EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

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# A Framework for Applying Cost-Benefit Considerations in the Recruitment and Selection Process for *Ab Initio* Trainee Controllers

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**Abstract**

This report describes a methodological framework which can be used to carry out a Cost-benefit Analysis (CBA) of the recruitment and selection process for *ab initio* trainee controllers. It is intended to be of practical use to National Administrations when making out a business case to support the introduction of enhanced recruitment and selection systems.



**Keywords**

*Ab initio* Trainees, Cost-Benefit, Economic Appraisal, Recruitment, Reliability, Selection, Validity



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# EXECUTIVE SUMMARY

This document looks at the cost-benefit aspects of improving the recruitment and selection process for *ab initio* trainee controllers. It is intended to be of value to national Air Traffic Service (ATS) administrations when preparing a business case to support the introduction of enhanced recruitment and selection systems. It complements the work which has been carried out by Selection Task Force (STF) II on providing information on available and emerging selection tests and methods for *ab initio* trainee controllers, and issuing guidelines on their implementation.

Chapter 1, "Introduction" puts the study into context and defines its scope. Two different approaches to the study are described and the reasons for selecting a particular approach are given.

Chapter 2, "Organisational Benefits" outlines the benefits from human resources in Air Traffic Control (ATC) in general and relates it to recruitment and selection activities.

Chapter 3, "The Recruitment and Selection Process" describes a generic model of the process and the principles on which the model is based. The various approaches to recruitment and selection taken by the European Civil Aviation Conference (ECAC) States are compared and some reasons for the differences in approach are given.

Chapter 4, "Cost-Benefit Analysis (CBA)" defines what is meant by CBA and compares the conventional use of CBA in project appraisal to its application in recruitment and selection. Methods for measuring the effectiveness of recruitment and selection are described and some trade-offs between costs and benefits are discussed.

Chapter 5, "Methodology for Applying CBA to the Recruitment and Selection Process" examines each of the stages involved in the process and identifies the impact that will arise on the process as a whole from making changes at individual stages. A framework is described for evaluating the economic effect of these changes. A hypothetical example of a recruitment and selection process is used to illustrate the data which is required to carry out a CBA and the link into Manpower Planning (MP) is discussed.

Chapter 6, "Application of the Methodology" illustrates how the methodology described in Chapter 5 could be applied to five different methods for increasing the effectiveness of recruitment and selection.

Annex A describes the relationship between predictor scores and criterion values for tests of varying reliability and validity. It demonstrates the effect of changing cut-off scores on errors arising from selection. The document in its annexes also contains a list of references, glossary, abbreviations and acronyms used in the document and a list of contributors.

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# 1. INTRODUCTION

## 1.1 Background

This document should be read in conjunction with the Human Resources Business Plan contained within the European Air Traffic Control Harmonisation and Integration Programme (EATCHIP) Work Programme - Level 2 Document (EWPD) (EATCHIP, 1996a). The study which this document describes forms part of HUM.ET1.ST11, a Specialist Task (ST) concerned with implementation aspects on human resources activities. The layer 1 task which it addresses is 'Risk Analysis and Cost-Benefit Studies' (ST11.4000).

This study provides one of the deliverables (DEL) for this task, namely 'Generic Models for CBA' (DEL03) and it deals in particular with the process for the recruitment and selection of *ab initio* trainee controllers. It is therefore linked to ST04.1000, entitled 'Selection Procedures and Tests for *Ab Initio* Trainee Controllers'. This task has been assigned by the Human Resources Team (HRT) to STF II and part of their Terms of Reference (TOR) was to consider and give feedback/advice to the scope and content of this document. Feedback has therefore been sought from members of the task force on the approach taken in this study and account has been taken of their views.

It is expected that similar cost-benefit studies will be undertaken in other sub-domains of human resources and these are likely to cover training, licensing, MP and human performance. It should be noted that there is significant interaction between selection and these other activities and that a comprehensive picture of the economic impact that human resources can have on the EATCHIP programme will not be available until all these CBA studies are complete.

## 1.2 Purpose

The purpose of this document is to consider the issues involved in applying CBA to the recruitment and selection process for *ab initio* trainee controllers and to describe a methodology which can be used to evaluate all changes which are proposed. It is hoped that the methodology will be of practical use to national ATS providers when developing business cases for the introduction of improved selection methods.

In developing the methodology the parameters in the selection process which affect its outcome have been identified and the study has considered how to evaluate the economic effect of changing each of these parameters. This approach can be used to help to prioritise possible improvements to existing processes.

## 1.3 Scope

The study has covered all the activities that can be carried out in recruitment and selection from attracting applicants through advertising and marketing to the placing of candidates on Air Traffic Controller (ATCO) training courses. The study has been restricted to the recruitment and selection process but it has been necessary to take into account the costs involved and the failure rate in training since a direct effect of improving selection is to reduce the frequency of failure during training.

## 1.4 Approach Taken

The study can be approached in two ways. The first is to consider the current positions on recruitment, selection and training in all ECAC States, and attempt to evaluate the effect of harmonising partially or fully the variety of methods in use. The second is to start from a generic reference model of recruitment and selection and to determine actual costs using data obtained from individual States. Having established a baseline for these States, planned or potential changes to existing recruitment and selection procedures can be compared in terms of the costs and benefits arising from these changes.

The first approach is closer in spirit to the EATCHIP programme but is not feasible due to the number and variety of methods in use, the lack of data on the validity and utility of different options and the difficulty in collecting actual costs and benefits of all these methods. The second approach is feasible and is of more practical use to an individual State. It has been the approach adopted in this study. In reality the two approaches are linked since the goals of EATCHIP will encourage individual States to identify appropriate changes to their own recruitment and selection procedures which will move them towards harmonisation with other States.

In theory it might be possible to extrapolate the results from individual studies to determine total potential financial benefits in very broad terms across ECAC as a whole. However, in practice this would be difficult to achieve because recruitment and training needs vary widely between States. For example the actual requirement for *ab initio* trainee controllers can range from 3 to 150 per year in each of the States. As training methods used by individual States are very different the failure rate in training which would result from implementing a common selection process would not be the same in every State.

## 1.5 Data Sources

Data used in the study has come mainly from sources within the European Organisation for the Safety of Air Navigation (EUROCONTROL). Internal reports have been used to gain an understanding of the variety of recruitment and selection methods in use, both within and outside ECAC States.

Textbooks and relevant papers published in psychology journals have been consulted to gain an understanding of the technical aspects of selection.

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# 2. ORGANISATIONAL BENEFITS

In line with more recent Human Resource Management (HRM) schools of thought the STF felt that it is important to argue that it is more appropriate to view human resources as assets as opposed to just a cost.

The importance of human resources is often highlighted in mission statements as, for example, in EUROCONTROL where the Agency Mission states that "our most valuable resource is our people". Germany's air navigation service provider (Deutsche Flugsicherung GmbH) Mission states that "the working environment should enable our staff to develop their potentials and to be rewarded for their contributions to promote the corporate goals".

## 2.1 Contribution of ATCOs to the Aviation Industry

Society, government and organisations, both ATS organisations and their stakeholders in the aviation industry, benefit from the positive contribution of ATCOs to the economy.

The aviation industry is one of the world's most vital resources and one of the fastest growing sectors of the world economy. People within ATS organisations, and ATCOs in particular, directly contribute to the economy by providing an essential service worldwide. The magnitude of this service can be gauged by the following facts, to name but a few:

- over 1.25 billion air passengers are carried per year;
- over a third of the value of the world's manufactured exports is transported by air per year;
- the annual gross output in the aviation industry is in the order of $ 1.140 billion per year leading also to high tax revenues;
- the maintenance of some 24 million jobs in the aviation industry with another 9 million jobs expected to be created within the next decade (Air Transport Action Group (ATAG), 1997).

In order to accommodate the items mentioned above and the expansion of Air Traffic Management (ATM) capabilities, the development of new technology and innovative research to cope with growth in traffic is necessary.

The importance of people in ATS might be envisaged if one would consider a sudden deprivation of the service e.g. due to a severe shortage. Anything that is done to support the timely provision of suitable controllers will therefore contribute to economic growth and prosperity.

The following Sub-chapters outline the more specific considerations to be given to recruitment and selection activities as they relate to the benefits of human resources in ATS.

## 2.2 Strategic HRM

The role of quality and safety in the workplace and the need to tie people in the organisation deeper into the business process led to integration of HRM into strategic planning systems known as 'people management'. This shifted the content of 'personnel management' away from traditional specialist aspects such as recruitment, selection, training and workforce management towards higher level issues of, for example, managing the organisational culture and resourcing the organisation with an appropriate set of competencies.

It is more and more acknowledged in ATS organisations that ATCOs bring with them to the job certain abilities, skills, knowledge, flexibility and motivation which enable them to contribute to the output which is in the first instance a safe, orderly, and expeditious flow of traffic. Expertise and commitment enable the growth, adaptation and development of ATS organisations as a whole.

## 2.3 Human Resources Benefits

From the above it is understood that it is in fact the resources which humans bring into the system that are likely to contribute to their performance.

These resources become 'scarce' to the extent that they are not always easily obtained. The supply of human resources is the result of

- a more or less lengthy educational and training process (learning);
- the availability of rare natural talents;
- the willingness of individuals to make their talents available.

### 2.3.1 Expertise as a Human Resource

In ATC it is assumed that all three factors: a certain 'innate' ability or talent (e.g. the ability to form spatial representations), learned skills which evolve into expertise during training and the motivation of individuals are the basis for human performance in ATC.

From this it seems to be a short step to the specification of those HRM practices that identify abilities and knowledge (recruitment and selection), encourage and develop skills (training) and ensure high motivation (reward and career system) and skill utilisation (task allocation). However, there are also other factors which are involved (rules, procedures and practices; technical infrastructure and support; time management tools etc.) which are

not bound completely to HRM practices. To what extent these factors contribute to human performance is yet not fully understood.

From the above rationale it is also obvious that it is difficult to measure the direct contribution of, for example, recruitment and selection on human performance. Human performance benefits are in most cases an effect of combined efforts. Part of this is explained in Sub-chapter 2.4.

### 2.3.2 Time as a Human Resource

In addition time is another scarce resource which humans 'own' and bring into the system. Both resources, time and expertise combine in an as yet not fully understood manner (possibly in a multiplicative function). However, it seems reasonable to assume that the value of the human input in the system will be especially high if the expertise is costly to obtain and will directly impact on the cost per time unit of using this expertise.

Efforts in resource allocation and skill / expertise utilisation (e.g. through appropriate task allocation) and appropriate time management are therefore important other HRM practices which more directly influence human performance.

The benefits from a highly qualified workforce can be easily jeopardised if the skills / expertise of the workforce is inappropriately used (e.g. on wrong tasks) or not used at all in the process.

