A systems dynamics model of manufacturing quality costs and benefits

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INTRODUCTION

Most manufacturing systems are themselves too complex for the human brain to understand without the aid of tools such as systems dynamics. The costs and benefits arising in manufacture are intangibles, often subject to arbitrary accounting practices and allocation conventions. So it is not surprising that manufacturing costs and benefits are even more difficult to predict, analyse, promote and control than the manufacturing system itself.

Yet industrial managers need to know the costs and benefits of alternative manufacturing strategies. How much a particular improvement action will cost and how much and when the benefits from it will be realised are important facts on which to base investment decisions. Without such guidance investment in quality improvement is misdirected, at best, or absent, at worst.

THE MODEL

We describe, in this paper, a model of manufacturing costs and benefits. The manufacturing costs are drawn from sources published by the British Standards Institution (BSI) and the American Society for Quality Control (ASQC). The benefits arising from investing in manufacturing quality are taken from recently published case studies and reports as well as from our own findings. Two elements which affect manufacturing quality are the level of skill of operators which can be changed through training and the level of preventive maintenance carried out on equipment such as machines, dies and other tools. The contributions that these two elements make are identified and linked in the model so that it is possible to trace how the costs and benefits change through time. Previous studies have shown (1) (2) (3) (4) (5) (6) that investment in prevention leads to future benefits. More general commentaries (7) (8) (9) support those specific cases. But the questions of how much and when need to be answered.

The manufacturing department of many companies is often one of the largest where the application of capital investment and human skill are directed to the task of ensuring products are made which conform to design specifications. However, as is well known, scrap and re-work can cause loss of revenue. Materials, machines, operators, handling, storage, delays and other aspects can all incur costs which are more than planned, so resulting in losses. These losses, together with other losses, can feed through the system to produce losses of customers and markets. While it is true that many of these are 'unknown and unknowable' (7), the model we have constructed concentrates on two important elements which can be quantified. The two, operator training and preventive maintenance are linked dynamically using causal loops (Figure 1). The costs and benefits of each and the cumulative costs and benefits are then in a form which can be traced to the overall costs and benefits, using the software 'Professional DYNAMO Plus' (10).

TRAINING

There are four components of training costs: identifying training needs, preparation of training courses, delivery of actual training and keeping records of training and skills. Investment to meet any of these four costs reduces the total financial reserves of the company but is paid back, with a delay, in terms of reduced defectives, less scrap, less re-work, more customer satisfaction and hence increased demand. The results of the test run showing the cumulative costs and benefits of training are shown in Figure 2.

PREVENTIVE MAINTENANCE

The condition of machine tools, fixtures, dies and other processing equipment has a direct effect on the quality of manufactured products. In addition to increasing the levels of scrap and re-work, equipment which malfunctions or even operates below an optimum level of performance also increases the costs of production. Greater care, more checks, more inspection, more adjustments are all incurred. Increased investment in maintenance activities to prevent all these has to come from a maintenance budget, which is part of the financial reserves of the company. The cumulative effect of such investment leads, after a delay to cumulative benefits as shown in Figure 3.

MANUFACTURING QUALITY

The continued cumulative costs and benefits are shown in Fig. 4, as modelled using DYNAMO (10). The equations and values used for the run shown will be shown in the conference presentation but space is insufficient to give details. Either of the authors can be contacted to supply the details (11). Of course, the model is generic and can be used with any data supplied by any company, so the exact quantitative values shown in the figures may vary from one situation to another but the general behaviour can be seen.

In Figure 2, estimated losses due to inadequate training of operators (ELITO) rise. An investment into training, costs of training operators (CTO), is made four years after the start which, later, begins to show a benefit (BTO). The cumulative benefits of training operators (CBTO) increases. In Figure 3, estimated losses due to inadequate preventive maintenance (ELIPM) rise. After six years an investment is made into preventive maintenance, costs of preventive maintenance (CPM), which, after a delay, brings benefits (BPM). This then becomes a cumulative benefit (CBPM). Figure 5 shows how these two combine. Quality costs of prevention in manufacturing (QCPM) bring quality benefits from prevention in manufacturing (QBPM) which eventually become cumulative quality benefits from prevention in manufacturing (CQBPM).

