 27 reports that are listed in the References. Twenty-two empirical studies of training were found in 13 of these reports (summarized in Table 1). Seven acceptance tests and analyses of training are described in six reports (summarized in Table 2). Five surveys and analyses of training are described in five reports (summarized in Table 3). Finally, survey methodology for evaluating training is discussed by three reports (summarized in Table 4). The reference list and Tables 1 through 5 are presented following the main text.

Alternative approaches to training were compared and evaluated in each of the 22 empirical studies shown in Table 1. All of the studies examined some type of simulation for use in military training. The measures of effectiveness and of costs used in these studies are also presented in Table 1. Quantifiable findings, whenever they were available or derivable, are also shown in this table.

Three ratios, described below, are used wherever possible to report the findings of these studies:

Transfer Effectiveness Ratio (TER)

Training Cost Ratio (TCR)

Cost-Effectiveness Ratio (CER).

In some cases, the ratios were provided by the studies. In other cases, we used data provided by the studies to calculate the ratios. In several cases, we did not have enough data to calculate any of these ratios.

The Transfer Effectiveness Ratio (TER) is the ratio of training time saved by use of simulation to the amount of time spent in simulation:

$$TER = \frac{A - As}{S}$$

where,

A = time required to reach criterion performance using actual equipment without prior use of a simulator,

A_S = time required to reach criterion performance using actual equipment with prior use of a simulator,

S = time spent training in the simulator.

In some studies (shown in Table 1), numbers of training trials are used as indicators rather than hours of training time.

The TER permits us to estimate the value added to a training program by the use of simulation. It is not suitable for all training programs. For instance, some training programs will not use actual equipment for reasons of economy or safety. Positive TERs indicate positive transfer of training, i.e., a savings in actual equipment time attributable to time spent in simulator training. Therefore, the larger the positive value of a TER, the greater the value added by simulation to training. However, how "good" a given TER value is depends on how much less expensive the simulator training is than the actual equipment training. The ratio of these costs is given by the Training Cost Ratio.

The Training Cost Ratio (TCR) provides a standardized measure of the amount of money saved by one (usually new, simulator based) versus another (usually existing, actual equipment based) training program or approach. It is defined as:

$$TCR = \frac{Cs}{C}$$

where,

Cs = cost of the new training approach,

C = cost of the existing training approach.

'Cost' must be defined. Often, it is the variable hourly operating cost of the simulator and of the actual equipment. In Table 1, the cost bases of each TCR are noted in the 'Measures of Cost' column. All TCRs reported in the table are based on hourly operating costs of simulators and actual equipment. In these cases, smaller TCRs favor simulator training. If the TCR is less than 1.0, it costs less to use simulators than actual equipment.

Variable operating costs refer to what it costs to use training equipment. Any costs saved by using a new simulator can be used to estimate how long it would take to recover spent funds, i.e., the amortization period. After this period, continued use offers absolute savings. These savings should be considered in light of all the costs associated with a method of training, i.e., research and development, initial investment, and operating and support costs.

Given standardized ratios of effectiveness and costs, we can turn to a standardized ratio of costs to effectiveness. The Cost-Effectiveness Ratio (CER) is defined as follows:

$$CER = \frac{TCR}{TER}$$

where,

TCR = the Training Cost Ratio,

TER = the Training Effectiveness Ratio.

Defined in this way, the closer the CER is to zero, the more cost-effective the simulator-based training. Under this definition there are no positive or negative theoretical limits to CERs, and it is impossible to tell from a single CER if some threshold for cost-effectiveness has been crossed

In summary, a cost-effective training approach should have a large Transfer Effectiveness Ratio, a small Training Cost Ratio, and a small Cost-Effectiveness Ratio. In keeping with common notions of quality, it is occasionally suggested that the Cost-Effectiveness Ratio be reversed and made an Effectiveness-Cost Ratio so that larger ratios indicate greater value. This is a reasonable suggestion, but the usual practice is to measure and report cost-effectiveness. That approach is used in this paper.

These ratios are essential components of cost-effectiveness studies. However, only three studies in Table 1 report CERs. All three of these studies were completed for the United Kingdom Armed Forces.

The 22 studies listed in Table 1 include nine on flight training, seven on maintenance training, and six on training for some type of military operation (called "operations training"). Three of the operations training studies concerned gunnery training. Three of the 22 studies were from Canada, seven from the United Kingdom, and 12 from the United States.

