

A DYNAMIC MODEL OF PURCHASE QUALITY

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ABSTRACT

The importance of quality costs and benefits is sometimes not fully recognised by industrial managers. Quality costs money. Industrial managers recognise this and tend to be afraid of spending on quality. But, quality also earns money. Industrial managers may need to be convinced of this fact. Unfortunately, existing publications on the subject do not encourage investment for higher quality. Most of the models about quality improvement costs and even about the costs of achieving the desired level of quality fail to incorporate the benefits of improved quality.

This paper describes a model of purchase quality costs and benefits. The purchase quality costs elements are drawn from various standard sources such as the British Standards and American Society for Quality Control (ASQC) publications on purchase quality. The benefits from investing for purchase quality are taken from recently published case studies and reports as well as from our own experience. The elements of quality related activities of a purchase department are - review of purchase orders, capability survey of suppliers and purchase planning. The contribution of each element, starting from estimation of losses due to inadequate purchase quality through to prevention of poor quality are isolated and linked dynamically so that costs and benefits are demonstrated through time.

The purchase quality costs and benefits model is developed using the system dynamics modelling approach, and simulated using a computer software package, 'Professional DYNAMO Plus'. The simulated results demonstrate the extent to which prevention investment in purchasing is justified by future earnings.

It is felt that the model can be a significant addition to course material for training programmes of purchase managers. It allows the user to explore the consequences of different levels, type and timing of investment on profit performance and the delays before profits are increased. It is hoped that the model will serve as useful tool for decision-makers, encouraging them to invest in improvement-related activities.

INTRODUCTION

Quality costs and benefits are sometimes not appreciated by industrial managers and, worse, are misunderstood. Misunderstandings determine attitude; determined attitudes lead to sub-optimal policy; sub-optimal policy leads the company to settle for mediocre quality targets; mediocre quality, being the reputation of the company, affects directly the demand of the customer for product(s). Industrial managers recognise costs but are often reluctant to spend money on achieving quality. Costs are obvious enough, since accounts need to be kept of them but the benefits and savings which arise from investing in quality are elusive and are never shown (Kaplan 1986) (Holusha 1986), (Park 1987). So, we never know how much more we could improve

benefits and save if we spent more on quality. A model which shows both costs and benefits seems to be needed.

GENERAL DESCRIPTION OF THE MODEL

Several case studies have shown that when manufacturing organizations increase their investment in prevention related activities, they gain higher future benefits. (Blank and Solorzano 1978, Brisac et al 1971, Chauvel and Andre 1985, Denton et al 1988, Isaac 1984, and Williams 1985). The experience of Deming (1980), Crosby (1979) and Oakland (1989) also favour higher investment in the form of so called prevention costs in order to increase future benefits. This is shown in the model.

The model uses System Dynamics (Forrester 1964) concepts of level and rates as shown in figures 1(a) and (b). The cumulative benefit is shown as a level and prevention costs and benefits are depicted as rates. There are two loops: a positive loop linking prevention costs, benefits and cumulative benefits, and a negative loop linking prevention costs and cumulative benefits. These two loops serve together as a closed loop feed-back system.

PURCHASE QUALITY

The role of industrial buyers in purchasing raw materials, components, sub-contract work etc, is crucial to the achievement of quality; poor quality materials, components and sub-contracted work cannot be manufactured into high quality goods (NEDC, 1985). There are many elements responsible for the quality prevention costs of a purchase department. These have been simplified into:

- 1 Review of purchase orders
- 2 Capability survey of suppliers
- 3 Purchase Planning

REVIEW OF PURCHASE ORDERS

A supplier starts to supply when he receives the purchase order of the company. An error in the purchase order, leading to the supply of non-conforming components, leads to financial losses. So purchase orders must be reviewed for accuracy before placement with the supplier. The latest drawings and specifications should be enclosed. Also, it is equally important that purchase orders should not contain specifications whose significance is questionable. An interesting example of this is cited in McRobb (1989).

"An order was received by a component supplier with a specification that had as one of its requirements the following clause: 'The components supplied against this specification shall have a guaranteed failure rate not exceeding 0.0001% per thousand hours.' This apparently innocuous requirement meant that to provide this guarantee, the supplier would have had to test well over 2000 components without a single failure for more than 100 years."

Confusion and chaos are added rather than improved quality.

More staff may be needed to review orders. This means additional costs but may be justified by benefits arising. The benefits could be:

- Timely availability of supplies

Parallel Program

- Reduction in scrap
- Reduction in rework by the supplier or by the customer, and
- Savings in handling, transportation and storage costs.

CAPABILITY SURVEY OF SUPPLIERS

A number of possible suppliers may be able to meet the specifications required. From which supplier should the company buy? It is helpful to survey the suppliers' capabilities. Conducting such a capability survey costs money but may have long term benefits. Some of the major benefits are:

- Only capable suppliers are chosen, incurring less incoming inspection costs.
- Materials do not have to be returned, leading to savings in handling and transportation costs
- Supplies which do not require reworking meaning that production schedules can be adhered to.

PURCHASE PLANNING

Poor planning may lead to shortages or to excessive stocks because times and quantities have not been controlled.