## 2.4 Recruitment and Selection Related to Organisational Outcomes

Organisational outcomes which could stem from HRM activities in recruitment and selection refer to performance of individuals who have been selected. As *ab initio* trainees undergo a lengthy training process their performance in training is at stake before one could actually embark on their performance in the job as ATCOs. This is described as the criterion problem in selection and training.

### 2.4.1 Performance Criteria for *Ab Initio* Trainee Controllers

Performance is determined by organisational criteria as the following example shows: It does not matter whether trainees selected could perform well in other tasks or functions in ATS organisations. They are supposed in the first instance to perform well in controller training and later in the job as ATCOs. Although it is recognised that ATCOs later in their career need to perform well in other job functions also (e.g. as trainers, supervisors, managers, project workers) their potential for this is currently not the subject of recruitment and selection activities in most ECAC States.

### 2.4.2 Links with Performance

If performance is the avenue by which individuals have an impact on productivity of organisations, it might be useful to inquire about the basic antecedents of performance (Campbell and Campbell, 1988). With regard to HRM activities in selection and training the question is how these activities are linked with performance.

This is outlined in the following rationale which addresses some of the antecedents (after Campbell and Campbell, 1988):

HRM practices (e.g. in recruitment and selection, training) are likely to contribute (are beneficial) to organisational performance when three conditions are met:

- when employees possess abilities and have developed job-specific knowledge and skills (expertise) which are needed in the organisation;
- when employees are motivated to apply them and direct effort at the task goals (persistence and effort expenditure);
- when the organisations' business or production can only be achieved when employees contribute to the process.

This definition applies in the first instance to employees who already possess all necessary skills / expertise required in a job, not necessarily to candidates selected for *ab initio* training. Taking account of what has been mentioned earlier, activities in recruitment and selection contribute **indirectly** to organisational performance benefits but **directly** to training performance. Organisational performance benefits, however, rely to a great extent on the expertise achieved during training.

Recruitment and selection can contribute to a large extent to the effectiveness of the training system by increasing organisational success (mainly success in training) in using effective and efficient procedures.

## 2.5 Benefits of Recruitment and Selection

The benefits from recruitment and selection activities in the overall ATS system (via selected individuals) are manifold. It is clear from the above Sub-chapters that human performance benefits are the outcome of a **process** rather than a given entity.

The interactions between contributing factors is probabilistic and regression-like rather than deterministic. This relationship is shown in Figure 1.

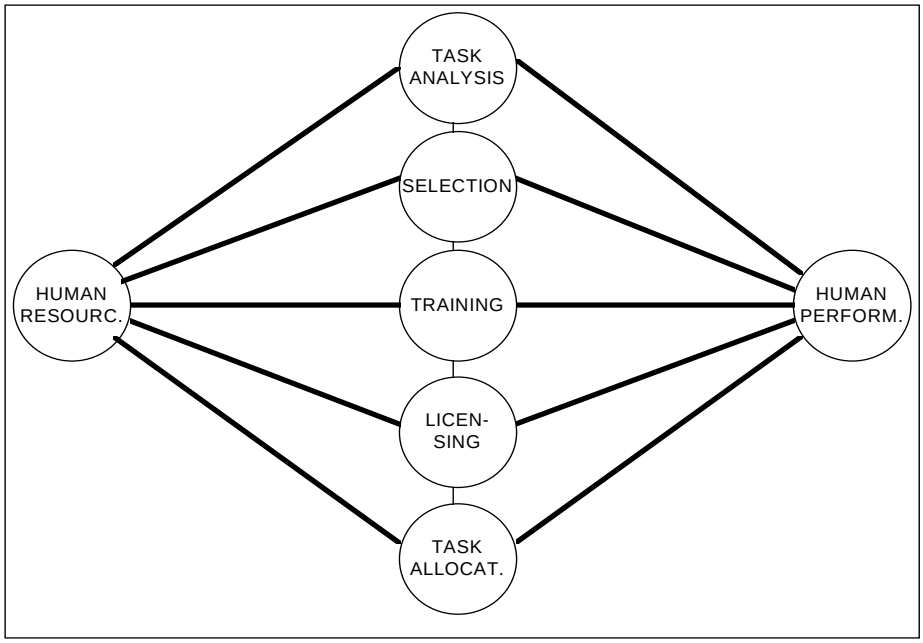


Figure 1: 'Lens' - model of relations between human resources inputs and human performance (output)

Figure 1 shows on the left 'input' side (human resources) several factors which impact on the 'output', human performance. However this effect is only partly related to performance due to 'environmental' factors (right part of the 'lens') which are either diminishing or increasing the extent to which the resources provided are actually used. That is, the benefits from human resources are only to some extent realised, depending on whether what is provided by humans is actually required or used.

Contributing factors on the input side are also interrelated. An ideally perfect recruitment and selection system will always only to that extent be effective as the human resources provided, for example, to the training system match with existing requirements in training. That is, the extent to which the training system can make use of / build upon the potential of trainees limits the contribution of selection to training success.

### 2.5.1 Controlling Random Errors

What recruitment and selection activities can contribute to the overall success of ATS organisations is controlled by the use of

- standardised, reliable selection tools;
- controlled and validated procedures;
- procedures in quality assurance;
- procedures in capacity utilisation of the ATS academy.

This report concentrates on the recruitment and selection process and the means and methods used to select candidates.

## 2.6 Additional and Alternative Benefits

Costs of recruitment and selection of appropriate candidates must first be balanced against the benefits of an ATM system ability to provide safe, efficient flying, and reduce delays due to well trained ATCOs. Therefore, a proper CBA study estimates not only the costs, but also identifies the benefits in terms of delay reduction. Costs of selecting suitable *ab initio* trainees are directly linked or attributed to customers needs (e.g. airline needs to avoid delays and possible re-routing). Selecting successfully future ATCOs contributes directly to the benefits of ensuring enough capacity improvement to fill a capacity shortfall.

A possible benchmark against which benefits (and costs) can be measured is a “do nothing scenario”. A benefit can be measured in Air Traffic Flow Management (ATFM) delay reduction (the difference between the old delay and the new one) or reduced unnecessary flight mileage. Both can be translated in a reduction of the airlines operating costs (Mahlich et al., 1997).

As well as comparing the alternative use of money (costs) (see Sub-chapter 4.1) it is possible to compare alternative benefits. An example for this is in hiring licensed controllers from other States which is about to become more and more a spreading tendency in Europe.

Although the so-called ‘poaching’ of ATCOs is seen as a threat to States which within their own wage system are not at the competitive edge, it can be regarded as one option with which the benefits from developing own human resources from ‘scratch’ can be compared taking into account

- selection costs (fixed and variable);
- costs of training (fixed and variable);
- conversion training costs.

# 3. THE RECRUITMENT AND SELECTION PROCESS

## 3.1 Generic Model of the Process

The recruitment and selection process consists of all or some of the following activities:

i) Developing marketing information to increase awareness in the population as a whole of the work carried out by an ATCO.

ii) Advertising vacancies to attract individuals from the right target population.

iii) Providing realistic job and training information for interested applicants to enable them to undertake self-selection.

iv) Sending out application forms to applicants requesting biographical and basic medical information.

v) Receipt of application forms and screening of applications using mandatory minimum requirements (for example age, educational standard, eyesight, etc.).

vi) Pre-selection of applications on the basis of additional criteria which have been empirically proven to be indicators of the ability of the applicant to undertake training and perform the duties of an ATCO. This is normally carried out by means of a ‘paper sift’.

vii) Inviting suitable applicants for further testing and assessment.

viii) Ability testing including assessment of cognitive abilities.

ix) Knowledge testing including assessment of English language ability.

x) Personality assessment.

xi) Interview.

xii) Medical examination applying medical requirements set by the International Civil Aviation Organisation (ICAO).

xiii) Security check.

A decision is normally made at the end of stages (v) - (vi) and (viii) - (xiii) as to whether an applicant should proceed to the next stage. Candidates may also decide to withdraw before the start of any of these stages.

Figure 2 gives an outline of this model.

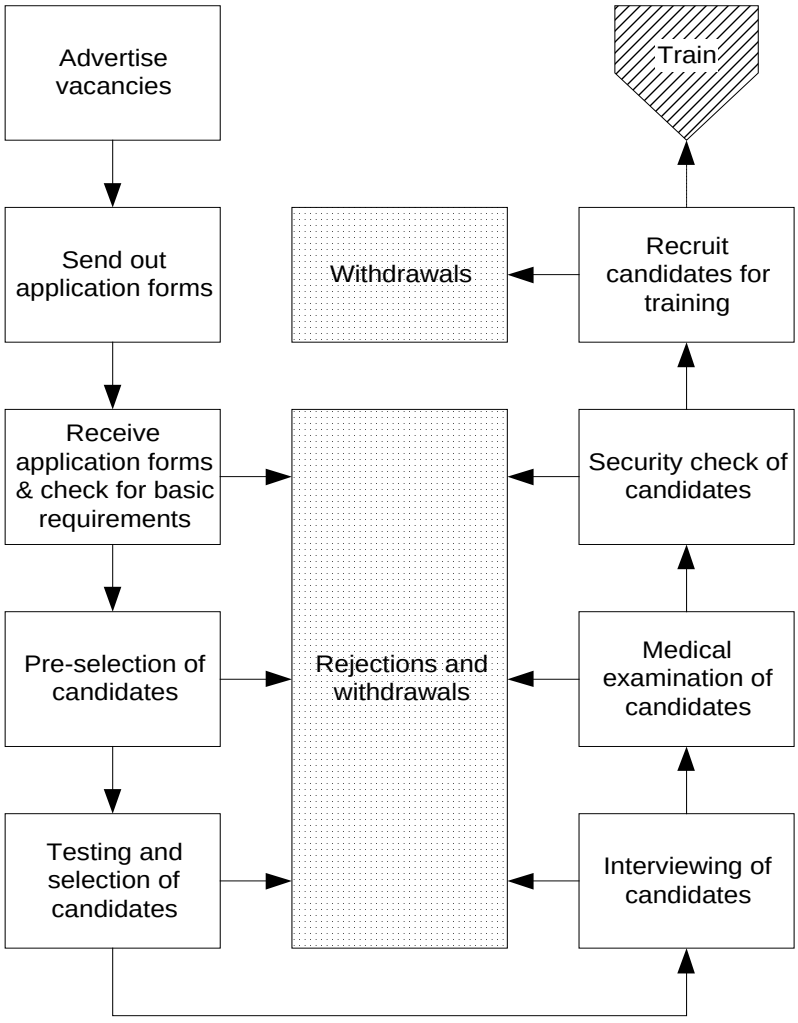


Figure 2: Generic model of multi-stage recruitment and selection process

The generic model is based on the following considerations and principles:

- Recruitment and selection is done in a consistent multi-stage process where decisions have to be taken at different stages.
- The objective at each stage of the process is to increase the success rate in the following stage and to avoid adverse impacts in all later stages. This ensures that the process is consistent.
- Each stage makes use of only those criteria which are effective in predicting success in later stages.
- A selection method is more cost-effective than another if it can better predict success in the following stages, i.e. it has a higher validity.