In the earlier TTCP report, Chatelier et al. (1982) presented a framework for estimating the cost and effectiveness of training devices and procedures. They also listed the categories of data needed from TTCP countries to expand on results already available. These categories are listed in Table 5 along with the number of studies from Table 1 that provide data for them.

III. RESULTS

The use of simulation for training, documented by the 22 studies listed in Table 1, appears to be effective. The Transfer Effectiveness Ratios range from .67 to .99 (Brearley, 1980). These ratios exceed the 50 percent median time savings reported by Chatelier et al. (1982) and shown in Table 3.

Some transfer from simulator training to actual equipment performance occurred in every case--although performance on actual equipment was not always superior among simulator trained students. There were 16 studies that compared simulator trained students with students who were trained using actual equipment. Among these studies, four reported superior performance proficiency among simulator trained students, eight reported equal performance, and four reported inferior performance. No studies reported a complete absence of transfer. These results are consistent with those reported in Table 3 by Chatelier et al. (1982) who concluded that simulators and actual equipment were generally equally effective for training.

Simulator training appears to reduce speed of performance with actual equipment, compared to training only with actual equipment. Seven of the TTCP studies included data on the time students needed to perform a given task on actual equipment. All of these studies concerned electronic or automotive maintenance. Six of these studies reported that students trained with simulators performed significantly slower on assigned criterion tasks than did students trained with actual equipment. This result was not anticipated by any of the surveys and analyses listed in Table 3.

Not surprisingly, these TTCP studies indicate that simulator training costs less than training using actual equipment. The five TCRs based on hourly operating costs range from .11 to .50 (see Brearley, 1980, in Table 1). These TCRs are all for aircraft and aircraft simulators used in pilot training. They are generally larger than the .12 median TCR found by Chatelier et al. (1982) but within the range of .02 to .59 found more recently by Orlansky et al. (1984) and reported as a median value of .08 in Table 3. They are well below the value of 1.00 that would obtain if the costs of simulation and actual equipment training were the same. The five TCRs based on acquisition costs range from .008 (Court and Sharrock, 1985) to 2.60 (Cicchinelli, Keller, and Harmon, 1984). The low value of .008 represents the ratio of the cost of a small computer system to a large sonar system. It does not include the cost of software required for simulating the operation of the sonar. It is a good argument for the use of a part-task trainer. The high TCR of 2.60 is based on initial acquisition of a single trainer. Acquisition of subsequent copies of the trainer reduce the TCR to .40. Two TCRs are based on life-cycle costs. They are 1.00 (Cicchinelli et al., 1984) and .03 (Pieper, Richardson, Harmon, Keller, and Massey, 1984).

Training using simulation was found to be cost-effective. The four CERs reported in Table 1 range from .11 to .74 (Brearley, 1980). These CERs are again for aircraft simulators used in pilot training. They are slightly lower than the results from similar studies that were reported by Chatelier et al. (1982), where the CERs range from .24 to 1.30 depending on what measures of cost are used (see Table 3).

IV. DISCUSSION

Seven general observations may be made about these 22 empirical studies. They are:

First, these studies show an overwhelming interest in the use of simulation for training. The original request for studies collected for this paper was only for comparisons of new with existing methods of training. There was no requirement for any of these studies to deal with simulation. Yet every one of the 22 empirical studies received and summarized here concerns simulation-based training.

Second, interest in simulation extends from the use of full task, highly realistic simulators to the use of part-task, lower cost simulators; both extremes are viewed as alternatives to training, at least in part, with actual equipment. Sayer's (1984) informal survey (Table 3) turned up 47 low cost, part-task trainers in the United Kingdom, New Zealand, and Australia (he did not receive responses from Canada and the United States). These studies show that the field of training has progressed beyond the notion that simulation is the province only of high cost aircraft simulators. Moreover, the basic assumption that we must have full-task simulators has been questioned. For instance, Waag's (1981) review (Table 3) suggests that motion platforms, one of the most costly components of aircraft simulators, do not improve performance or save flight time. As we evaluate and eliminate various components that heretofore seemed essential to our training programs, the issue of cost-effectiveness becomes increasingly important. We need to know how much a cost savings in training reduces its effectiveness--if at all. Alternatively, we need to know how much increased resources for training will buy in terms of increased effectiveness.