Both of these cause financial loss to the company. Material which fails to arrive on time, causes delays in production and chaos on the shop-floor. Delays in production schedules affect delivery to customers. Loss of customers is an intangible form of financial loss, which is difficult to estimate. In Deming's work these are 'unknowable numbers' (Deming 1986). On the other hand, excess material arriving also causes financial loss (Bajpai 1990). The benefits of purchase planning are reduction in delays in production schedules, savings in storage costs, savings in interest payments or in excessive stocks of supplies.

PURCHASE DEPARTMENT

The model of the purchase department, incorporating the above purchase quality elements, is shown in figure 2 in the form of causal loops. This is drawn by combining causal loops for review of purchase orders, capability survey of suppliers and purchase planning. Each of the individual quality cost elements affects the overall quality costs of prevention. Also, the quality benefits from prevention in purchasing are the sum of benefits emerging from review of purchase orders, capability survey of suppliers and purchase planning. The full costs and benefits model as well as the model of individual quality elements, with system dynamics symbols are given in Bajpai (1990).

EQUATIONS OF THE MODEL

The equations of the model use the DYNAMO (Pugh-Robert, 1986) format. Costs and benefits are considered as rates and shown using rate equations, while cumulative benefits are expressed as level equations. The model listing is given in the appendix.

A test run established the behaviour of the model under, a set of pre-defined conditions, which copy current economic and industrial conditions. The results of the test run for purchase order review are shown in figure 3, and show various costs and benefits elements are related to the review of purchase orders, and the estimated losses due to inadequate review. It can be seen that no investment has been made for the review of purchase orders, thus, no benefits emerged and the cumulative benefits curve (CBRPO) remained at its original level for 6 consecutive years. The

investment was made in the sixth year, shown by CRPO, which resulted in a reduction in total funds represented as a dip in CBRPO plot. But, thereafter due to the incoming cumulative benefits (BRPO), total funds continuously increase.

The test run for capability survey of suppliers is shown in figure 4. As for purchase orders, costs, benefits, cumulative benefits and losses due to inadequate capability surveys of suppliers are shown. No investment in supplier's capability survey was made for first 6 years, so the CBCSS curve (representing total funds) remained unchanged. During the seventh year, an amount equal to the estimated losses, of that year was invested for a capability survey of suppliers. Its immediate effect is the reduction in CBCSS. However, 3 years later the benefits start to emerge, reaching a peak value during the eleventh year and thereafter declining again due to lack of further investment. Nevertheless the incoming benefits raise the CBCSS, but at a slower pace.

Quality elements for purchase planning are shown in figure 5. The estimated losses due to inadequate purchase planning (ELIPP) are rising continuously. Investment in purchase planning is made in the eighth year equal to the cost of purchase planning (CPP). The outcome of planning takes times, so benefits can be seen only after three more years, during the eleventh year. These emerging benefits ultimately improve cumulative benefits.

Figure 6 shows the test run for the purchasing department. The quality costs for prevention in purchasing (QCPP) is the sum of the investment for review of purchase orders of capability survey of suppliers and of purchase planning. Similarly, the quality benefits from prevention in purchasing (QBPP) curve is the sum of the above benefits. The estimated losses (ELPQ) are also reproduced for quick reference. As no investment was made before the sixth year the cumulative quality benefits from prevention in purchasing (CQBPP) curve remains unchanged and horizontal until the sixth year. The investment is represented by an immediate dip followed by continuous rise due to further incoming benefits.

CONCLUSION

The model provides a tool to examine the benefits of improved quality of purchasing. Purchase quality cost elements - review of purchase orders, capability surveys of suppliers and purchase planning are identified. There are linked dynamically so that costs and benefits are demonstrated through time. The model allows users to explore the consequences of different purchase quality policies, such as the amount and nature and timing of investment on profit performance. It is also hoped that the model will serve as a useful tool in the hands of decision-makers encouraging them to invest more for review of purchase orders, capability survey of suppliers and purchase planning, in order to improve purchase quality and capture the benefits.

ACKNOWLEDGEMENTS

This study was possible because of a Commonwealth Scholarship and by with kind permission of M M M Engineering College, Gorakhpur, India.

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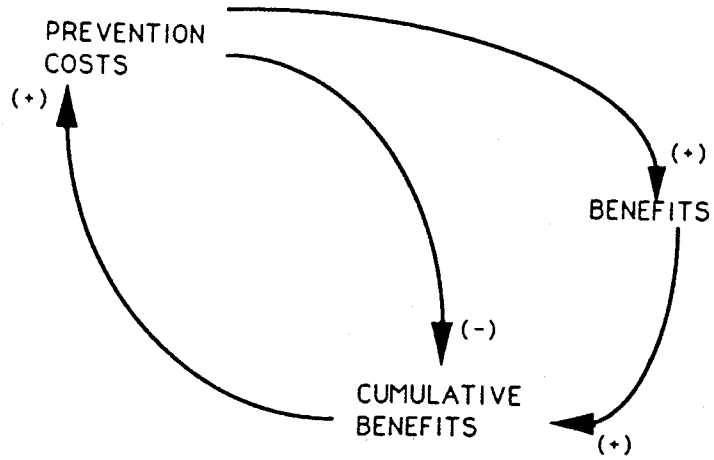