This model illustrates the principle that the cost-effectiveness of a method applied at an early stage of the selection process should take into account all reductions in cost at later stages of the process which can be attributed to applying the method.

## 3.2 Current Position in ECAC States

Most ECAC States have their own specific systems for the recruitment and selection of *ab initio* controllers. These systems have evolved over many years of use. Some States subcontract their recruitment and selection to third parties who are normally experienced in developing and applying selection methods in the aviation industry. These subcontractors often have more than one client in the ATS sector and may also undertake the selection of pilots for civil airlines or the military.

The success of a specific test battery, as measured by the resulting success rate in training, when used in selection for more than one ATS provider may not be the same and can differ by a large margin.

Most States undertake research and development activities on selection methods independently of other States. However, some States or Organisations use selection methods developed in other States and it is becoming more and more the custom for States to informally exchange information with each other on the reliability, validity and utility of selection methods in use.

### 3.2.1 STF Survey Data

As part of its work programme a survey was undertaken by the STF with responses from 34 States including States outside Europe. The survey concluded that there is wide variation in the quantity and quality of selection tools in use. The following information was revealed by the survey (EATCHIP, 1997):

- There is a large variation in the number of tools used by individual States. At the extremes, one State uses a single interview which has not been validated as its sole means of selection, while another makes use of a test battery containing 22 different tools.

- In 11 States the majority of tools included in the test battery were designed for ATC or have been validated against ATC. But in 10 States the majority of tools in use are general purpose tools which were not specifically designed for ATC.

- There is no agreement between States on which attributes required by an ATCO should be tested during the selection process. Consequently the composition of test batteries is different in each State.

- The type of interview used by a State can be structured, semi-structured or situational and the majority of States have not validated the interview against a candidate's ability to successfully complete the training course or to succeed in the job.

- In 7 States testing is carried out solely by paper-and-pencil tests while 10 States use only computer-based tests. Some States use a combination of the two.

There are many reasons why the methods used for selection vary so greatly. For example, some of the problems which States face are:

- The high cost of buying or developing effective scientifically based tests.

- Lack of expertise in identifying or developing suitable tests.

- Lack of resources to administer and maintain a comprehensive test battery.

- The number of trainees required being too small and recruitment too infrequent to justify the cost of the tests and to enable a validation.

One effect of having such a wide range of selection tools in use is a highly variable failure rate in training achieved by each State. The lowest failure rate reported in another survey (EATCHIP, 1996b) is 2% and the highest 70%. However, this data should be considered with extreme caution because, for example, of different training schemes, different evaluation criteria applied in training, relocation policy, different standards set concerning the proficiency to be achieved in training, different procedures in regard to the number of re-sits allowed after examination failures etc.

The STF concluded that tools which test certain attributes such as logical reasoning and English language ability are in common use but there is diversity among the States on the value of testing other abilities or skills. There is agreement on the need to validate the tools which form a test battery, to use tools which have been validated and are relevant to ATC, and to provide more information on the utility of these tools. However, no communal actions have yet been taken in this respect.

# 4. COST-BENEFIT CONSIDERATIONS

## 4.1 Definition

CBA is a process for systematically identifying the costs and benefits arising in a project in both quantitative and qualitative terms and takes into account their timing. It provides a means of comparing a number of project options which represent different courses of action to meet the same project requirements. The economic viability of the project can then be established and a decision can be made on which option, if any, to pursue with a full understanding of the likely financial consequences.

Costs and benefits over the lifetime of the project are normally reduced to present day values by taking into account the expected rate of inflation and then a discount rate is applied. The discount rate represents the true rate of return which could be obtained if the capital required by the project was put into an alternative investment such as bonds issued by European Governments or European equity markets. The discount rate chosen will depend on the view that is taken of whether the capital required is competing against other government budget items or other commercial investments.

Because the benefits, and to a lesser extent the costs, are forecast, and assumptions are made about the operating parameters which will prevail, sensitivity analysis is undertaken to determine the effect that changes in these forecasts and assumptions will have on the economic viability of the project. Thus optimistic, realistic and pessimistic scenarios can be developed and compared with the base case, which is normally to do nothing.

## 4.2 Differences Between Conventional Use of CBA and its Application to the Recruitment and Selection Process

While it is necessary for individual States to develop Business Cases to support the proposed implementation of enhanced recruitment and selection systems, there are some fundamental differences between the conventional application of CBA in capital investment appraisal and its use in justifying changes in the recruitment and selection process where the primary objective is to make the process more efficient and cost-effective. These differences are summarised in the following Sub–chapters.

### 4.2.1 Improvement of Efficiency and Cost-Effectiveness

CBA is more commonly used in the financial evaluation of large capital projects where several project options exist or where there is competition for scarce funding from several competing projects. For example, in the aviation business, significant investment is required continuously in order to maintain safety and reliability, improve the quality of service and minimise delays in an

environment where traffic is increasing year by year. The providers of ATS, the airlines and the financing organisations all need to be convinced of the economic viability of proposed new projects.

In recruitment and selection, relatively small sums of money are involved and the emphasis is on providing value for money in the ATC service. It will be demonstrated later that even a poor selection system is capable of performing better than selecting at random from the applicant population.

### 4.2.2 Improvement Based on Best Practice

In an infrastructure project, for example, the airlines and other users of ATS will not find it worthwhile to invest in the necessary equipment to gain benefit from the new infrastructure unless it is applied in many, if not all, of the ECAC States.

However, in recruitment and selection, the aim is not to propose and evaluate a set of specific options which are intended to be applied in every ECAC State. If every State in the ECAC area were to apply the same standard approach it is most unlikely that the outcome would be the same in each State. This is due to many causes including differences in culture, differences in the quality of training provided, and differences in complexity of the range of tasks that a controller is expected to carry out.

The aim is to provide an evaluation framework which can be used by any ATS provider in making changes to its current process for recruitment and selection. Those actions which should be undertaken as part of a process improvement programme could be identified and justified.

### 4.2.3 Minimisation of Costs While Satisfying Operational Needs for New Controllers

In conventional capital appraisal there is normally a small number of feasible options to evaluate and compare. In recruitment and selection there is a large number of changes which could be made at each stage of the process and each of these changes will impact on all of the subsequent stages.

Conceptually there is a set of changes which could be applied which would optimise the cost-benefit of the process as a whole. The CBA framework which is set up should explain the interaction between changes made at different stages of the process.

## 4.3 Measurement of Error Costs

The purpose of recruiting and selecting *ab initio* trainee controllers is to provide the exact number of trainees required to fill the number of places available on each planned training course. Ideally, a successful selection system will identify trainees who have the potential ability to undertake training, pass all the examinations and tests which are set during training and

emerge as licensed ATCOs who are capable of pursuing successful careers working for an ATS provider. One way of measuring the effectiveness of the recruitment and selection process is to calculate the cost of two types of error.

### 4.3.1 Sources of Error

There are two sources of error in the selection system:

1. The first is that someone is selected who, it later emerges, does not have the required ability to complete the training course successfully or operate as a licensed controller.

2. The second is that someone is rejected during the selection process - due to a less than perfect selection - who would have had the ability to complete the training course and go on to be a successful ATCO.

The first source of error can be measured and manifests itself as a failure sometime after employment as an *ab initio* trainee. The second source of error cannot be measured directly and is usually ignored but it is shown in Annex A that it can be estimated if certain assumptions are made.

### 4.3.2 Consequences of Error

The consequence of the first source of error is that money is invested by an ATS provider in training someone who will eventually fail. If failure takes place during training no return will ever be provided on the investment, and the longer the person stays in training the more costly the investment will be. An exception would be if that person could be employed in some other capacity in the ATS organisation.

The consequence of the second source of error is that time and money will be spent on putting someone through the selection process who would have filled a vacancy and succeeded in the job but is rejected by a less than perfect selection process. An additional cost will be incurred by putting someone else through the system to fill this vacancy. From the standpoint of a perfectly effective selection system, each of these costs is unnecessary.

However, both types of error are inevitable in any practical recruitment and selection system. The difficulty comes in obtaining the right balance between the two. The magnitude of the errors can be altered by changing parameters in the selection process, for example, by increasing the validity of the test battery. But the general difficulty will remain: reducing one type of error may invariably cause the other type to increase. This can be derived from Figure 8 in Annex A where a full explanation of a hypothetical example is given.

### 4.3.3 Calculating the Costs of Errors

While it is relatively straightforward to calculate the cost to an ATS provider of someone failing during training or in the early part of their career, it becomes

more and more difficult to trace the cause of failure to a faulty selection process the further beyond the time of selection that the failure occurs. For example, failure may be due to the content of the training course, poor instruction during training, the desire for a young person to make a complete career change after a few year's experience in ATC or conflict with colleagues at work.

For the purposes of this study the time horizon used for measuring the cost of failure due to selection will be up to the point where an *ab initio* trainee receives his or her first operating licence. It is recognised that this will overstate the cost since the cost of failure due to imperfect training will also be included. However, some assumptions have to be made. One assumption is that it is valid to compare the difference in cost between two selection options since the error in each calculation due to the cost of imperfect training will be the same.

An alternative way of measuring the effectiveness of the process is to compare its outcome with what would have happened if no selection had taken place, i.e. applicants were chosen to attend the training course at random from the list of all applicants. However, it is well understood that a random selection is not a practical option for reasons of safety, national laws, and the moral responsibility for and motivation of applicants and trainees, for example.

## 4.4 Trade-offs Between Costs and Benefits

When setting up or modifying a recruitment and selection system there are many choices and decisions which need to be made, all of which will affect the outcome and the overall cost of the system. Some of these choices are:

- Whether to aim for blanket coverage in an advertising campaign so that large numbers of people will be aware of vacancies and will consider their suitability to fill these vacancies, or whether to structure the advertising campaign to target only those people who have a strong interest in aviation.

- Whether to use a small number of tests which are known to have high reliability and validity in the selection of ATCOs, or whether to use a broad range of general tests, some of which may not have been specifically validated for ATC but which may add value to the process when validation has been achieved.

- Whether to set cut-off scores in selection tests high so that a small number of people are selected and progress to the next stage of the process with a relatively high probability of success, or whether to set cut-off scores low so that a large number of people are selected with a relatively low probability of success at later stages.

- Whether to make frequent decisions about whether an applicant should proceed to the next stage of the process, perhaps after every individual test, or whether to delay a decision until all the test results are available.

- Whether to reject an applicant unreservedly if he or she scores below the cut-off point, or whether to allow the applicant to re-sit a test if their score lies within a predefined range.

In the examples given, except the last one, the alternatives fall at the extremes of the range of choices which could be made and the best choice is likely to lie somewhere in between. Each example involves trade-offs such as the two illustrated below.