Third, the range of cost data provided by these studies remains narrow. As Table 5 shows, only four of ten possible cost categories were considered in this sampling of studies; this can only mean that the cost data are incomplete (and potentially misleading). For that matter, 14 of the 22 studies listed in Table 1 did not provide any cost data. Of the remaining studies, three reported hourly operating costs for simulators and actual equipment, one reported annual operating costs, three reported acquisition costs, and two reported life-cycle costs. Although student cost savings were not considered by any of the studies, student time savings were. Eight of these time savings measures were directly related to student costs. In these studies a direct attempt was made to measure the amount of time students required to reach training criteria using actual equipment. In all of these cases, the 'actual equipment' was an aircraft. In the six acceptance testing and analysis studies listed in Table 2, the range of cost categories was only slightly wider. Five studies considered acquisition costs, three considered student time to reach criterion, three considered development costs (usually measured as conversion or transition costs), two considered operating costs (in one of these cases operating costs were measured by ammunition costs), and one considered instructor costs (number of instructors).

Fourth, the range of effectiveness measures considered by each individual study remains narrow. No study considered all five of the effectiveness categories listed by Chatelier et al. (1982). Only seven studies considered attitudes of either students or instructors, only three considered student attrition, and none considered on-the-job performance. On the other hand, all of the studies considered end-of-course effectiveness, and all but two of the studies considered transfer of training from simulators to real equipment. Student time savings in use of actual equipment was treated as both a cost and an effectiveness measure: eight studies measured time to complete a task using actual equipment; four other studies measured success in maintaining or operating actual equipment as an indicator of effectiveness.

Fifth, the emphasis in these studies is on simulation as an inexpensive form of training rather than as a source of unique training capabilities. Despite our extension of simulation technology beyond the full-task, high fidelity simulators used in pilot training, simulation is still viewed as a substitute for the actual equipment training we would prefer to have. Transfer effectiveness, with its focus on training time saved in actual equipment usage, typifies this notion. Simulation provides capabilities for less costly and safer training. These capabilities are fairly well captured by notions of transfer and cost-effectiveness. However, simulation also provides levels of feedback on performance, control over the difficulty and sequencing of instructional events, and replay capabilities that are unattainable for most actual equipment used for training. These capabilities were infrequently considered in the TTCP studies.

Sixth, nearly all the studies were concerned with high technology approaches to training. The four studies that were exceptions concerned slide-based simulation. However, they involved one degree or another of interaction, i.e., the slide-based simulator reacted in some veridical fashion to the actions and decisions of students. Low technology still has a role in training. Cost-effectiveness studies should help determine what that role is.

Seventh, just as there are effectiveness studies that neglect cost considerations, there are acceptance studies that neglect effectiveness considerations. Fourteen of the empirical studies listed in Table 1 did not consider any measures of cost, and three of the 7 acceptance studies listed in Table 2 did not consider any measures of effectiveness.

V. CONCLUSIONS

1. Training using simulation is effective, based on data contained in the TTCP studies. All the TERs reported were for aircraft simulators. The savings in flight time were about 40 minutes for every hour spent in a simulator. There was great variability in the size and type of performance improvements reported; the average percentage improvement among all measures of effectiveness was about eight percent.

2. Some transfer of performance from simulator training to actual equipment always occurred; no negative TERs were reported. However, four studies found that simulator trained students performed less well on criterion tasks than did students trained on actual equipment; these studies did not report TERs. An interpretation of these findings that simulator trained students would perform less well than a control group that received no training should be tested.

3. Performance speed in maintenance tasks on actual equipment is initially slower among students who were trained with simulators than among those who were trained with actual equipment. These findings all occurred in studies of maintenance simulation and indicated that simulator trained students took about 31 percent longer to perform criterion maintenance actions. This finding has not been reported previously.

4. Simulator training costs less than training that uses actual equipment. Simulator training appears to reduce training costs by at least 50 percent. Notably, however, the TTCP studies generally considered operating costs and did not include research, development, or initial investment costs.

5. Training based on simulation is more cost-effective than training using only actual equipment. The cost-effectiveness ratios reported in these studies indicated a savings of about 50 percent in cost to obtain a unit of effectiveness. This conclusion is based primarily on operating costs.

There are good reasons to be pleased with this sampling of studies. They show that although much remains to be done, there has been steady progress, and much has been accomplished.

VI. RECOMMENDATIONS

These studies were performed in a variety of environments and for a variety of purposes. Even without a common strategy, however, they provide a perspective not otherwise attainable and lead to five recommendations.