Figure 1(a) Causal loops diagram showing prevention costs and benefits

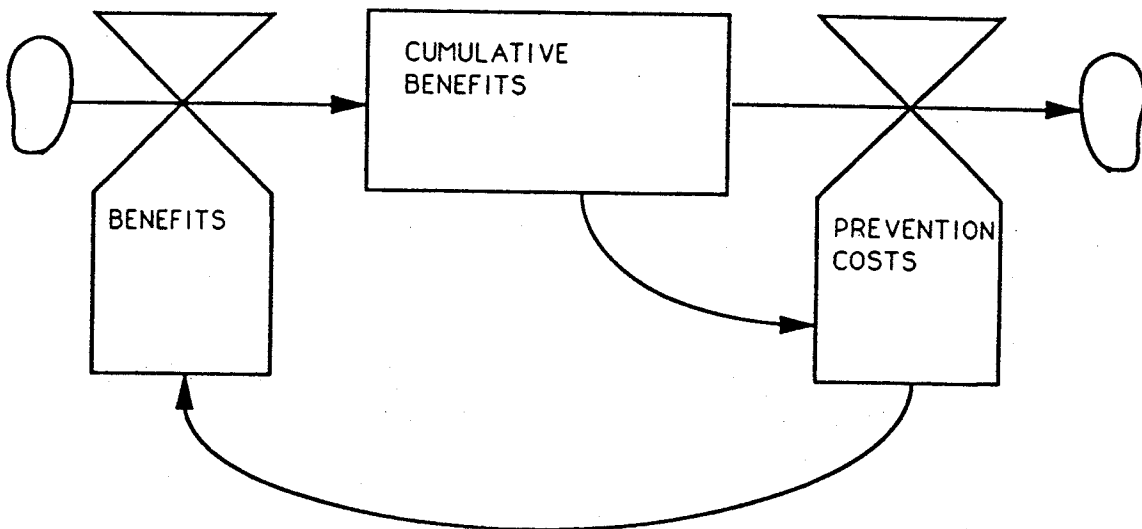


Figure 1(b) Flow diagram showing prevention costs and benefits

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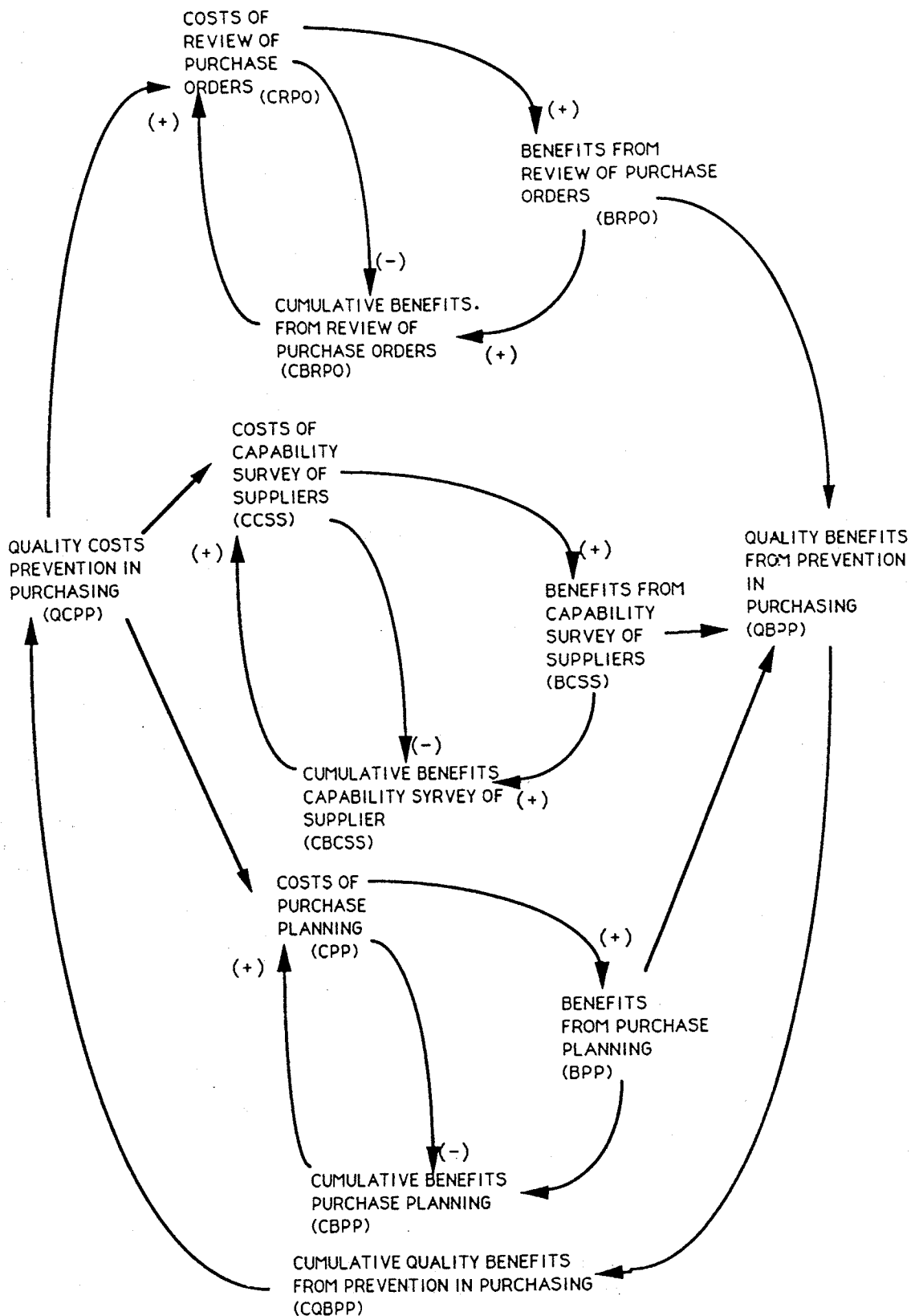