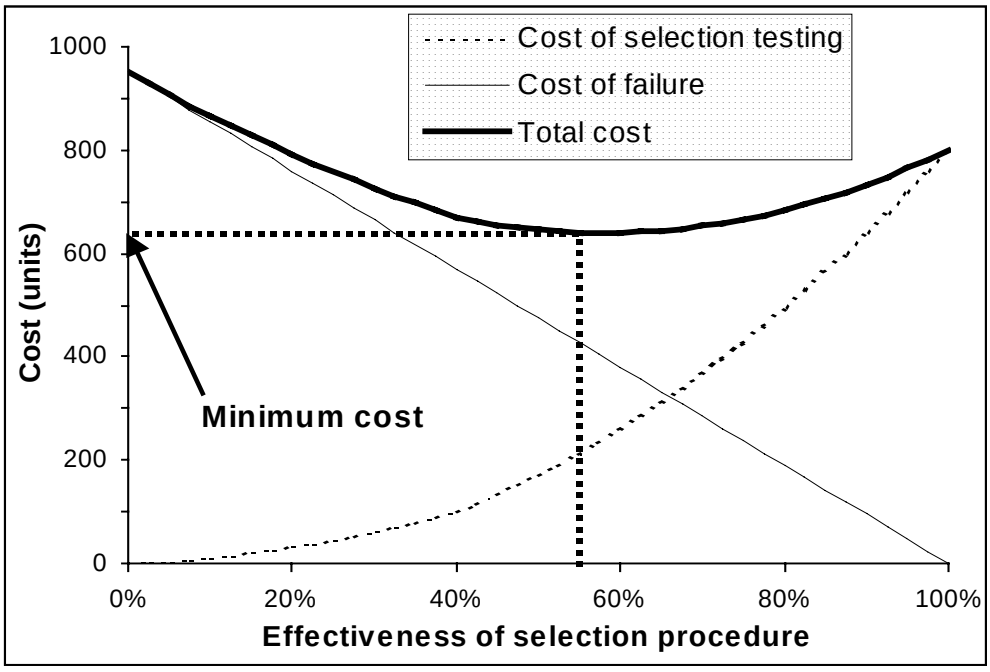


Figure 3: Trade-off between cost of selection testing and cost of failure in training as the effectiveness of the selection procedure increases

In Figure 3 it is assumed that the effectiveness of the selection procedure is linearly related to the cost of failure rate in training. This is shown as the 'Cost of failure' line. If an effectiveness of 100% (perfect selection) could be achieved everyone will pass training and the cost of failure would be zero. If, on the other hand, the effectiveness of selection was 0% (totally ineffective selection) it could well be that the pass rate in training is even less than by selecting at random from the applicant population. It should be noted that it is possible for the effectiveness to be less than 0% since a selection test could select **unsuitable** people. If this would be the case (not shown in Figure 3), the costs of failures would be even higher than selecting at random with the additional cost for selection adding up to very high total costs.

Intuitively one would expect the cost of selection testing to increase as the effectiveness of the selection procedure increases, although this is not always the case. This is shown as the 'Cost of selection testing' line in Figure 3. At the 0% effectiveness point where selection is made at random, the cost of selection testing will be zero. At the lower end of the effectiveness scale testing may consist of a small number of simple tests or in the extreme one short simple test at low cost. At the higher end of the scale complex tests of high sophistication may be used at high cost.

However, it should be mentioned that it might well be possible to design and implement an effective selection system at relatively low costs. This would move the total cost line in Figure 3 towards higher effectiveness at lower total costs.

It can be seen in Figure 3 that there is a trade-off between the cost of selection testing and the cost of failure. As the cost of selection testing rises the cost of failure in training falls. When the two costs are added the total cost reduces until some minimum cost is reached when the cost begins to increase. There is therefore some level of effectiveness of the selection procedure where the total cost is minimised. Although the success rate in training would be increased if this level of effectiveness was exceeded, the additional cost of selection would be greater than the financial benefit realised from a reduced failure rate. There would therefore be no economic case for raising the effectiveness further by spending more money on selection and other options (e.g. raising effectiveness in the training system) should instead be considered.

Another illustration of a trade-off is the effect on total cost as the number of applications received for each training place available increases (see Figure 4).

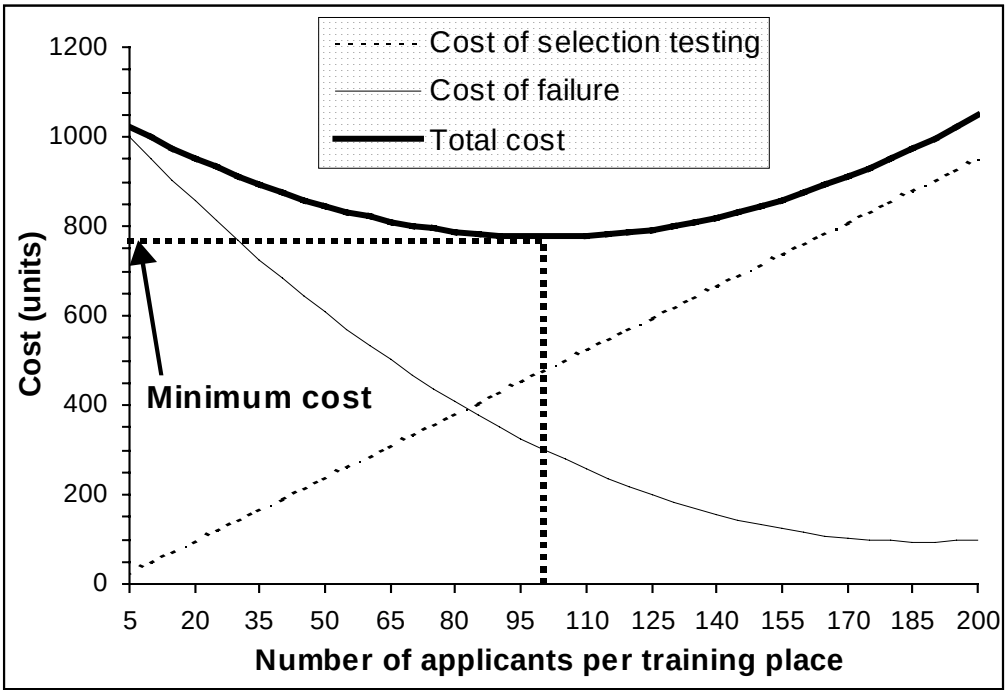


Figure 4: Trade-off between cost of selection testing and cost of failure in training as the number of applicants per training place increases

In the case of a top-down approach and provided that all candidates were tested, the cost of selection testing will increase as the number of applicants per training place increases. This is because selectors can become more demanding as the number of applicants per training place increases. As can be seen from Figure 4 there will be a certain number of applicants per training place where the total cost is minimised.

Both examples described are based on **hypothetical** data and no numerical inferences should be made.

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# 5. METHODOLOGY FOR APPLYING CBA TO THE RECRUITMENT AND SELECTION PROCESS

## 5.1 Overview

The process for producing a newly licensed ATCO, qualified to work on his or her own in some sector of airspace, consists of a number of stages. The stages which are undertaken will depend on the ATS provider but typically consist of those illustrated in Figure 5.

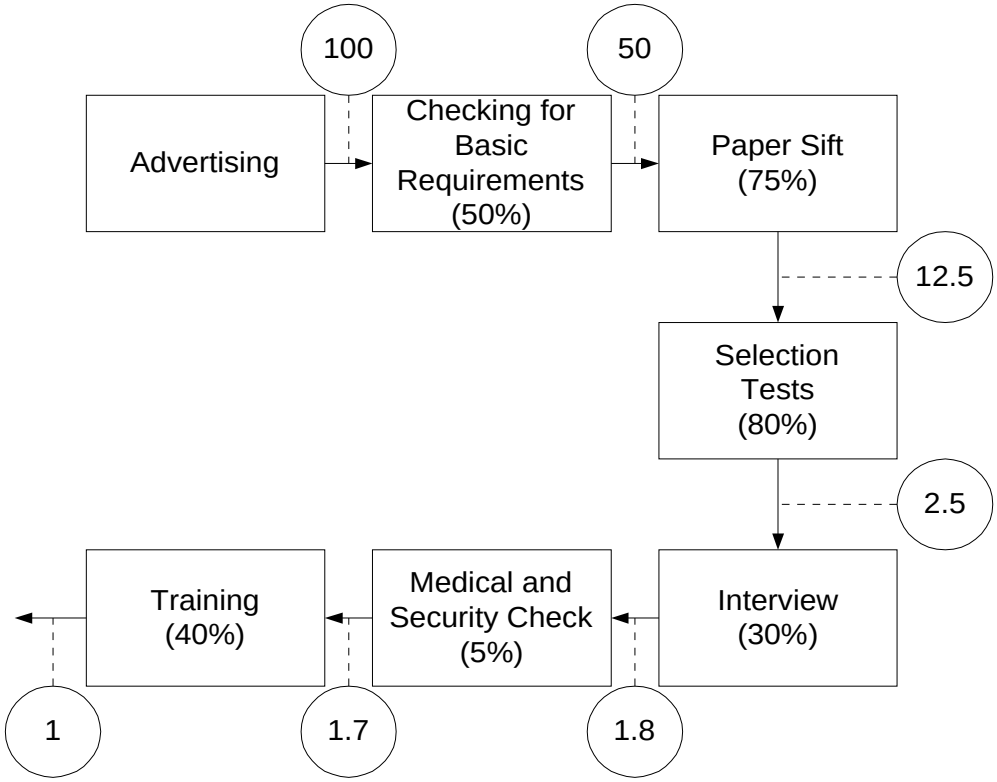


Figure 5: Simplified process for the recruitment, selection and training of *ab initio* controllers

Note: At each stage of the process applicants are rejected and, in the simplified **hypothetical** example shown in Figure 5, average rejection rates at each stage are shown in brackets. The numbers shown in circles indicate the average number of applicants who are required to enter each stage of the process to produce one licensed controller at the end of training. In this example 100 people responding to an advertising campaign could be expected to yield a single licensed controller. Clearly a change in the acceptance rate at any stage of the process will directly affect the number of applicants required at all previous stages.

The actual process used by an ATS provider may be more complex than that shown above and, in particular, the stage shown as 'Selection Tests' could consist of a number of separate activities. This stage will be discussed in greater depth in Sub-chapter 5.2.4. For the time being the simplified process shown in Figure 5 will be sufficient to illustrate several principles related to carrying out CBA on recruitment and selection.

Training is not part of the recruitment and selection process and is not covered by this study. However, it is shown in the process diagram because the failure rate in training is a measure of how well the recruitment and selection process is performing. A change made in any stage prior to training will almost certainly affect this failure rate.