First, the range of cost data collected by evaluation studies should be extended. Some progress has been made because it is increasingly common to find some cost data in training where none had been the rule. However, many effectiveness studies continue to neglect cost data, and the range of cost data that is reported is limited to one or two categories that differ from study to study.

Second, the range of effectiveness data collected by evaluation studies should be extended. Considerable progress has been achieved in gathering end-of-course and transfer data. More needs to be done to measure attrition, assess student and instructor attitudes, and link alternative training approaches with on-the-job measures of effectiveness. Studies, reviews, and analyses of training approaches, such as those listed in Table 2, have limited value if they neglect effectiveness data.

Third, studies of the cost and effectiveness of various training approaches should not stop with these measures. We need descriptive information that explains the successes and failures of new approaches and prescriptive information that provides guidance to training designers. We need to know how and why these approaches achieve their ends as well as whether or not they succeed.

Fourth, there should be agreed upon guidelines for minimum required cost data reported in studies that members of TTCP may wish to exchange for common use. A comprehensive treatment of research and development, initial investment, and operating and support cost categories, such as the treatment outlined by Knapp and Orlansky (1983), may exceed the budget, energies, and competencies of most training evaluators. However, some practicable guidelines might be devised that would generally suffice for training program designers.

Fifth, there should be agreed upon guidelines for minimum required effectiveness data reported in studies that members of TTCP may wish to exchange for common use.

Again, a comprehensive treatment of training outcomes may exceed the budget, energies, and competencies of training evaluators. However, some practicable guidelines might be devised for general practice.

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Table 1. Empirical Studies of Training in TTCP Countries

Type of Training	Comparison	Measures of Effect	Measures of Cost	Findings	Study
Rotary wing flight. U.S./Army	AH-1 aircraft training required with different numbers of repetitions of 31 different maneuvers in AHLFS simulators (N = 34).	Required repetitions to criterion in aircraft	N/A	Exponential model accounts for most savings in flight time due to prior use of simulator. Economically optimal mixes of simulator and flight time can be derived using the model and operating costs.	Bickley (1980)
Fixed wing flight. UK/RAF	JP5A Basic Flying Training before (N = 72) and after (N = 66) introduction of simulator.	Number of successful students. Required hours of dual flying. Required hours of solo flying. Total hours in simulator and aicraft combined. Student attitudes. Instructor attitudes. Academic test scores. Transfer Effectiveness Ratios. Training Cost Ratios. Cost per successful student.	Hourly operating cost for simulator. Hourly operating cost for aircraft.	No change in student output quality or quantity with use of simulator TER = 0.99 Worst case TCR = 0.50 CER = 0.50 Best case TCR = 0.11 CER = 0.11	Brearley (1980)
Same as above.	JP3A Basic Flying Training before (N = 109) and after (N = 117) introduction of simulator.	Same as above.	Same as above.	No change in student output quality or quantity with use of simulator TER = 0.67 Worst case TCR = 0.50 CER = 0.74 Best case TCR = 0.11 CER = 0.17	Same as above.
Aircraft recognition and identification. UK/RAF	Training using slides versus videotape presentation (N = 26).	Number of aircraft correctly identified. Number of aircraft correctly recognized.	N/A	Equal recognition and identification accuracy for slide and video presentations.	Burnett (1983)

Table 1. Empirical Studies of Training in TTCP Countries (continued)

