IDRC

RESEARCH MANAGEMENT SYMPOSIUM

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APPLIED RESEARCH METHODOLOGY

Presented by

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I Introduction

In food research, applied projects aim to create or adapt new knowledge concerning food and food products to the benefit of the consumer, the processor, and the producer, who make up the food system-- the consumer in terms of secure, stable, safe and acceptable food supplies; the processor in terms of opportunities for increased profitability, for example, reduced costs or increased productivity from changes in raw materials and ingredients, formulation, processing technologies, equipment, quality and process control procedures, etc.; and the producer in terms of opportunities for markets for his produce contributing to income.

Of course, unless consumers accept and regularly purchase the food or food product generated as the result of some research activity, none of these benefits will come about. Thus, in food research an awareness of the consumer or market characteristics is an essential element. Similarly, research which does not take into account the characteristics of processing companies, be they technical, marketing, or financial, is unlikely to be adoped. Again, no benefits flow through the system.

The case of the producer is often not so critical, since the researcher, processing industry, or consumer may utilise whatever he produces. However as a result of the research, by meeting particular specification for processors or consumers--e.g. potatoes with specific reducing sugar content for potato chip manufacture, fruit of specific size and colour for processing--a more secure and perhaps more profitable market might be created. These specifications must, of course, be achievable by the producer, ptherwise no benefit is possible.

If it is to be adopted, the result of applied research directed at any specific component within the food system, must fit the characteristics of the entire system, and its component sub-systems, primarily the consumer aspects. Therefore in any methodology, becoming aware of the system characteristics, and the likely impact of the change being researched, should precede the research activity, so that all relevant factors are considered in the research, to try to ensure "appropriateness". This study may often identify other opportunities for research activity.

In this discussion, I wish to focus on the processing sub-system, and argue that researchers, be they in industry, government or university, develop a research methodology based on real company operations.

Where they exist, research activities within processing companies most frequently seem to be short-term projects responding to day-to-day problems as they appear. Some longer term studies are undertaken to find ways to improve operations to increase profitability. More rarely, new ventures for the company, outside their present field of operations are investigated, e.g. new products, expansion to new plants, adoption of new processing technologies, etc.

While research on the latter, high risk opportunities often attracts the most attention, there are many opportunities within the company's operations, for research on increased profitability, without the risk associated with moving outside the company's present system boundaries. While focusing staff time and effort on the detailed work to assess a calculated risk on a possible high-yielding venture, such as a new product, company management may miss the opportunities to reap similar benefits from cost savings, increased yield, etc. with minimal risk since consumer and producer subsystems may not be perturbed. This is not to say that there should not be any risk-raking projects, since this is the essence of innovation. It is important that it should always be a calculated risk, taking into account all the likely problems in production, processing and marketing in the food system and the associated financial costs and returns. This area of evaluation has been covered elsewhere at the meeting.

II Systematic Approach to Process Improvement

I want to describe a systematic approach for this type of research. In this discussion it is applied to the processing operations in the company, although the same approach could be applied to any component of the company operation--it is termed "process improvement".

The methodology has the components as shown in Table 1 (p.5). A description of each component follows:

1. Description of company operating system and constraints

Figure 1 (p.6) indicates how the processing or production fits into the complex array of activities within the boundaries of a company system. The process improvement researcher must assess which operations and functions affect the processing system and so define the constraints for his research. Some of the operations and activities which are important to consider are:

Raw materials The researcher must be aware of the effects of raw material quality on the process and on final product quality. He must also know about alternative raw material sources, their qualities and prices.

Working capital How much money can the company afford to have tied up in raw materials, final product inventory, and labour? If the researcher recommends a high speed machine for producing a product, what effect will this have on finished product stock levels? Even if the company has the means to acquire the machine, it may not be able to afford carrying a large inventory of finished product.