CONCLUSION

The work described here is just one module in a larger model (Figure 5) of the quality costs and benefits of the different yet integrated activities of typical companies. The elements in the larger model (11) are purchasing, design and marketing as well as manufacture. Overall the model allows industrial managers to explore the consequences of different levels, types and timings of investment. It is possible to explore how profit performance changes quantitatively and the delays involved. This helps in the training of industrial managers as well as being a useful tool for decision makers, encouraging them to invest in quality improvement with the advantage of knowing where and how benefits in manufacture are likely to occur.

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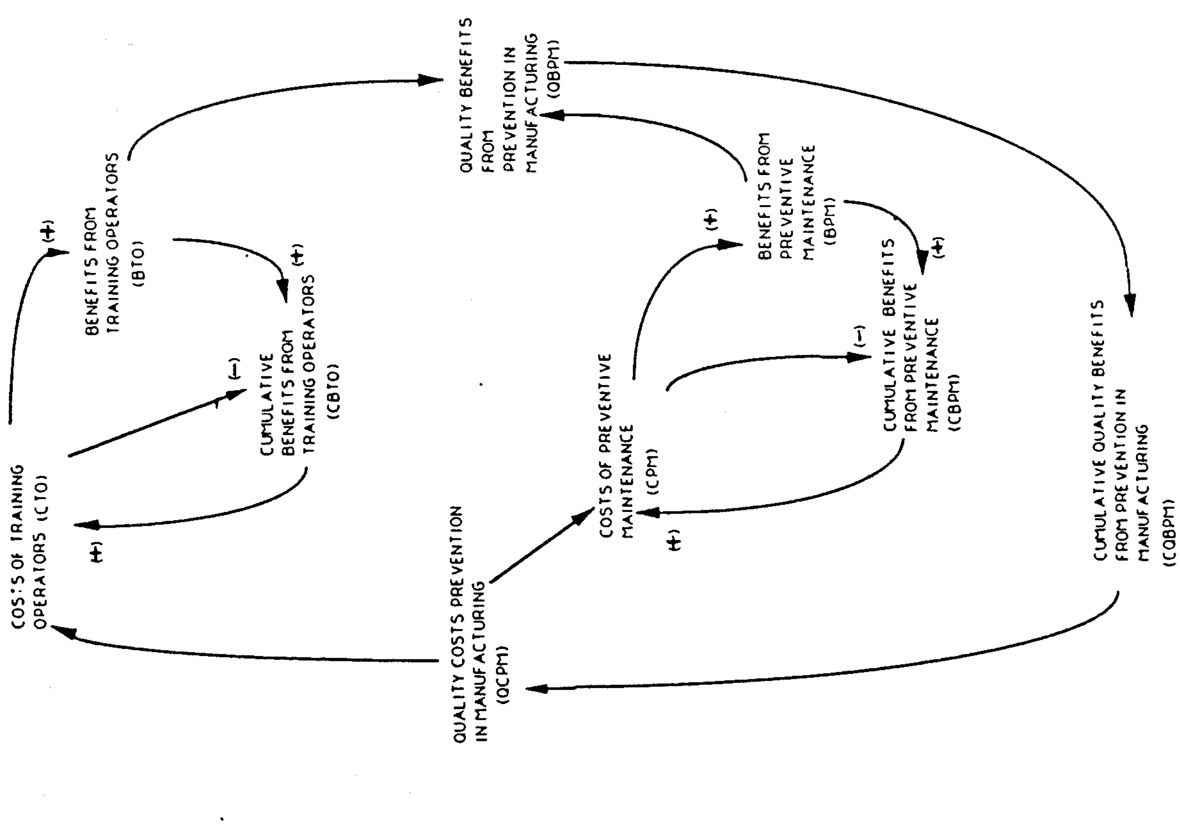

Figure 1 Quality Costs and Benefits Model for Manufacturing department Causal loops.