Type of Training	Comparison	Measures of Effect	Measures of Cost	Findings	Study
Electronic maintenance. U.S./USAF	Training using simulator (2D-EEMT) (N = 100) versus actual equipment (AN/SPS-10) (N = 47).	Troubleshooting accuracy on actual equipment. Troubleshoting speed on actual equipment. Student attitudes. Instructor attitudes.	Acquisition and life cycle costs of simulator. Acquisition and life cycle costs of actual equipment.	Equal troubleshooting accuracy for simulator and actual equipment groups. Troubleshooting speed 6-31% slower for simulator groups. TCR = 2.60 (acquisition of 1st copy) TCR = 0.40 (acquisition of 2nd copy) TCR = 1.00 (life-cycle)	Cicchinelli, Keller, & Harmon (1984)
Radar Operation for Air Traffic Control. U.S./RAF	Training with and without simulation.	Successful operation of actual equipment.	N/A	Performance of groups with simulators apparently superior.	Court & Sharrock (1985)
Sonar Operation. UK/RAF	Training using part-task versus full mission simulator.	Successful operation of actual equipment.	Acquisition costs of part-task simulators. Acquisition costs of full mission simulators.	Performance of part task and full mission groups about equal. TCR = 0.01	Same as above.
Rotary wing instrument flight. UK/Army	Training using Lynx simulator (N = 3) versus Lynx aircraft training (N = 3).	Instructor ratings in aircraft. Hours to criterion in aircraft. Transfer Effectiveness Ratios. Training Cost Ratios. Cost Effectiveness Ratios.	Hourly operating costs for simulator. Hourly operating costs for aircraft.	Simulator training is as effective as aircraft training. TER = ---[a] TCR = ---[a] CER = ---[a]	Fegetter & Allnutt (1983)
Air Support Flying. U.S./USAF	Training with (N = 11) and without (N = 14) flight simulator for A-10 surface attack skills.	Sortie "survival" in close air support (RED FLAG) missions in aircraft.	N/A	14% greater survival in simulator group when simulator configured closely to aircraft. 21% lower survival in simulator group when simulator configured less closely to aircraft.	Hughes, Brooks, Graham, Sheen, & Dickens (1982)

[a] Reported but restricted information.

Table 1. Empirical Studies of Training in TTCP Countries (continued)

Type of Training	Comparison	Measures of Effect	Measures of Cost	Findings	Study
Fixed wing Flight. UK/RAF	Basic Flight Training with and without University Air Squadron program.	Required hours to criterion in aircraft. Number of successful students.	Annual program costs.	Break-even occurs when - - -[a] ex-University Air Squadron students enter pilot training.	Kilner & Elshaw (1984)
Tank Gunnery.	Training with (N = 6) and without (N = 6) gunnery simulator for Leopard battle tank.	Average score on simulator. Hit time on simulator. Number of hits on simulator. Rounds required to achieve a hit on simulator. Number of 1st round hits on simulator.	N/A	Average score improved 90% over ten 16-mission sessions. Time to achieve hit reduced 21%. No significant increase in any accuracy measure.	Magee (1984a)
Tank Gunnery. Canadian Army	Training using gunnery simulator (N = 20) versus conventional instruction (N = 16) for Leopard battle tank.	Gunnery scores in "live" firing.	N/A	Simulator crews scored 4-10% better in 2 of 4 conditions. No significant difference in remaining 2 conditions.	Magee (1984b)
Tank commander training. Canadian Army	Training using gunnery simulator (N = 20) versus conventional instruction (N = 16) for Leopard battle tank.	Same as above.	N/A	No significant differences between simulator and conventionally trained crews.	Same as above.
Fixed wing flight. U.S./USAF	Simulator training with (N = 14) and without (N = 14) out-of-the-window visual cues for C-130 piloting.	Instructor ratings of students in aircraft. Amount of instructor assistance given. Deviations from desired performance parameters.	N/A	Visually cued group reached proficiency with 25-30% fewer sorties. About 10% of visually cued group required instructor input compared to 40-50% of non-visually cued group.	Nullmeyer & Rockway (1984)

[a] Reported but restricted information.

Table 1. Empirical Studies of Training in TTCP Countries (continued)

Type of Training	Comparison	Measures of Effect	Measures of Cost	Findings	Study
Fixed wing flight; mission qualification. U.S./USAF	Simulator training with (N = 14) and without (N = 12) out-of-the-window visual cues for C-130 piloting.	Required sortie repetitions to criterion. Proficiency ratings.	N/A	Visually cued group required 33% fewer repetitions to meet criterion. Mean proficiency ratings significantly higher for visually cued group.	Nullmeyer & Rockway (1984)
Fixed wing flight; mission qualification. U.S./USAF	Simulating training with (N = 12) and without (N = 11) out-of-the-window visual cues for C-130 piloting.	Required sortie repetitions to criterion. Proficiency ratings.	N/A	Visually cued group required 32-63% fewer repetitions to meet criterion. Mean proficiency ratings 6-17% higher for visually cued group. Twice as many pilots in visually cued group met criterion on first attempt.	Same as above.
Avionics maintenance. U.S./USAF	Training using simulator (N = 21) versus actual equipment (N = 22) for 6883 Converter Flight Control Test Station.	End-of-block knowledge test (paper-and-pencil). Equipment operation test (hands-on). Equipment troubleshooting test (hands-on).	Acquisition costs. Life-cycle costs.	Simulator group scored 19% higher in troubleshooting. No other difference in performance speed or accuracy. TCR = 0.27 (acquisition) TCR = 0.03 (life-cycle)	Pieper, Richardson, Harmon, Keller, & Massey (1984)
Automotive maintenance. U.S./Army	Training using slide-based simulator with 3-D module (N = 20) versus conventional lecture and actual equipment (Cummins NHC-250 diesel engine) (N = 20).	In maintenance of actual equipment: Time to complete tasks. Amount of instructor intervention required. Student attitudes. Instructor attitudes.	N/A	No difference in number of correctly performed steps. 39% more time and 40% more interventions required in simulator group.	Unger, Swezey, Hays, & Mirabella (1984)