Figure 2 Quality costs and benefits model for Purchase Department. Causal Loops

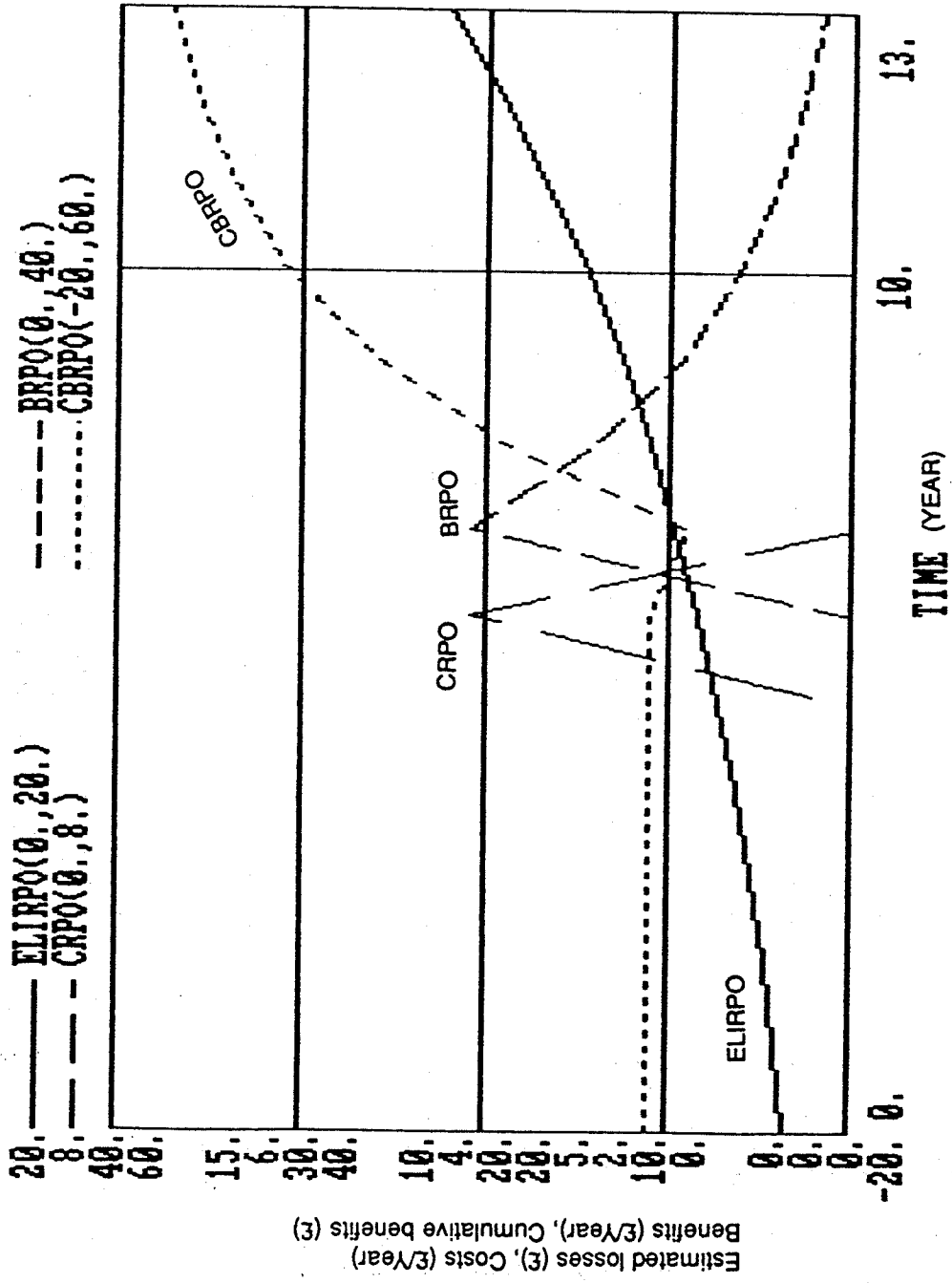


Figure 3 Test run for estimated losses due to inadequate review of purchase orders (ELIRPO), costs of review of purchase orders (CRPO), benefits from review of purchase orders (BRPO) and cumulative benefits from review of purchase orders (CBRPO)