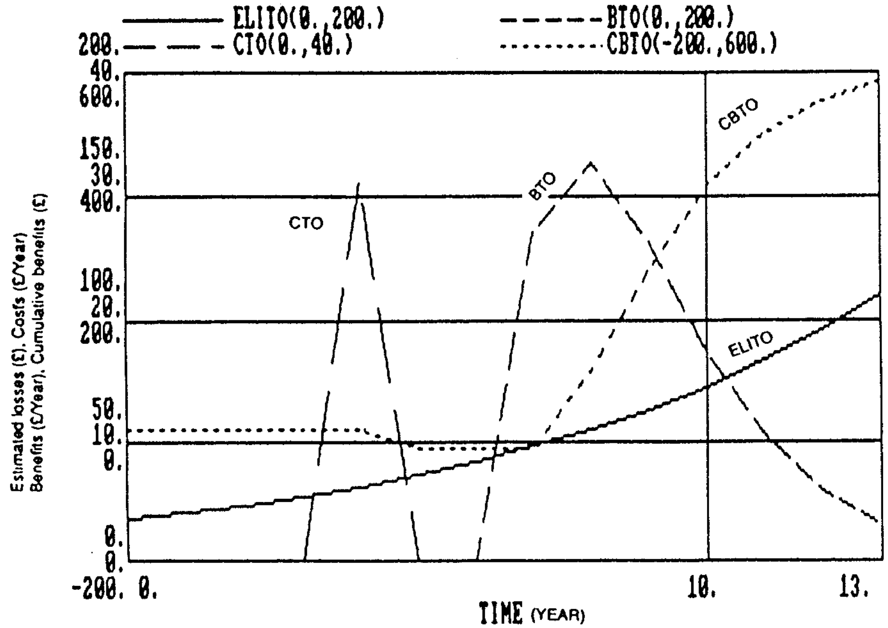

Figure 2 Test run for estimated losses due to inadequate training operators (ELITO), costs of training operators (CTO), benefits from training operators (BTO) and cumulative benefits from training operators (CBTO).

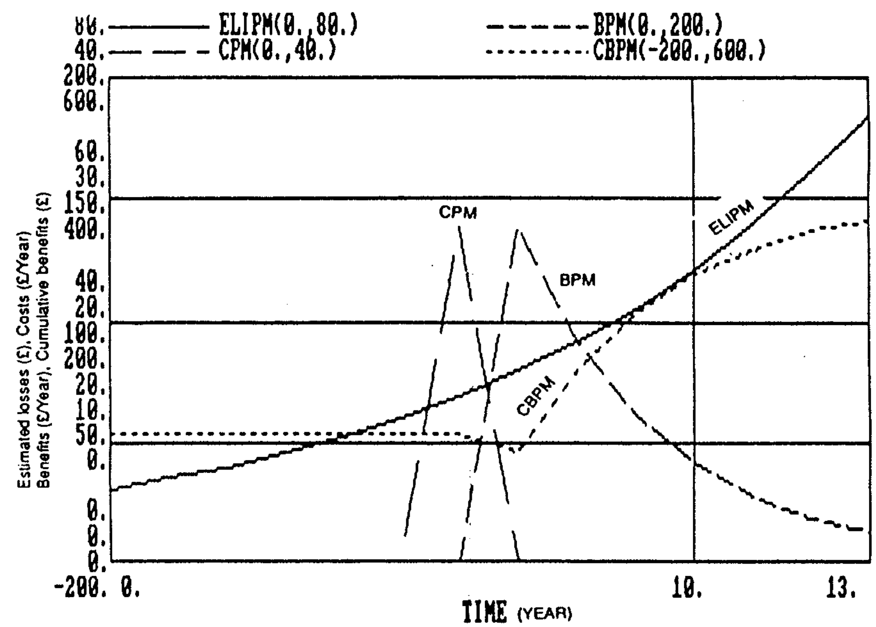

Figure 3 Test run for estimated losses due to inadequate preventive maintenance (ELIPM), costs of preventive maintenance (CPM), benefits from preventive maintenance (BPM) and cumulative benefits from preventive maintenance (CBPM).