### 5.1.1 Fixed and Variable Costs

Each stage of the process has a cost associated with it. This cost can be split into a fixed element (which may be small or close to zero in some stages) which is independent of the number of people passing through the stage and a variable element which is incurred by every person who passes through the stage. The total variable cost element of the process as a whole is therefore dependent on the failure rate at each stage.

An example of a fixed cost would be an annual licence fee which is payable for being able to use a particular selection test, whereas an example of a variable cost would be the expenses paid to an applicant for attending a testing session.

Fixed costs for a particular stage will depend on how that stage is organised. There may be a trade-off between reorganising a stage to reduce its fixed cost and a consequent increase in its variable cost. Conversely it may be possible to reduce the variable cost incurred at a stage by increasing the fixed cost. Any reorganisation of a stage may change the rejection rate at that (and / or subsequent) stages, so its financial impact is not easily calculated.

### 5.1.2 Time Span of the Process

The time span of the process illustrated in Figure 5 is long. Recruitment and selection may take 2-6 months to complete and there may be a delay of 6-12 months before a place becomes available on a training course. The longer the delay the more likely it is that a recruit will decide to withdraw and take up alternative employment. Also, the longer the delay in conducting medical and security checks, the less valid the tests might be.

Training can take 1-3 years to complete and will depend on the training academy which the *ab initio* trainee attends. Trainees are assessed continuously during training and failure can take place at any time. The cost of failure will increase the longer a trainee attends the course before training is terminated.

Cost savings could be made if those trainees who are going to fail could be identified as early as possible in training. However, even if this were the case, the training place would most probably be lost and no improvement in the success rate would ensue. For the purposes of evaluating alternative methods for recruitment and selection it will be assumed that any improvement in the overall success rate in training will be spread across all the stages in training where a trainee can fail. Thus the cost of failure in training is directly proportional to the failure rate in training.

## 5.2 Effect on Total Process of Making Changes at Individual Stages

The impact on the process as a whole of making changes at individual stages will now be considered.

### 5.2.1 Advertising

The objective of advertising is to attract quality applicants with the characteristics and abilities that are considered to be necessary to succeed in both training and in the work of an ATCO. However, in the hypothetical example shown in Figure 5, only 1% of those responding to advertisements would eventually gain licences to work as ATCOs. Anyone responding to an advertisement will result in cost being incurred in at least the next stage of the process and, because the selection system is imperfect, some poor quality applicants will not be filtered out until later stages and a few will inevitably enter training. The less well targeted that advertising is, the greater will be the cost through sheer numbers of applicants.

Improving advertising by correct targeting of the potential applicant population and encouraging a high level of self-selection before an application form is returned would lead to significant financial benefits since it impacts on every stage of the recruitment, selection and training process.

Test batteries were designed to filter out people who are predicted not to have the necessary abilities, knowledge and skills required by an ATCO. Less focus has, in general, been put on developing appropriate marketing and advertising literature and designing application forms which will filter out unsuitable people before they even apply.

When the conversion rate of applicants to licensed controllers is low, suitable applicants may be deterred from applying because of their perception of the low likelihood of eventually succeeding in their chosen career. It will appear to them that a controller is a very special person with a rare combination of abilities and skills, although this perception may be incorrect. A further benefit of taking a more focused approach to advertising is that the likelihood of success would be higher, perhaps considerably higher, and this may encourage a greater number of suitable individuals to apply.

### 5.2.2 Checking for Basic Requirements

The objective of checking is to ensure that applicants satisfy the basic requirements to proceed to the next stage. These requirements should be known to applicants before they apply. A well designed application form will enable checking to be undertaken very quickly. Provided that the basic requirements have been identified correctly and can be shown to be absolutely necessary to perform the job of an ATCO, suitable people will not be rejected by the checking procedure. There is therefore little further that can be done at this stage which will benefit the process as a whole.

Because checking is a mechanical process it could, in theory, be carried out by a computer. This would be possible if application forms were electronically scanned or if an electronic application form were used, perhaps through the Internet. However, there are still various technical and legal issues to be addressed before applying this procedure.

### 5.2.3 Paper Sift

The objective of paper sift or pre-selection is to eliminate applications of persons who have little chance of succeeding at selection testing and subsequent stages of the process. It is normally an administrative necessity to carry out a paper sift to reduce the applicant population to a manageable size for selection testing.

Paper sift is similar to checking but is often a much more subjective process carried out by recruitment personnel or people with experience in ATC. A score may be assessed on the overall impression projected by the applicant through the application form when compared with one or more assessors' personal view of the profile necessary to succeed in ATC. Decisions on whether to allow an applicant to proceed to the next stage of the process are made on this score, or the sum of scores if more than one assessor is used.

The validity of paper sifting is rarely calculated and if done in a subjective way can be expected to be low. However, it is possible to improve paper sifting using more objective methods (see EATCHIP, 1998c).

The errors inherent in any selection method (i.e. wrongly accepting unsuitable applicants and / or wrongly rejecting suitable applicants) were explained in Sub-chapter 4.3. If the validity of a method is low the errors resulting from that method will be high and the balance between the two types of error will be determined by the cut-off score which is set. If the cut-off score is set high (on a measurement scale where a high score predicts high potential ability) few applicants will be selected but the failure rate of those applicants at later stages will be low. However, many applicants of suitable ability will be rejected. Conversely, if the cut-off score is set low, many applicants will be selected but the failure rate of those applicants at later stages will be high.

The former strategy may appear to cost less in the short term but could result in places available on training courses not being filled. If insufficient licensed

controllers emerge from training to fill the vacancies available in ATC, shortages will appear and grow in future years. The effect of these shortages will be insufficient capacity at an Area Control Centre (ACC) to meet future traffic growth resulting in delay to aircraft wishing to fly through an area or re-routing of aircraft through another area. Delay will result in a cost to the customers and re-routing may result in route charges being lost to another ATS provider.

The latter strategy may appear attractive because few suitable applicants are rejected and filters are in place at later stages of the process, where the validity of the selection procedure is likely to be higher, to reject unsuitable applicants (i.e. errors at the paper sift stage). However, the system may not be able to cope with a large number of applicants successfully emerging from the paper sift stage.

It can be seen from this analysis that the cut-off score which is set will have a major impact on the costs at each subsequent stage of the process. Hence, there is no simple way of determining the added value of paper sift in financial terms.

### 5.2.4 Selection Tests

The comments made about setting cut-off scores in the previous Sub-chapter are equally true in selection testing. However, because it can be assumed that tests have a higher objectivity, reliability and their validity is likely to be greater than the validity of both paper sift and interviews, there is therefore a case for applying a finer filter at the testing stage than at any other stage of the process.

The variety of selection tests and test batteries in use in a number of States are described in an EATCHIP report (EATCHIP, 1997) and guidelines have been written for selection procedures and tests for *ab initio* trainee controllers (EATCHIP, 1996b, 1998a, 1998b, 1998c).

### 5.2.5 Interview

Interviews are normally carried out by an interview board and last at least an hour. They are therefore labour intensive and should be undertaken in the latter stages of the process to minimise cost. In spite of the many selection tests which may be given to filter out applicants before the interview, rejection rates at this stage are quite high and a figure of 30% is not unusual.

Research has shown that the consistency of ratings given by an interviewer or interview panel is often low and that the validity of interviewing as a selection technique is also low but positive (Hunter and Hunter, 1984). This implies that the interview is giving a small amount of added value to the process but that the errors are high. Because those accepted will go on to undertake training and the cost of failure in training is high, it would be better to be biased towards rejecting suitable applicants at this stage unless the validity of interviewing could be increased.

### 5.2.6 Medical and Security Checks

The objective of the medical and security checks is to screen out applicants who do not meet the medical requirements set by ICAO and to screen out applicants who may be a threat to security. These checks are normally carried out as the final stage of the recruitment process on applicants who are otherwise considered suitable for training. Rejection rates are normally low compared with the rates at other stages of the process. Medical and security suitability can be considered to be independent of all other characteristics which are tested at other stages of the process. For this reason the rejection rate would be the same at whatever stage of the process the checks were carried out. To minimise cost it is sensible to carry them out on the smallest number of people as possible, which will occur immediately prior to training.

## 5.3 A Framework for Applying CBA in Recruitment and Selection

It has been shown in Sub-chapter 5.2 that there are a number of interdependencies in recruitment and selection which make it very difficult to maximise the cost-effectiveness of the process as a whole.

This Sub-chapter describes a framework which can be used to evaluate the cost-benefit of making changes to an existing process. The framework is most easily described by making reference to a hypothetical recruitment and selection system. This will be based on the simplified sequence of activities and failure rates shown in Figure 5.

### 5.3.1 Identification of Costs

Costs should be identified for each activity in the process. They should be split between a fixed element, which is independent of the number of people passing through that stage of the process, and a variable element which is incurred by each person, whether they succeed or are rejected at that stage. The total cost of the process will depend on the number of people passing through each stage, and this number will depend on the failure rates at all previous stages.

In the hypothetical example it will be assumed that 2 training courses are run during a year and the capacity on a training course is 15 people. Thus 30 people enter the training stage of the process.

A cost structure relating to this example in some unspecified monetary units might be as follows (see Table 1).

Table 1: Cost structure for a hypothetical example of recruitment and selection as illustrated in Figure 5 (**hypothetical** figures)

| Stage of Process | Fixed Cost /Year | Variable Cost /Person | Rejection Rate at Stage | Number of People at Stage | **Total Cost /Year** |
|---|---|---|---|---|---|
| Advertising | 30,000 | 200 | 0% | 1808 | 391,600 |
| Checking | 0 | 20 | 50% | 1808 | 36,160 |
| Paper sift | 0 | 80 | 75% | 904 | 72,320 |
| Selection tests[1] | 80,000 | 400 | 80% | 226 | 170,400 |
| Interview | 0 | 200 | 30% | 45 | 9,000 |
| Medical | 0 | 150 | 3% | 31 | 4,650 |
| Training | 1,400,000 | 120,000 | 40% | 30 | 5,000,000 |
| **Total** | **1,510,000** | **--** | **99.0%** | **18** | **5,684,130** |

Once the costs for each activity have been identified, they can be broken down into a cost/year under each of four categories:

i) **Fixed cost**

ii) **Variable cost**

This is the total variable cost incurred by those people who are selected for training and emerge from training as licensed controllers.

iii) **Recruitment and selection rejection cost**

This is the total variable cost incurred by those people who are put through all or part of the recruitment and selection system but are rejected at some point before training starts. Note: It does not include the cost of those people who fail in training (for these costs see next bullet iv).

[1] Costs for selection tests include costs for necessary development and maintenance.

iv) **Training failure cost**

This is the total variable cost incurred by those people who start but do not complete training. It consists of the recruitment and selection cost of the unsuccessful trainees and their training costs. Note: These are the costs that need to be spent again in order to **regain** (e.g. through advertising, selection etc.) the training place for those that were already selected but failed during training.