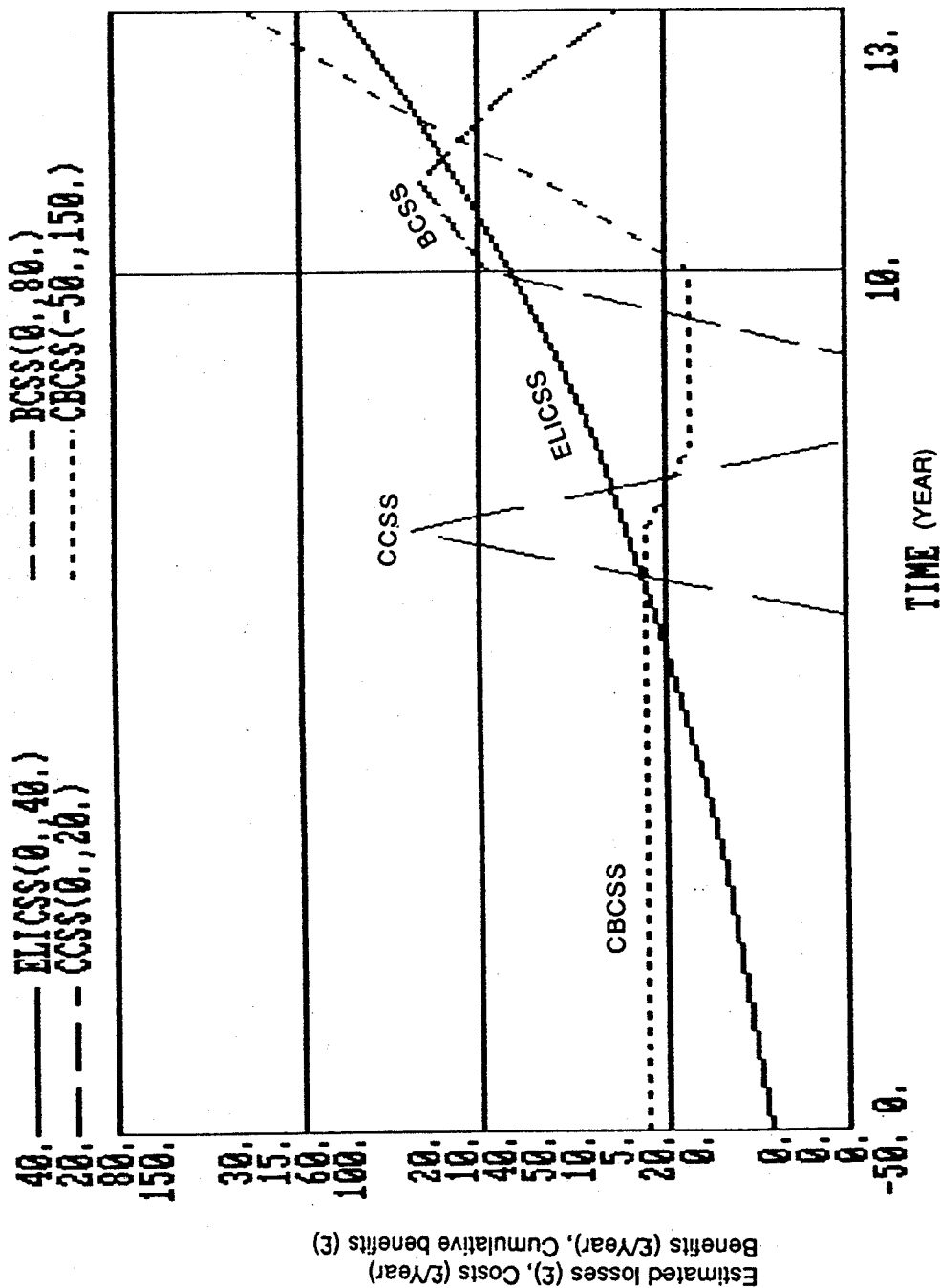


Figure 4 Test run showing estimated losses due to inadequate capability survey of suppliers (ELICSS), costs of capability survey of suppliers (CCSS), benefits from capability survey of suppliers and cumulative benefits from capability survey of suppliers (CBCSS).

