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Why bother to design an experiment?

1.1 Introduction

There are many aspects involved in successful experimentation. This book concentrates mainly on designing and analysing experiments but there is much more required from you, the experimenter. You must research the subject well and include prior knowledge available from previous experiments within your organization. You should also consider a strategy for the investigation such as considering a series of small investigations. You must plan the experiment operationally so it can be successfully undertaken and, lastly, having analysed the experiment you must be able to interpret the analysis and draw valid conclusions.

If you follow that path, then you should have completed a successful project.

If not, then you may have wasted resources, had insufficient trials or data to be able to make conclusions that will stand up to scrutiny, or end up by making invalid claims.

There is no guarantee of finding all the answers, but you will have been well informed and will have made the most efficient use of the information and data available.

Let us consider some situations that illustrate the benefits of using designed experiments.

1.2 Examples and benefits

1.2.1 Develop a better product

An oil formulator has been charged with the task of improving the formulation of a lubricating oil in order to improve the fuel economy of motor engines. There are two important components of the formulation – type of base oil and level of friction modifier. Without knowledge of experimental design, he does not wish to change both variables at once. He keeps to the current level of friction modifier and changes the base oil, gaining an improvement. The next trial therefore uses the new base oil and he changes the level of friction modifier. It also

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gains a small improvement. He reports that the new oil should be made with new base oil and changed level of friction modifier and can be called 'New Improved'.

This is an inefficient way of exploring the experimental space, even assuming that only two levels of each variable are possible. He has assumed that a change resulting from changing the level of friction modifier when using one base oil will be repeated with the other, but this does not often happen with manufacturing processes. There are often interactions. He should have tested all four combinations of the two levels of both variables in a factorial experiment. It may be that the best combination is none of those that he examined, as in the example in Chapter 4.

Such an experiment, if replicated (more than one trial at each set of conditions) would give him the following benefits:-

(i) determination of the effects of each variable and knowledge of whether or not there is an interaction between them;

(ii) determination of whether an improvement can be made;

(iii) a measure of the batch-to-batch variability that enables him to test differences for significance.

1.2.2 Which antiperspirant is best?

A toiletries company has developed some formulations of an antiperspirant and wishes to determine which one is most effective. After chemical and microbiological tests the only realistic way is to test them out on volunteers in a carefully controlled environment. Perhaps at first thought a large number of volunteers should be assembled, and formulations allocated at random to the volunteers, each person testing one formulation. The trouble with this approach is that there is a lot of variation between one person and another in amounts of perspiration and the effectiveness of an antiperspirant, which would obscure any differences that there might be between formulations.

An experimental design is needed so that person-to-person differences ('nuisance' variation) can be identified but their effect removed when comparing the formulations. Thus, a panel of volunteers is gathered, and each one tests every formulation. The person-to-person variation would be there but would affect all the results, but differences between formulations should be more consistent. This design is known as a randomized block design, introduced in Chapter 18.

The benefits of this design are:-

(i) formulations can be directly compared;

(ii) person-to-person variability can be quantified but its effect eliminated in the comparison of formulations;

(iii) the best formulation can be identified.

1.2.3 A complex project

Bungitallin Spices are developing a new spice for lightly flavoured cheeses. They have identified 30 ingredients, decided on a composition and produced a trial sample. The taste seems reasonable and they decide to proceed with a marketing campaign to launch their new product.

Now clearly Bungitallin have a great knowledge of spices and it is perhaps not surprising in the spice industry that 30 ingredients have been included. However, there are many questions that are readily brought to mind.

i. How did they decide on the composition?

ii. Could they have done better if they used experimental design?

iii. Do all 30 ingredients contribute to taste? How many can be discerned and at what levels? How many can be removed without any discernible effect in the taste?

iv. How many of the 30 ingredients are necessary for texture or other parameters and at what levels?

v. How do the ingredients interact with each other?

vi. How is the spice to be produced? What are the process conditions? How robust are the conditions?

vii. How much variation can we expect from batch-to-batch? Is this acceptable or does it need reducing?

Clearly there are a lot of questions to be answered. If we attempt to answer all the questions in an unstructured manner the cost may be far greater than the profit from launching the spice. On the other hand, if we do nothing Bungitallin may be left with a failure at great cost. Thus, we must investigate, but in an efficient way.

Experimental design offers an approach that will enable us to achieve our objective in an efficient manner and give us unbiased results, thus enabling us to have confidence in our conclusions.

Different chapters of this book will help you to answer these questions.

Questions iii), iv) and v) can be investigated using *factorial* or *fractional factorial designs* followed by *response surface methods* to achieve the best formulation. If the experiment is too large to carry out in one trial a *central composite design* may be employed.

Questions vi) and vii) can be investigated using *saturated designs* or *computer-aided experimental designs* (*CAED*).

Question vii) can be investigated using *randomized block* or *Latin Square designs.*

1.3 Good design and good analysis

Of course, it is not only necessary to carry out a good design but it must be followed by a good analysis – in fact, when designing an experiment we should also consider how it is to be analysed.

This book starts with a chapter that covers *summary statistics*, *the normal distribution, confidence intervals* and *significance testing*. Later it refers to *multiple regression*, a necessary tool when the design has an imbalance which can occur for many reasons such as 'lost' data.

All these designs and methods of analysis will greatly enhance your experiments but we must not forget the most important aspect of experimental design – the researcher's knowledge. The design is aimed at increasing this knowledge and making it more rigorous so that we have a high degree of certainty that actions resulting from the design will prove to be successful.