Table 1 STEPS IN SYSTEMATIC PROCESS IMPROVEMENT

1. Description of company operating system and constraints
2. Identification of priorities for improvement
3. Description of processing operations
4. Selection of operations with greatest potential for improvement
5. Systematic research
6. Implementation of improvement into company operating system

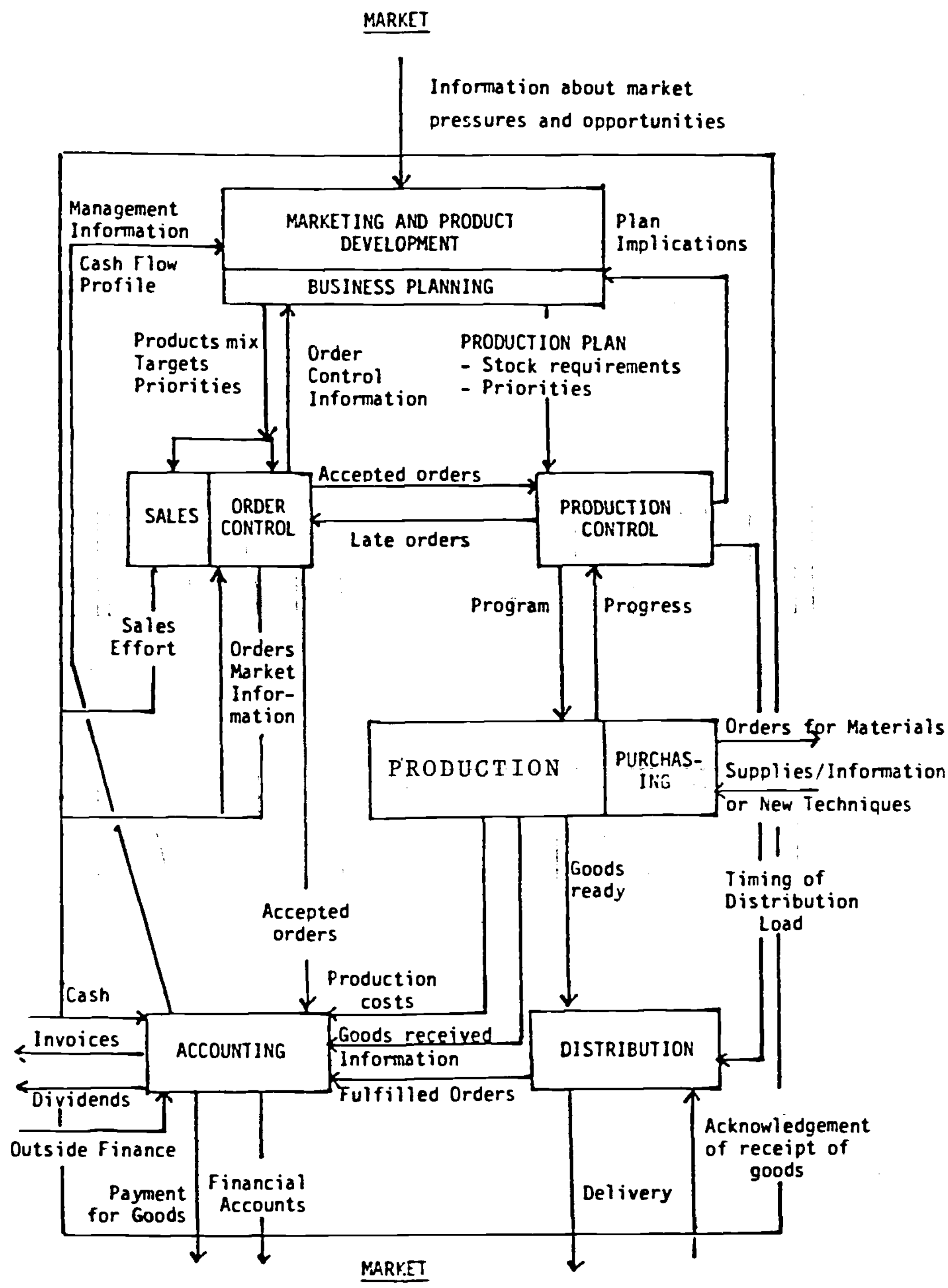

Figure 1 A Model of a Small Manufacturing Firm

Investment capital How much money has the company available for investment in new buildings and equipment? There is very little point in spending much time studying new equipment alternatives to improve a process if the company is unwilling or unable to make the necessary capital investment.