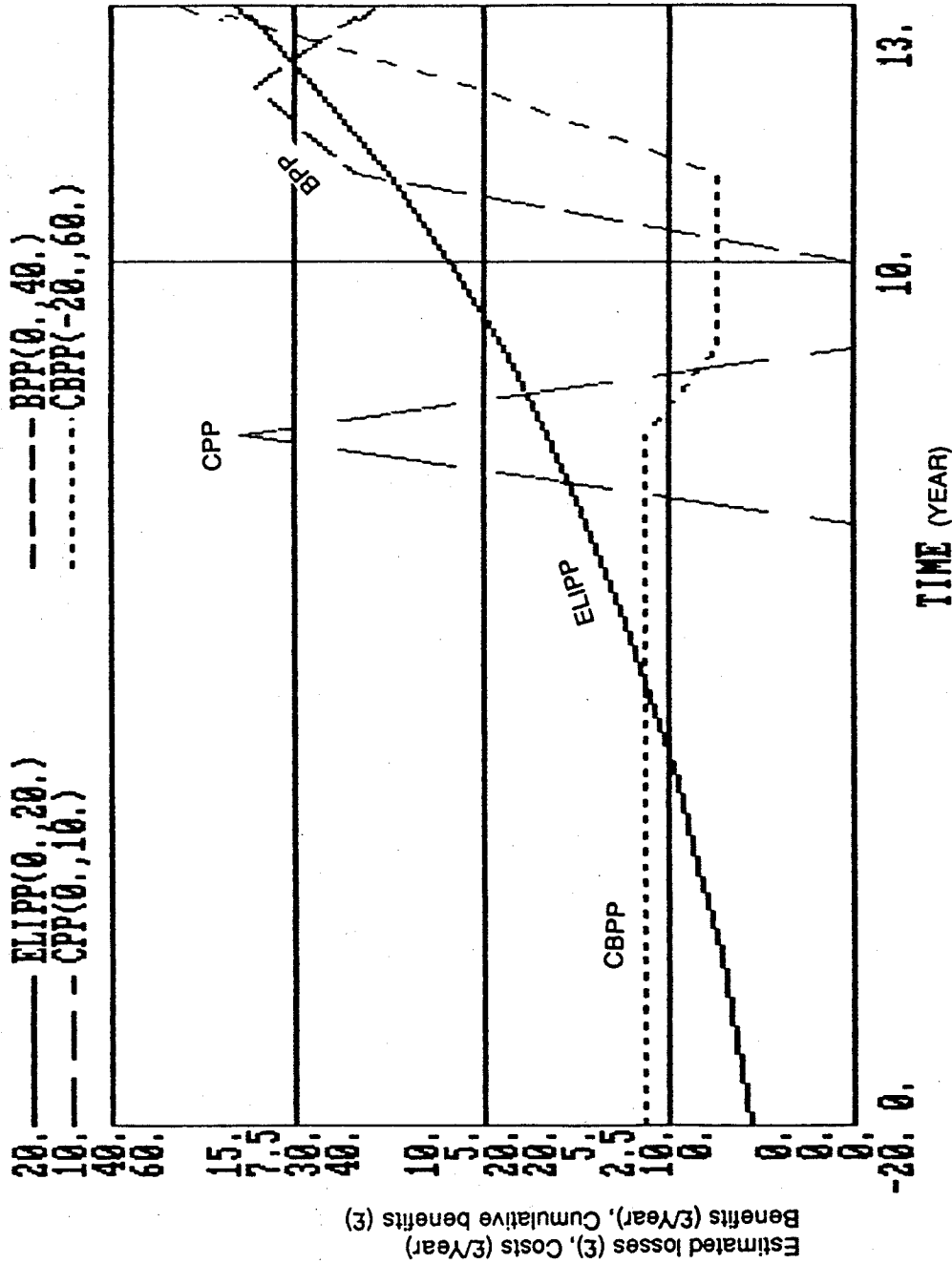


Figure 5 Test run showing estimated losses due to inadequate purchase planning (ELIPP), costs of purchase planning (CPP), benefits from purchase planning (BPP), and cumulative benefits from purchase planning (CBPP).