The cost breakdown for the **hypothetical** example with 18 successful trainees (and the effects of the 12 unsuccessful trainees) (see Table 1) is shown in numerical form in Table 2 and in graphical form in Figure 6.

Table 2: Cost breakdown for a **hypothetical** example of recruitment and selection

| Stage of Process | Fixed Cost/Year | Variable Cost/Year (18 people) | Rec & Sel Rejection Cost/Year[2] | Training Failure Cost/Year[3] |
|---|---|---|---|---|
| Advertising | 30,000 | 3,600 | 213,360 | 144,640 |
| Checking | 0 | 360 | 21,336 | 14,464 |
| Paper sift | 0 | 1,440 | 41,952 | 28,928 |
| Selection tests | 80,000 | 7,200 | 47,040 | 36,160 |
| Interview | 0 | 3,600 | 1,800 | 3,600 |
| Medical | 0 | 2,700 | 90 | 1,860 |
| **Rec. & Selection** | **110,000** | **18,900** | **325,578** | **229,652** |
| | | | | |
| **Training** | **1,400,000** | **2,160,000[4]** | **0** | **1,440,000** |

[2] 'Total Cost/Year' as shown in Table 1 minus 'Fixed Cost/Year' minus 'Training Failure Cost/Year' minus 'Variable Cost/Year (18 people)' as shown in Table 2.
[3] 40% of total cost/year minus fixed cost/year as shown in Table 1.
[4] Variable cost for 18 people for the whole training stage.

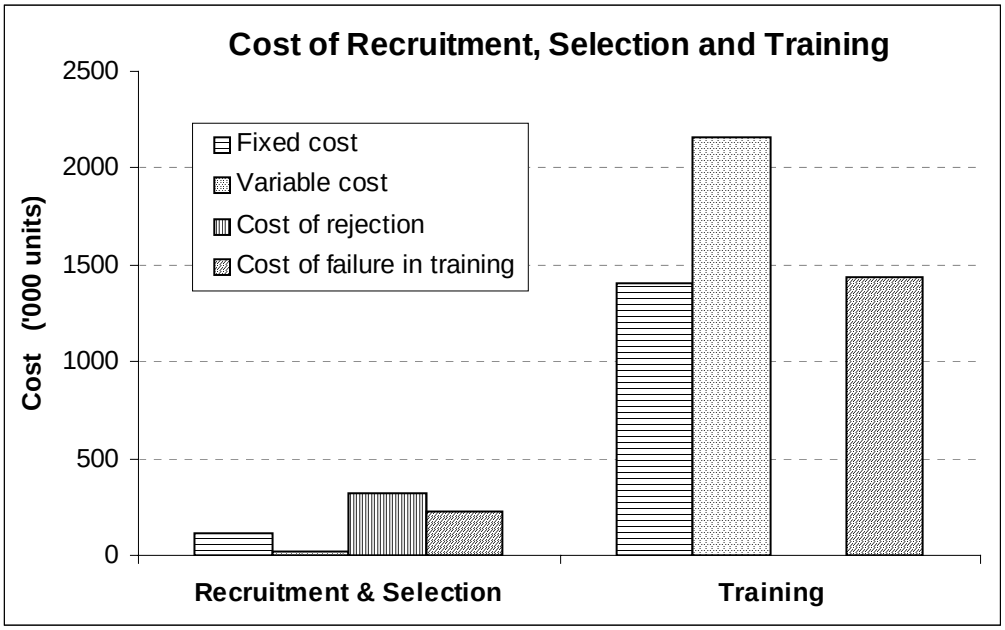


Figure 6: Breakdown of cost of recruitment and selection and cost of training

Note: In the example shown in Figure 6 the total fixed and variable cost per annum of recruitment and selection including rejections is 454,478 monetary units whereas the total cost per annum of failure in training is 1,669,652 monetary units.

A modified recruitment and selection system will be beneficial if any additional cost incurred in recruitment and selection to reduce the failure rate in training is more than compensated for by the reduction in the cost of failure. This can be evaluated by constructing Table 2 with new costs and rejection rates at the stages which are to be changed.

### 5.3.2 Identification of Benefits

In Sub-chapter 5.3.1 it was assumed that a fixed number of people would enter training each year and that the benefit of better selection would be realised through a reduction in cost of the total process. No account was taken of the increase in the number of licensed controllers per year which an enhanced recruitment and selection system would produce. The benefits arising from reducing the failure rate in training depend on whether the supply of new controllers under the current system is less than, satisfies, or exceeds demand.

**Benefits if Demand of Controllers is Satisfied**

If demand is currently being satisfied, increasing the output of licensed controllers will create a surplus which will lead to additional costs from employing people who are not necessary to meet demand in the short-term. This temporarily costly situation will require MP adjustments, which can be

avoided if the frequency with which training courses are held could be reduced. This should enable some of the variable cost associated with training to be removed.

For example, the number of people required to administer training would be less. This might free more resources to be used operationally, in other projects, e.g. to deliver training using underutilised simulators to other ATS providers who either do not have such sophisticated facilities or whose equipment is being used to capacity.

**Benefits of Reduced Failure Rate in the Case of Controller Shortage**

If there is a shortage of operational controllers in an ACC and training courses are producing too few newly licensed controllers to fill these vacancies, a reduction in the failure rate in training would enable more controllers to be produced from the same number of training courses.

The effect of having a shortage of controllers is that insufficient capacity will be available at peak times to handle the number of flights requested by the airlines to fly through the airspace controlled by the ATC. This will result in a cost to the airlines due to either re-routing aircraft onto non optimal flight paths to avoid congested sectors, or delays imposed by ATFM to ensure that capacity is not exceeded, or both. It will also result in the loss of route charges to the ATS provider if aircraft are re-routed through another region of airspace under another ATS provider's control.

Future research at the Central Office for Delay Analysis (CODA) may look into the impact of shortages in the required ATCO number on delays.

### 5.3.3 Time Span for Cost-Benefit

So far costs and benefits have been identified on a per annum basis. However, since training may take several years to complete the full benefit of improving the recruitment and selection process will not be felt until all controllers selected by the new system have gained their licence. There will therefore be a time lag between making improvements to recruitment and selection and experiencing a reduced failure rate in training.

In addition, benefits for a particular year will depend on whether there is a shortage or over supply of newly licensed controllers for that year. An analysis could be performed on the costs and benefits of improving selection over several discrete years to examine the effect of the time lag. This would be necessary if a capital investment in new selection methods was being made which had a payback period of more than one year.

However, as suggested by Figure 6, the additional cost of improving selection is likely to be small compared with the reduction in the cost of failure in training which it achieves and some improvements, such as changing cut-off scores, will require no one-off investment at all. In many cases there will be a net benefit in the first year of the change and this benefit will continue to grow

until the full reduction in the training failure rate has been achieved. In these cases it will be even sufficient to justify a change by examining the benefit in a single, full year if indeed the change in failure rate is stable.

### 5.3.4 Relationship to Manpower Planning

The number of places available on training courses and the average failure rate will determine the expected number of newly licensed controllers who will come out of training each year. However, the actual number for any future year is unknown. Assuming all training places are filled, this is due to two reasons:

- The variance in the annual failure rate in training.
- The variance in the time taken for an *ab initio* trainee controller to complete training.

Both reasons are further considered in the following Sub-chapters.

### 5.3.5 Variance in Failure Rate in Training

The first and most significant reason for uncertainty in the number of newly qualified controllers who will emerge in a year is that the failure rate is not the same every year and in many States has a very high variance. Take, for example, a State where the average failure rate is 40% per annum but where the rate in any particular year could be in the range 10% to 70%. If 30 people enter training in this State every year, the number of licensed controllers emerging in a year could be anywhere between 27 and 9. If demand matches the average supply of 18 newly licensed controllers a year, in any one year there could be up to 9 too few or 9 too many controllers completing training, and the error could be in the same direction for several concurrent years.

High variance in the success rate in training makes it impossible to undertake MP in any sensible way and is clearly expensive. It would be possible to model this variance and provide a probability distribution for the range of costs that a State could experience each year as a consequence of the selection and training process but this would not help in decision making. It is important for a State to understand the reasons for this variance which may be due, for example, to poor selection or training practices (or both), and take steps to control it. Other sources of a high variance to consider could be:

- change in training scenarios and training evaluation;
- sampling error (e.g. the numbers change yearly, see below);
- change of recruitment sources;
- the way in which failures are perceived in an organisation.

It is good practice when undertaking an improvement programme to bring a process under control before attempting to improve any of its component parts. If the process is out of control it is impossible to measure whether any change which is made to one part of the process is having a beneficial effect. In the example in the previous paragraph, if one would change the selection system and measure the failure rate in three consecutive years as 35%, 25% and 45% (average 35% compared with a long term average of 40%) one could not be sure that the failure rate had been permanently reduced if nothing had been done to reduce its variance.

### 5.3.6 Variance in Course Completion Time

A second reason for uncertainty in the number of newly qualified controllers emerging in a year is that the time taken for an *ab initio* trainee to qualify for a licence is not constant. In certain circumstances it is possible for trainees to retake an examination which they have failed; this will extend the training time. The time taken to complete OJT will also vary depending on various reasons, not always related to the trainee.

A considerable investment will have been made in an individual once they have started training and a decision has to be taken as to whether it will be more beneficial to extend training time rather than fail someone if they are eventually able to qualify for a licence and work successfully as an ATCO.

# 6. APPLICATION OF THE METHODOLOGY

Within the foregoing Chapter some suggestions have been made as to how the process might be improved and guidance has been given on the data which needs to be collected to identify the cost of the existing process and the benefits which might arise from improvements which are made to it.

A theoretical model of a selection test is provided in Annex A which, after calibration, allows the proportion of people selected by a test who will fail later on in the process to be calculated when changes are made to the parameters of the test.

The following Sub-chapters describe some specific examples of changes which might be made to the selection process and how the benefit of those changes can be evaluated.

## 6.1 Increasing the Reliability and Validity of Selection Tests

Increasing the reliability and / or validity of a selection test or selection test battery will reduce the errors inherent in the test. In the context of the terms used in Annex A, and assuming that the cut-off score does not change, the percentage of False Negatives (FNs) and False Positives (FPs) will reduce and the rejection or failure rate at the next and subsequent stages of the process will also reduce. The number of people selected from a given number of applicants (i.e. the selection rate) may rise or fall depending on the value set for the cut-off score.

In introducing selection tests with higher reliability or validity the fixed and variable costs of selection testing may change and the rejection rates at the selection testing and subsequent stages will also change in a way that can be determined by the theory described in Annex A.

By constructing cost tables for the current and new scenarios in the format illustrated in Table 2, the total cost/year of both scenarios can be compared and any benefit from increasing reliability or validity can be quantified.