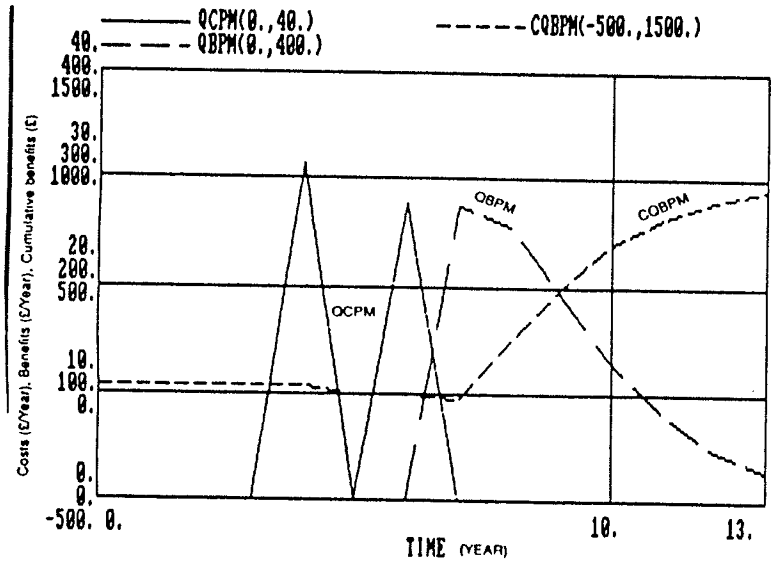

Figure 4 Test run for quality costs of prevention in manufacturing (QCPM), quality benefits from prevention in manufacturing (QBPM) and cumulative quality benefits from prevention in manufacturing (CQBPM)

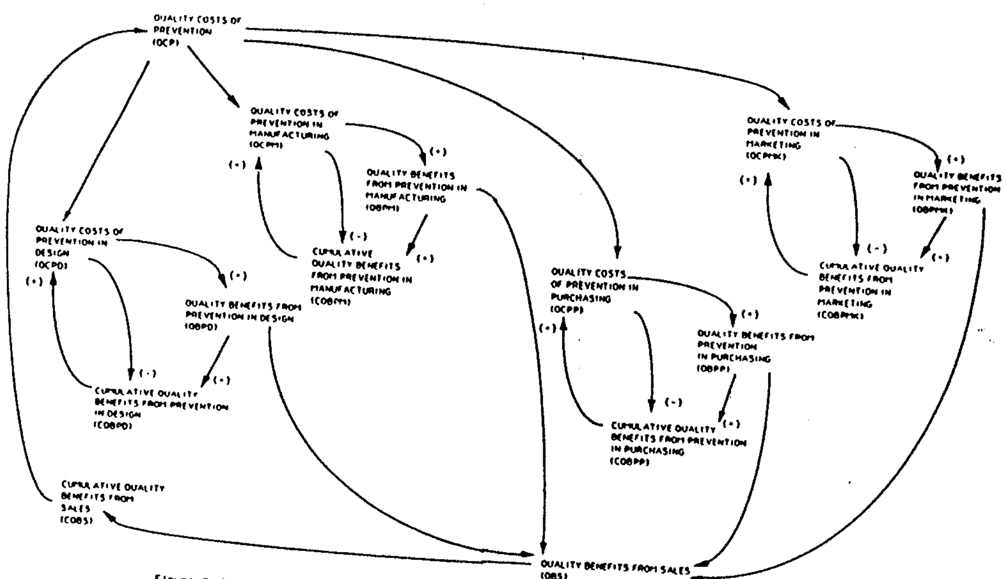

Figure 5 Macroscopic structure of the Quality Costs and Benefits Model Causal loops