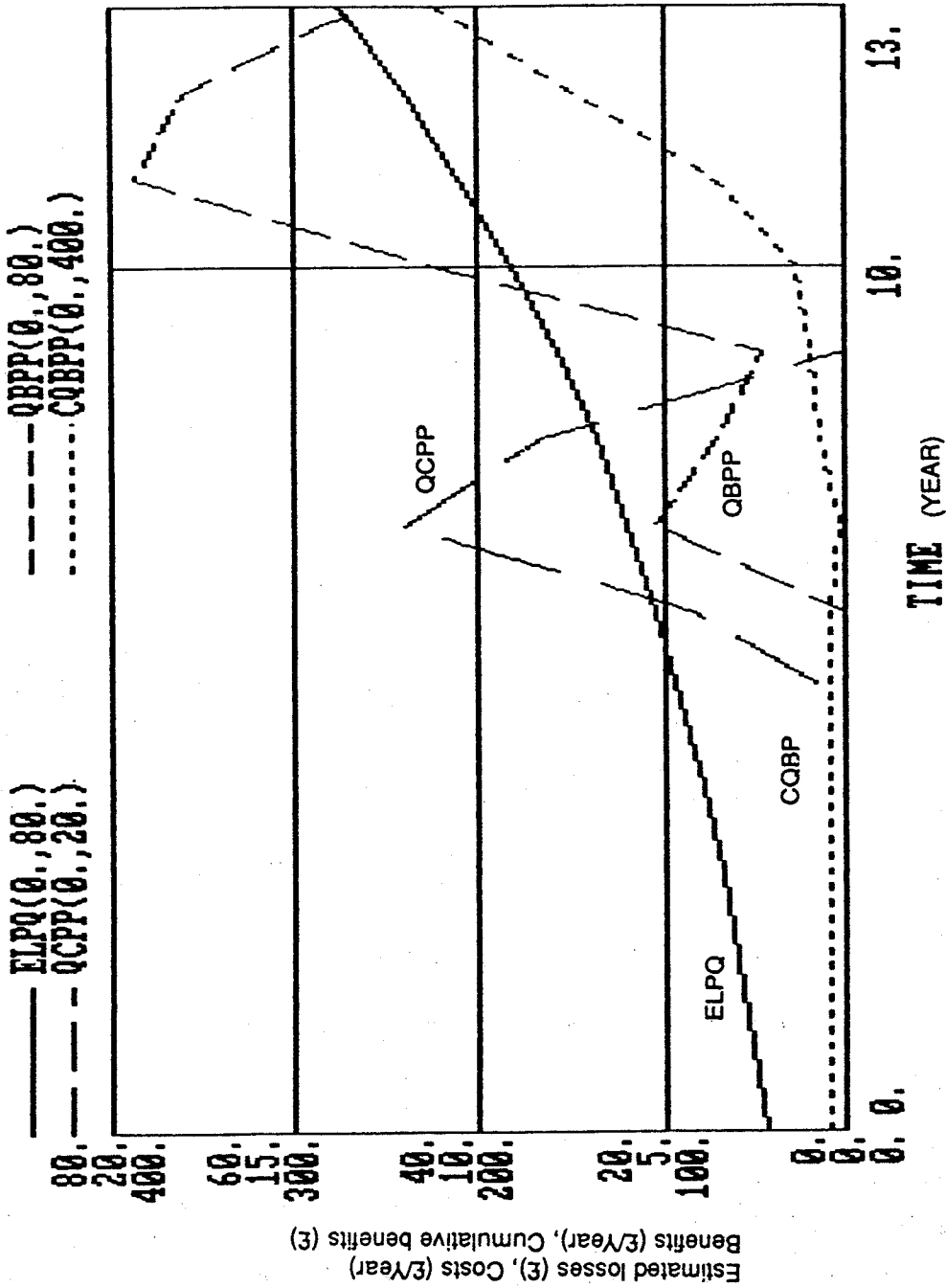


Figure 6 Test run showing estimated losses due to inadequate purchase quality (ELPQ), quality costs of prevention in purchasing (QCPP), quality benefits from prevention in purchasing (QBPP), and cumulative benefits from prevention in purchasing (COBP)

APPENDIX
MODEL LISTING

NOTE
NOTE *****
NOTE PURCHASE DEPARTMENT
NOTE *****
NOTE
L CQBPP.K=CQBPP.J+(DT)*(QBPP.JK-QCPP.JK)
NOTE CUMULATIVE QUALITY BENEFITS FROM PREVENTION IN
NOTE PURCHASING (£).
N CQBPP=NCQBS*FRFPUR
NOTE INITIAL VALUE FOR CUMULATIVE QUALITY BENEFITS FROM
NOTE PREVENTION IN PURCHASING.
C FRFPUR=0.15
NOTE FACTOR FOR PURCHASING.
NOTE (FRFDES+FRFMNF+FRFPUR+FRFMK=1)
R QCPP.KL=CRPO.KL+CCSS.KL+CPP.KL
NOTE QUALITY COSTS OF PREVENTION IN PURCHASING (£/YEAR).
R QBPP.KL=BRPO.KL+BCSS.KL+BPP.KL
NOTE QUALITY BENEFITS FROM PREVENTION IN PURCHASING (£/YEAR).
A ELPQ.K=ELSB.K*LFPQ
NOTE ESTIMATED LOSSES DUE TO PURCHASE QUALITY (£)
C LFPQ=0.15
NOTE LOSS FACTOR-PURCHASE QUALITY.
NOTE (LFDQ+LFMQ+LFPQ+LFMKQ=1)
NOTE
NOTE *****
NOTE REVIEW OF PURCHASE ORDERS
NOTE *****
NOTE
L CBRPO.K=CBRPO.J+(DT)*(BRPO.JK-CRPO.JK)
NOTE CUMULATIVE BENEFITS FROM REVIEW OF PURCHASE ORDERS (£).
N CBRPO=CQBPP*FRFRPO
NOTE INITIAL VALUE FOR CUMULATIVE BENEFITS FROM
NOTE REVIEW OF PURCHASE ORDERS.
C FRFRPO=0.20
NOTE FACTOR FOR REVIEW OF PURCHASE ORDERS.
NOTE (FRFRPO+FRFCSS+FRFPUP=1)
A ELIRPO.K=ELPQ.K*LFRPO
NOTE ESTIMATED LOSSES DUE TO INADEQUATE REVIEW OF
NOTE PURCHASE ORDERS (£).
C LFRPO=.20
NOTE LOSS FACTOR -REVIEW OF PURCHASE ORDERS (LFRPO<1).
NOTE (LFRPO+LFRPCSS+LFRPP=1)
A ARPO.K=ELIRPO.K*FARPO
NOTE AMOUNT FOR REIVEW OF PURCHASE ORDERS.
C FARPO=1
NOTE FACTOR FOR AMOUNT FOR REVIEW OF PURCHASE ORDERS.
R CRPO.KL=PULSE(ARPO.K,DIRPO,FIRPO,IIRPO)*(1/DT)
NOTE COSTS OF REVIEW OF PURCHASE ORDERS.
C DIRPO=1
NOTE DURATION OF INVESTMENT FOR REVIEW OF PURCHASE
NOTE ORDERS (YEAR).
C FIRPO=6
NOTE FIRST TIME INVESTMENT FOR REVIEW OF PURCHASE
NOTE ORDERS (YEAR).