## 6.2 Changing Cut-off Scores at Different Stages of the Selection Process

The effect of changing the cut-off score used at some stage of the process will be to change the percentage of people who fall into each of the four quadrants shown in Figure 8 of Annex A. If the cut-off score is increased, the selection rate will reduce and the failure rate after selection will also reduce. If the cut-off score is reduced, the selection rate and failure rate after selection will both increase.

The financial impact of changing a cut-off score can be evaluated by modifying the data shown in Table 2. The fixed and variable costs will remain the same but the rejection rates will change at the stage where the cut-off score is changed and in subsequent stages. The theory described in Annex A can be used to determine the new rejection rates. Revised values for the people entering each stage and the total cost/year for each stage of the process can then be calculated and the overall cost per year for different cut-off scores can be compared.

There is a trade-off between the cost of reducing the selection rate, and therefore increasing the number of applicants required to fill a place in training, and the benefit of fewer people failing in training. In a single stage process there will be some cut-off score which minimises the cost of the process. In a multi-stage process there will be cut-off scores which should be set at each stage to minimise the cost of the whole process.

## 6.3 Increasing Reliability / Validity and Changing Cut-off Score

As described in Sub-chapter 6.2 there is a cut-off score for a selection test which will minimise the cost of the selection and training process. This score will depend on the characteristics of the distribution which describes the relationship between predictor score and criterion value. These terms are defined in Annex A.

When a test is replaced by a test of higher reliability and / or validity the characteristics of this distribution will change and the optimum cut-off score for the new test will therefore also change.

## 6.4 Re-testing of Marginal Cases

Because the reliability of a selection test is not perfect applicants may score more or less than their true score on a particular test or set of tests. If the error is in the negative direction their measured score will be less than their true score. If their true score lies at or a little above the cut-off score for the test they may be rejected when in fact they should have been selected. In the terms described in Annex A, these applicants will be FNs.

The likelihood of a FN score increases as the measured score approaches the cut-off score and there is a region near the cut-off score where there may be benefit in re-testing people in an attempt to identify the FNs who should have been selected. However, some of the people who are re-tested and then selected will end up as FP.

Provided there is no adverse affect it might be financially beneficial to re-test a small number of marginal cases. However, the STF has not yet found any empirical evidence with sufficient sample size to indicate that re-testing is (or is not) a beneficial procedure (EATCHIP, 1998a).

## 6.5 Encouraging Self-selection Before Application

Effective self-selection before application would result in higher success rates at each stage of the process. This would lead to two main benefits:

- Fewer applicants would be required to produce one licensed controller at the end of training and the cost of the process as a whole would be lower.

- Suitable applicants are more likely to consider it worthwhile applying if they perceive that there is a reasonable chance of them succeeding at each stage of selection and training.

The benefit can be readily quantified by reducing the rejection rate at each stage in Table 1.

For example if, by means of focussed marketing and advertising, the success rate from initial application to receiving a licence could be increased from 1% to 20% in the example shown in Table 1 and the rejection rate was improved by the same proportion at each stage of the process, the total cost per annum could be reduced from 5.68 million units to 5.18 million units, assuming that the fixed and variable costs remained the same.

A page on the Internet would be one way of communicating pertinent information to people who have the qualities to become a successful ATCO and, if it was carefully designed, could encourage a greater degree of self-selection before application.

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# ANNEX A: THEORETICAL MODEL OF A SELECTION TEST

In selection, tests are used (in conjunction with other information, for example, from application forms or from interview) to make predictions about later performance of individuals in training and / or in the job and to arrive at decisions whether an applicant should be accepted or rejected (EATCHIP, 1998a).

The criterion should be related to a person's ability to carry out the job for which they are being considered. If the criterion is measured on some numerical scale there will be some threshold value above which a person has the required ability to perform in training and / or in the job satisfactorily and below which they do not. In Figure 7 the criterion threshold value is assumed to be 5.6.

**Test - Criterion Relationship in Idealistic (Perfect) Selection**

The following illustrates an idealistic, that is, practically not achievable example of a perfect selection test or test battery: If the selection test or test battery was a perfect predictor of a person's performance in training and / or in the job the test score of a person would relate exactly to a certain true criterion value.

With a perfect selection test or test battery, selection would be simple and precise. The cut-off score for the selection test would be set at that value which corresponded to the threshold criterion value (in Figure 7 the cut-off score is derived at 5.5). Everyone scoring above the cut-off score would therefore be accepted; those who score below the cut-off score would be rejected. This is illustrated in Figure 7.

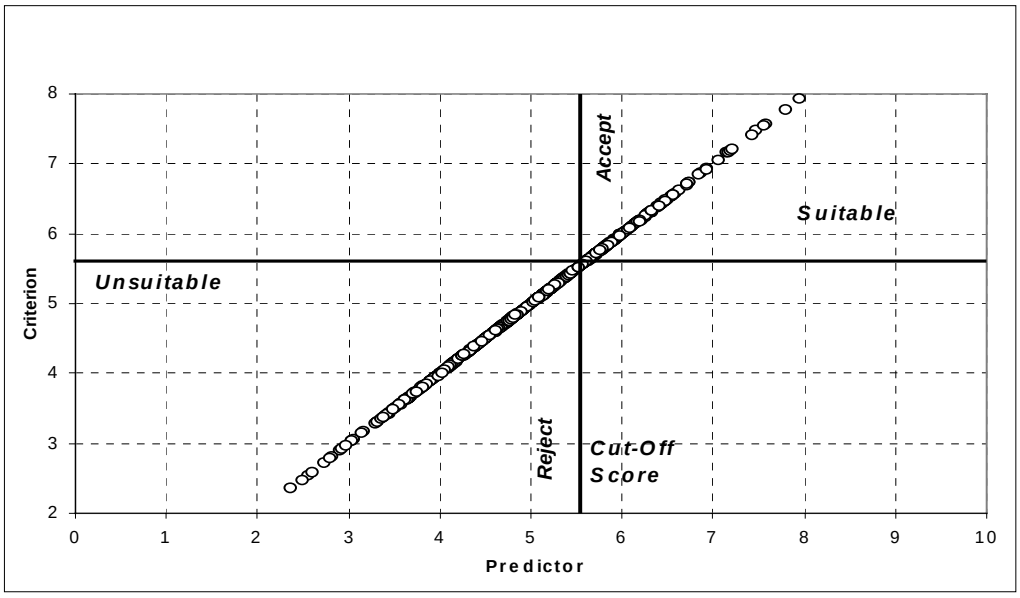


Figure 7: Relationship between predictor and criterion for an idealistic (perfect) selection test / test battery

**Test - Criterion Relationship in Practical (Imperfect) Selection**

However, in practice no selection is perfect. There are three major causes of error:

1. The first is related to the **reliability (or internal consistency) of the test**.

   The reliability is measured by a correlation coefficient being in the range [0,+1] [5]. In practice no selection test will be perfectly reliable, that is, a reliability coefficient for an acceptable test should be in the range [.70 - .95] with .70 as the lowest acceptable value (EATCHIP, 1997, Sub-chapter 2.1). See EATCHIP, 1998b, Chapter 6 for detailed information on reliability.

   In simple terms the reliability of a test measures the extent to which a person taking the same test a number of times (or when alternative forms of this test are used) will score the same on each occasion. Reliability is therefore related to the degree of randomness in the score obtained from a test. For the purposes of the following analysis it is assumed that this randomness is normally distributed about a person's unknown 'true' score. The lower the reliability of the test the greater will be the variance of a person's scores.

2. The second cause is related to the **reliability (or internal consistency) of the criterion**.

[5] Note: The correlation coefficient is normally in the range [-1,+1]. However, it is assumed here that under normal circumstances a test will have a positive reliability > 0.

The criterion used will in practical applications not be perfectly reliable. In fact, the reliability of the criterion will very often be even lower as the reliability of a standardised test, for example, if un-standardised assessment methods or ratings are used (e.g. in OJT). Evidence available shows that the average criterion reliability is about .60. See for more details EATCHIP, 1998a, Sub-chapter 4.3.1; EATCHIP, 1998b, Sub-chapter 4.4.2.

3. The third error is related to the **predictive validity of a test / test battery**.

   The validity is also measured by a correlation coefficient which will normally be positive and in the range [0,+1] [6]. Again, in practical applications no selection test / test battery will be a perfect predictor of a criterion. The validity coefficient for an acceptable test should be in the range [.25 - .60] with a coefficient close to or above .25 as the lowest acceptable value (EATCHIP, 1997). See for more details on validity EATCHIP, 1998b, Chapter 4.

   The validity of a test measures the variation in the criterion values for people who all have the same true predictor score and therefore the same estimated criterion value. It is assumed in the following analysis that true criterion values are normally distributed about the estimated criterion value. The lower the validity of the test the greater the variance in criterion values.

An important application of validity and reliability is in selection decision making. By examining both as well as the selection rate / ratio and cut-off scores, the predictive usefulness of a selection test can be assessed. This can then be compared to either the usefulness of another test or to a (hypothetical) situation where no test is used and persons would be selected at random. This is demonstrated in the following hypothetical example.

**Assessing the Usefulness of a Selection Test: A Hypothetical Example**

Figure 8 shows a hypothetical example of individual predictor-criterion relationships which are simulated for 1000 people sampled at random from a theoretical population of 30.000 applicants. It is a hypothetical representation but will be true if the foregoing assumptions on reliability and validity are accepted.

The distribution of predictor-criterion scores is known statistically as a bivariate normal distribution (Wonnacott and Wonnacott, 1990) and its shape is determined by the value of the reliability and validity coefficients. The hypothetical example assumes that the test used has a reliability of 0.8 and a validity of 0.4. The reliability of the criterion was assumed to be 0.5.

[6] Note: As mentioned in Footnote 2 the correlation coefficient is normally in the range [-1,+1] which would mean that a test / test battery could have a negative validity. Although this is not totally unlikely it is assumed here that under normal circumstances a test / test battery will show a positive validity with values > 0.

The scenario is further based on the following data:

- The **selection rate** is known from past experience being 15% (15 out of 100 applicants tested are selected). It can be seen from Figure 8 that the selection rate depends on where the cut-off score is set. Reverse to this one can calculate the theoretical cut-off score for a given selection rate.

The bold vertical line shows the assumed cut-off score for the test.

- The **success rate** is also known from past experience as being 60% (60 out of 100 candidates selected for training were successful). Reverse to this one can calculate the number of people that fail as a percentage of the number of people selected, i.e. failures / selection rate.

The success rate determines where the bold horizontal line in Figure 8 should be drawn which give the theoretical threshold criterion value in the example.