Table 1. Empirical Studies of Training in TTCP Countries (continued)

Type of Training	Comparison	Measures of Effect	Measures of Cost	Findings	Study
Automotive maintenance. U.S./Army	Training using slide-based simulator with 3-D module (N = 21) versus conventional lecture and actual equipment (Cummins NHC-250 diesel engine (N = 20).	In maintenance of actual equipment: Time to complete tasks. Amount of instructor intervention required. Student attitudes. Instructor attitudes.	N/A	13% fewer correctly performed steps, 92% more time, and 104/5 more required interventions in simulator group.	Unger, Swezey, Hays, & Mirabella (1984)
Same as above.	Training using video-disc-based simulator with 3-D module (N = 10) versus conventional lecture and actual equipment (starting and charging system for self-propelled Howitzer) (N = 12)	Same as above.	N/A	5% fewer correctly performed steps and 16% more time, but 24% fewer required interventions in simulator group.	Same as above.
Same as above.	Training using video-disc-based simulator with 3-D module (N = 12) versus conventional lecture and actual equipment (starting and charging system for self-propelled Howitzer) (N = 11)	Same as above.	N/A	8% fewer correctly performed steps, 35% more time, and 67% more required interventions in simulator group.	Same as above.
Electronic maintenance. U.S./Army	Training using slide-based simulator with 3-D module (N = 10) versus conventional lecture and actual equipment (I-HAWK missile maintenance) (N = 12)	Maintenance of actual equipment. Time to complete tasks.	N/A	11% fewer correctly performed steps and 33% more time required in simulator group.	Same as above.

Table 2. Acceptance Testing and Analyses of Training Equipment in TTCP Countries

Type of Training	System(s) Studied	Measures of Effect	Measures of Cost	Findings	Study
Command and Control. UK/Army	Low-cost, interactive graphics (3-D) based battlefield engagement simulator.	N/A	Acquisition costs.	Less expensive than other computer-based systems. Might provide facilities useful for training.	Heaton (1984)
Tank Gunnery. Canadian Army	Low-cost, part-task, videodisc-based tank gunnery trainer for Leopard battle tank.	Tank gunnery proficiency.	Acquisition costs.	High face validity at low cost. Possible reduction in cost by a factor of 14.	Magee & Rodden (1984)
Automotive operation and maintenance. Australian Army	3 light-weight utility trucks (0.7-1.0 tons).	N/A	Training days to criterion. Number of conversion courses. Training aids cost.	Ratio of worst case projections of training costs to best case projections = 2.19.	TSP: Project Perentie
Same as above.	2 light cargo trucks (1.5 - 2.0 tons)	N/A	Same as above.	Ratio of worst case projections of training costs to best case projections = 1.50.	Same as above.
Small arms shooting. Australian Army	Small arms training systems (Lindsay Knight Rifle Trainer and Superdart Projectile Location System).	Shooting proficiency.	Training time. Referenced study on required training resources. Acquisition and development costs.	With equal training efficiency, 1st year costs 13% higher, subsequent years 35% lower. With improved efficiency, 1st year costs 14% lower, subsequent years 79% lower.	TSP: Small Arms Training Systems (1985)

Table 2. Acceptance Testing and Analyses of Training Equipment in TTCP Countries (continued)

Type of Training	System(s) Studied	Measures of Effect	Measures of Cost	Findings	Study
Infantry air defense operator training. Australian Army	3 air defense systems	Tracking proficiency. Interaction with selection policy. Transfer of skills.	Training days to criterion. Transition training days. Number of instructors. Acquisition costs. Training resources costs (e.g., CAI). Operating costs per year.	Without validation capability, ratio of worst case to best case = - - -[a] With validation capability, ratio of worst case to best case = - - -[a]	TSP: VLLADWS Operator Training (1984)
Tank Gunnery. Australian Army	7 classes of systems. 5 turret interaction.	Gunnery proficiency.	Ammunition required.	No adequate cost-effectiveness data yet available. Operator proficiency testing needed. Operator training should be included with new systems.	Williams (1984)

[a] Reported but restricted information.