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C IIRPO=20
NOTE INTERVALS BETWEEN INVESTMENT FOR REVIEW OF
NOTE PURCHASE ORDERS (YEAR).
R BRPO.KL=DELAY1(CRPO.KL,ATRPO)*IMFRPO
NOTE BENEFITS FROM REVIEW OF PURCHASE ORDERS (£/YEAR).
C ATRPO=3
NOTE AVERAGING TIME FOR REVIEW OF PURCHASE ORDERS (YEAR).
C IMFRPO=15
NOTE IMPACT FACTOR FOR REVIEW OF PURCHASE ORDERS.
NOTE
NOTE *****
NOTE CAPABILITY SURVEY OF SUPPLIERS
NOTE *****
NOTE
L CBCSS.K=CBCSS.J+(DT)*(BCSS.JK-CCSS.JK)
NOTE CUMULATIVE BENEFITS FROM CAPABILITY SURVEYS OF
NOTE SUPPLIERS (£).
N CBCSS=CQBPP*FRFCSS
NOTE INITIAL VALUE FOR CUMULATIVE BENEFITS FROM CAPABILITY
NOTE SURVEYS OF SUPPLIERS.
C FRFCSS=0.5
NOTE FACTOR FOR CAPABILITY SURVEYS OF SUPPLIERS.
A ELICSS.K=ELPQ.K*LFCSS
NOTE ESTIMATED LOSSES DUE TO INADEQUATE CAPABILITY
NOTE SURVEYS OF SUPPLIER (£).
C LFCSS=.5
NOTE LOSS FACTOR -CAPABILITY SURVEYS OF SUPPLIERS.
A ACSS.K=ELICSS.K*FACSS
NOTE AMOUNT FOR CAPABILITY SURVEYS OF SUPPLIERS (£).
C FACSS=1
NOTE FACTOR FOR AMOUNT FOR CAPABILITY SURVEYS OF
NOTE SUPPLIERS (£).
R CCSS.KL=PULSE(ACSS.K,DICSS,FICSS,IICSS)*(1/DT)
NOTE COSTS OF CAPABILITY SURVEYS OF SUPPLIERS (£/YEAR).
C DICSS=1
NOTE DURATION OF INVESTMENT FOR CAPABILITY SURVEYS OF
NOTE SUPPLIERS (YEAR).
C FICSS=7
NOTE FIRST TIME INVESTMENT FOR CAPABILITY SURVEYS OF
NOTE SUPPLIERS (YEAR).
C IICSS=20
NOTE INTERVALS BETWEEN INVESTMENT FOR CAPABILITY SURVEYS OF
NOTE SUPPLIERS (YEAR).
R BCSS.KL=DELAY3(CCSS.KL,ATCSS)*IMFCSS
C ATCSS=5
NOTE AVERAGING TIME FOR CAPABILITY SURVEYS OF SUPPLIERS (YEAR).
C IMFCSS=15
NOTE IMPACT FACTOR FOR CAPABILITY SURVEYS OF SUPPLIERS.

NOTE
 NOTE *****
 NOTE PURCHASE PLANNING
 NOTE *****
 NOTE
 L $CBPP.K = CBPP.J + (DT) * (BPP.JK - CPP.JK)$
 NOTE CUMULATIVE BENEFITS FROM PURCHASE PLANNING (£).
 N $CBPP = CQBPP * FRFPUP$
 NOTE INITIAL VALUE FOR CUMULATIVE BENEFITS FROM PURCHASE
 NOTE PLANNING.
 N $FRFPUP = 1 - (FRFRPO + FRFCSS)$
 NOTE FACTOR FOR PURCHASE PLANNING.
 A $ELIPP.K = ELPQ.K * LFPP$
 NOTE ESTIMATED LOSSES DUE TO INADEQUATE PURCHASE PLANNING
 NOTE (£).
 N $LFPP = 1 - (LFRPO + LFCSS)$
 NOTE LOSS FACTOR-PURCHASE PLANNING.
 A $APP.K = ELIPP.K * FAPP$
 NOTE AMOUNT FOR PURCHASE PLANNING (£).
 C $FAPP = 1$
 NOTE FACTOR FOR AMOUNT FOR PURCHASE PLANNING.
 R $CPP.KL = PULSE(APP.K, DIPP, FIPP, IIPP) * (1/DT)$
 NOTE COSTS FOR PURCHASE PLANNING.
 C $DIPP = 1$
 NOTE DURATION OF INVESTMENT FOR PURCHASE PLANNING (YEAR)
 C $FIPP = 8$
 NOTE FIRST TIME INVESTMENT FOR PURCHASE PLANNING (YEAR).
 C $IIPP = 20$
 NOTE INTERVALS BETWEEN INVESTMENT FOR PURCHASE PLANNING
 NOTE (YEAR).
 R $BPP.KL = DELAY3(CPP.KL, ATPP) * IMFPP$
 NOTE BENEFITS FROM PURCHASE PLANNING (£/YEAR).
 C $ATPP = 5$
 NOTE AVERAGING TIME FOR PURCHASE PLANNING (YEAR).
 C $IMFPP = 15$
 NOTE IMPACT FACTOR FOR PURCHASE PLANNING.