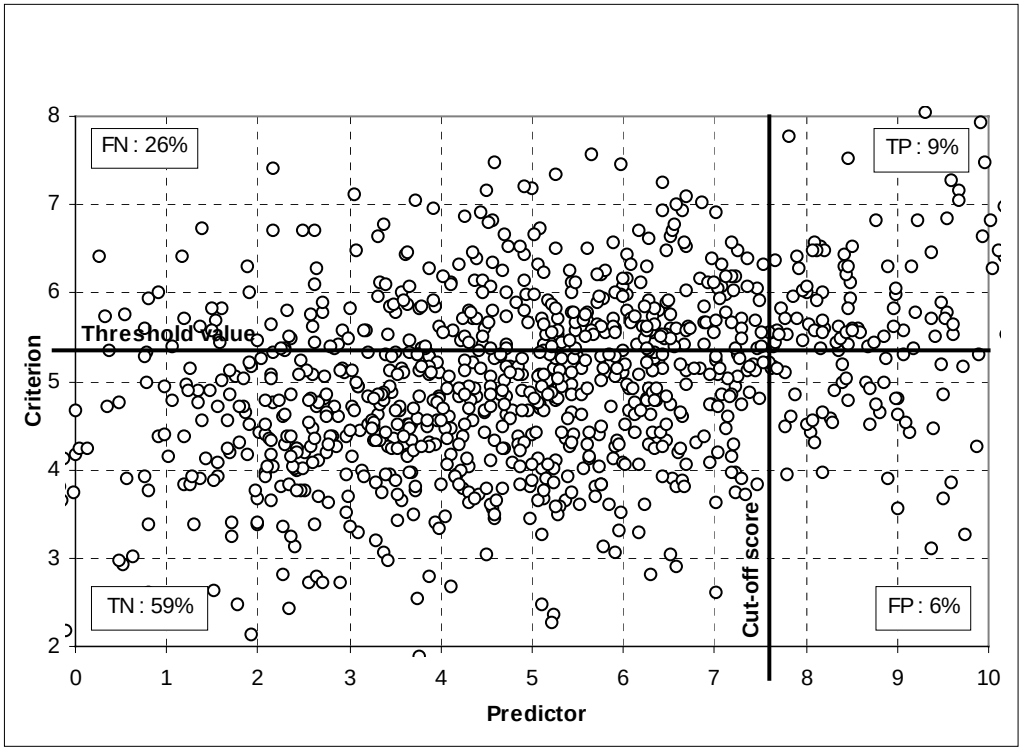


Figure 8: Relationship between predictor and criterion

The two lines divide the graph into four segments:

- The top right segment contains those people who have been correctly selected since they lie above the criterion threshold value and therefore have the ability to carry out the job. They are the **true positives (TP).**

- The bottom right segment contains those people who have been incorrectly selected since they do not have the required ability - the **false positives (FP)**.

- The bottom left segment contains those people who have been correctly rejected - the **true negatives (TN)**.

- The top left segment contains those people who have been incorrectly rejected - the **false negatives (FN)**.

Once the two lines have been fixed it is straightforward to calculate the number of people who fall into each of the four segments. This could be done by using tables for the bivariate normal distribution or, as has been done here, by means of a spreadsheet where the variance in the true predictor score, the variance in the criterion value for a given true predictor score, the cut-off score and the criterion threshold are set to calibrate the model to fit the data available.

**Estimating the Base Rate**

The percentage of people in the population taking a selection test who have the ability to succeed in the job (i.e. fall above the criterion threshold value) is called the base rate. Normally nothing is known about the value of the base rate or the number of people who are being incorrectly rejected but, as described above, these numbers can be derived from known information provided the assumptions are correct.

**Conclusions / Information Derived from the Hypothetical Example**

In the example in Figure 8 it can be seen that:

The selection rate is 6% + 9% i.e. 15%

The base rate is 26% + 9% i.e. 35%

The failure rate in selection is 6% / (9% +6%) i.e. 40%

False decisions are made about 26% + 6% i.e. 32% of the population and errors are weighted towards rejecting suitable people rather than accepting unsuitable people.

The model described in the foregoing and demonstrated by an example provides the means for evaluating the consequences of changes in any of the parameters of a selection test, e.g. validity, reliability or cut-off score.

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## GLOSSARY

For the purposes of this document the following definitions shall apply:

**Ability**[7]: What a person brings to the job situation without specialised, job specific training, education or experience. There are many kinds of abilities. As regards to ATCO selection the focus is on relatively broad mental abilities.

**Ability Tests**: A standardised and controlled method for measuring abilities in different areas (e.g. memory, spatial, perception, attention). Ability tests cover speed or power tests, paper and pencil or computer based.

***Ab Initio* Trainee Controllers**: Selected individuals, with no previous relevant qualifications, who are given basic instruction and training to enable them to obtain theoretical qualifications.

**Base Rate**: The percentage of people in the population taking a selection test who have the ability to succeed in the job (i.e. fall above the criterion threshold value).

**Candidates**: Individuals whose applications have been accepted for further consideration in the selection process but have not yet been selected finally as *ab initio* trainee controllers.

**Correlation**: The degree to which two sets of measurements vary together (SIOP[8], 1987).

**Cost-Benefit Analysis (CBA)**: A process for systematically identifying the costs and benefits arising in a project in both quantitative and qualitative terms, whilst taking into account their timing.

**Criterion**: A measure of job performance or job behaviour, such as training score or supervisory ratings.

**Cut-off Score**: A score in a predictor distribution of test scores below which candidates are rejected.

**Fixed Cost**: A cost which accumulates with the passage of time irrespective of the volume of input or output. It may change from period to period due to price inflation, market forces, etc.

[7] There is yet no final position in the professional literature with regard to the question whether abilities are 'innate' qualities or have been already partly shaped by general education and experience.

[8] Society for Industrial and Organizational Psychology (SIOP), Inc. (1987). *Principles for the Validation and Use of Personnel Selection Procedures*. Third Edition. pp. 1-44.

**Interview**: A structured, or unstructured, one-to-one or one-to-several on a panel conversation with a job-applicant for the purpose of identifying knowledge, skills, abilities and behaviours that may be predictive of success in subsequent training and in the job. To this effect biographical, or situational, performance and or motivation related information from the applicant is taken into consideration in order to make a decision on employment.

**Job:** A group of a certain number of core tasks, direct support tasks and indirect support tasks which require a certain level of abilities, knowledge and skills.

**Knowledge**: The job-specific content or information which a person has gained through training, education and / or experience. Knowledge is built upon the foundation of mental abilities that a person brings to the situation

**Mental Abilities**: The operations of the mind which are the fundamental, basic - and to some degree abstract - capacities and processes of perceiving, thinking, and deciding.

**On-the-Job Training (OJT)**: The integration in practice of previously acquired job related routines and skills under the supervision of a qualified coach in a live traffic situation (EATCHIP, (1995) Air Traffic Controller Training at Operational Units, HUM.ET1.ST05.4000-GUI-01).

**Operational Controller**: The holder of a certified qualification to permit that individual to control air traffic at a specific unit.

**Paper Sift**: The sift of application forms and attached application material in order to pre-select candidates according to previously defined criteria.

**Payback Period**: The elapsed time from the commencement of expenditure on a project to the point where the value of benefits have exactly covered accumulated costs.

**Personality Tests**: Questionnaires (or inventories) to measure personality traits or behavioural tendencies (CDSEPT[9], 1996).

**Predictive Validity**: A demonstrated relationship between test scores of applicants and some future behaviour on the job (SIOP, 1987).

**Psychological Testing**: The measurement of some aspects of human abilities by standardised procedures consisting of carefully prescribed content, methods of administration, and interpretation. Tests are usually administered

[9] Committee to Develop Standards for Educational and Psychological Testing, (CDSEPT), of The American Educational Research Association, The American Psychological Association, and The National Council on Measurement in Education, chaired by M. R. Novick (1996*). The Standards for Educational and Psychological Testing*. Washington, DC: American Psychological Association.

by qualified psychologists or specially trained staff according to professional and ethical principles.

**Reliability**: A measure of consistency or dependability or repeatability. The results of a particular testing session should be replicated if the same individuals were re-tested under similar conditions. Reliability of a test means that the test behaves the same way under a variety of circumstances (e.g. the test yields similar results when different persons administer it, when the test is administered on different occasions, when alternative forms of the test are used, etc.).

**Sector**: A means of dividing a piece of airspace for which controllers are responsible in order to make the workload more manageable.

**Selection Instrument**: Any method or device used to evaluate characteristics of persons (SIOP, 1987).

**Selection Procedures**: Selection procedures provide guidelines for accepting, or rejecting, applicants for a job on the basis of data from application forms, psychological tests, personality inventories or interviews.

**Selection Ratio**: The percentage of those candidates considered who are selected.

**Skill**: Competence to perform the work required by the job (SIOP, 1987).

Skills refers usually to the combination of ability and knowledge after training and practice which is required to perform a specific job.

**Test**: A standardised and controlled method for measuring abilities, knowledge or personality of applicants based on a sample of behaviour.

**Training**: The planned systematic development of the knowledge, understanding, skill, attitude and behaviour pattern required by an individual in order to perform adequately a given task or job.

**Validation**: The effort through which the appropriateness and meaningfulness of interpretations from scores on a measure can be estimated (SIOP, 1987).

**Validity**: The degree to which inferences from scores are justified or supported by evidence (SIOP, 1987).

The extent to which predictor samples of behaviour effectively overlap with performance domains could serve as an operational definition of validity.

**Validity Coefficient**: A coefficient of correlation showing the strength of relationship in a criterion-related study (SIOP, 1987).

**Variable Cost**: A cost which varies directly with fluctuations in the volume of input or output.

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## ABBREVIATIONS AND ACRONYMS

For the purposes of this document the following abbreviations and acronyms shall apply.

| | |
|---|---|
| ACC | Air Traffic Control Centre |
| ATAG | Air Transport Action Group |
| ATC | Air Traffic Control |
| ATCO | Air Traffic Controller / Air Traffic Control Officer |
| ATFM | Air Traffic Flow Management |
| ATM | Air Traffic Management |
| ATS | Air Traffic Services |
| CBA | Cost-Benefit Analysis |
| CDSEPT | Committee to Develop Standards for Educational and Psychological Testing |
| CODA | Central Office for Delay Analysis |
| DEL | Deliverable |
| EATCHIP | European Air Traffic Control Harmonisation and Integration Programme |
| ECAC | European Civil Aviation Conference |
| EUROCONTROL | European Organisation for the Safety of Air Navigation |
| EWPD | EATCHIP Work Programme Document |
| FN | False Negative |
| FP | False Positive |
| HRM | Human Resources Management |
| HRT | Human Resources Team |
| HUM | Human Resources Domain in EATCHIP |
| IANS | Institute of Air Navigation Services Luxembourg |
| ICAO | International Civil Aviation Organisation |

| | |
|---|---|
| MP | Manpower Planning |
| OJT | On-the-Job Training |
| SIOP | Society for Industrial and Organizational Psychology |
| ST | Specialist Task |
| STF | Selection Task Force |
| TOR | Terms of Reference |
| TN | True Negative |
| TP | True Positive |

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