Table 3. Surveys and Analyses of Training

Sponsor	Area Reviewed	Findings	Study
TTCP-UTP-2	Cost-effectiveness of military training using flight simulators, computer-based instruction, and maintenance simulators.	Simulators and actual equipment are equally effective. Savings (compared to actual equipment) from: Flight simulators (2-year amortization): 30-60% of acquisition costs: 12% of operating costs; 65% of life-cycle costs. Computer-based instruction: 30% of student time. Maintenance simulators (4-year amortization): 20-50% student time; 20-60% acquisition costs; 50% operating costs; 40% life-cycle costs.	Chatelier, Harvey, & Orlansky (1982)
UK/Navy	Training simulators for submarine command teams.	Simulators are expected to: reduce instructors' workload; generate and prepare training materials; improve performance evaluation; provide realistic/intelligent opposition; aid in development of new tactics.	Cook & Maddrell (1984)
U.S./OUSDRE	Operating costs of aircraft and flight simulators, 1980-1981.	Operating costs range from $116-$170 per hour for all types of simulators, across a diversity of simulated missions and/or aircraft. Simulator-to-aircraft operating cost ratios remained at about 0.08 from 1976 to 1981. Concerning 15 Air Force simulators and fixed-wing aircraft: Both aircraft and simulator operating costs doubled from 1976 to 1981. Aircraft operating cost increases are consistent with inflation; only 40% of simulator operating cost increases are. Simulator use reduced 30% from 1976 to 1981.	Orlansky, Knapp, & String (1984)

Table 3. Surveys and Analyses of Training (continued)

Sponsor	Area Reviewed	Findings	Study
Australian Navy	Part-task, low-cost trainers used by TTCP member countries.	Total of 47 trainers listed for UK, New Zealand, and Australia: 8 for flight training; 14 for gunnery and small arms training; 14 for maintenance training; 11 for operations training.	Sayer (1984)
U.S./USAF	Visual and motion simulation for flight training.	Of 26 studies of visual simulation, 18 concerned transition training. Visual simulation shows positive transfer across all types of aircraft. Most transfer obtained for formation flying and surface attack weapons delivery--less transfer obtained for aerobatic and air combat skills. In none of 10 studies was aircraft performance significantly enhanced by simulator training with platform motion.	Waag (1981)

Table 4. Studies of Methodology for Evaluating Training

Sponsor	Area Reviewed	Findings	Study
TTCP-UTP-2	Evaluation of unit (collective) training.	Theoretical plan and practical means for applying evaluation technology in the field. Approach keyed to Systems Approach to Training requiring analysis, design, development, implementation, and evaluation.	Hudson, Jans, Thornley, & Desmond (1985)
U.S./DoD	Costs for military training.	A model that identifies and structures a list of all cost elements needed to conduct life-cycle cost-effectiveness analyses of alternative programs for military training. Cost elements are defined under the general headings of Research and Development, Initial Investment, and Operating and Support. Applications of the elements to academic training, maintenance training, and flight training are illustrated.	Knapp & Orlansky (1983)
U.S./Navy	Current practices in cost-benefit analyses of military manpower and training research and development.	Taxonomy of generally accepted and widely used techniques and precepts. 14 elements of cost-benefit analysis are identified and defined. These elements are shown to have been applied to different degrees in 11 economic analyses of Navy manpower, personnel, and training.	McMichael (1985)

Table 5. Effectiveness and Cost Data Provided by 22 Empirical TTCP Studies

Types of Data	Number of Studies
Effectiveness Measures	
End of Course	22
Transfer	20
On-the-Job	0
Student Attrition	3
Instructor Attitudes	7
Student Attitudes	7
Cost Data	
Research and Development	0
Initial Investment	
Program Development	0
Acquisition	3
Operating and Support	
Student Pay and Allowance	0
Instructor Pay and Allowance	0
Maintenance and Repair	0
Program Modification	0
Student Time Savings	8
Operating	4
Life-Cycle Costs (includes all of the above)	2