Management What is the management structure of the company? Is management old or young? Forward thinking or traditional? A knowledge of management thinking and attitudes may suggest constraints which will have a definite bearing on the implementation of any process improvement.

Processing staff How readily available are factory workers? What is labour cost? What level of skills do they have? The answers to these questions will influence decisions on level of mechanizarion, working conditions, training requirements, etc.

Equipment What equipment is being used now? What are the alternatives and costs? Are there benefits to be gained by installing new equipment to replace labour, old machinery? Equipment purchases will be influenced to a large extent by availability of investment capital. They will also be influenced by availability, cost and skills of factory workers.

Technical staff What level of training does the technical staff have? How would the staff in general cope with changes in processes and equipment?

Quality control and facilities Besides staff, what facilities are available for quality control? Are these adequate to meet the demands of process improvement? Are they the cause of existing poor product quality?

Packaging What packaging materials are being used at present? What are the alternatives? Is packaging being done by hand--are machines available?

Marketing What is the final market price for the product? How is the product distributed? Who buys the product? What features do the consumers look for in the product? What quality standard is required?

This initial study will identify a series of constraints which will influence the improvement strategy since the improvement must fit these constraints for successful implementation. Where conflict occurs, this should trigger some evaluation within the company as to whether or not the conflicting constraint can be overcome.

2. Identification of priorities for improvement

Armed with the constraints information, the researcher next defines the various processing areas in which the company is involved. Where a problem area has not already been suggested by management or earlier studies, systematic procedures are available to identify the areas where improvements will be of greatest benefit to the company in terms of the objective.

Generally the objective will be increased profitability and/or cost reduction. This might be accomplished, for example, through a reduction in energy requirement/cost; reduction in waste treatment load; reduction in manpower. Pareto's law can be of value to select these areas for attention; viz, classification of the activities, products, ideas resulting in identification of the vital few and the trivial many. In a company with several products, the few major products, say 10-15 per cent of total number, will account for perhaps 80 per cent of the company's profit. It is important then to identify those few products or processing activities, individual machines, etc., which have the greatest impact on total company profits, costs, or problems, so as to concentrate research efforts in these areas. Several methods are available for this as indicated in Table 2 (p.10).

In many instances, of course, one is responding directly to a specific problem in a trouble-shooting role, so the problem area is already defined. Generally, in this type of situation, once the specific problem is solved, time is not taken to identify other opportunities for improvement within the company.

In any case, after clearing it with management, the problem area with opportunity for greatest improvement is chosen for detailed study, if the problem already identified by management, is not clearly a priority.

3. <u>Description of processing operations</u>

Where the area of attention is an individual product or process line, the next step is to draw up a detailed process flow chart, showing all the steps in the process in their logical sequence (see Figure 2 for illustration, p.11).

In association with this chart, it may be necessary to record other factors depending on objectives:

- process conditions at each operation--times, temperature, pressures, etc., i.e. process specifications
- quality control procedures at each control point--methodology, sampling, criteria for acceptance/rejection
- staff requirements at each step, taking note of working

Table 2 SOME PROCEDURES FOR IDENTIFYING PRIORITY AREAS FOR PROCESS IMPROVEMENT

Method	Description
1. Profitability analysis	Calculation of contribution to annual profit for each product
2. Cost analysis	Contribution to production cost/standard cost of each cost centre
3. Energy audit	Contribution to over-all energy cost/requirement of each unit operation/product/company activity
4. Quality control	Contribution to average total defects of each production unit
5. Process control	Relative occurrence of out-of-control situations for each product/production unit
6. Maintenance audit	Contribution to over-all maintenance cost/time for each machine
7. Work sampling	Time spent/labour use at each operation

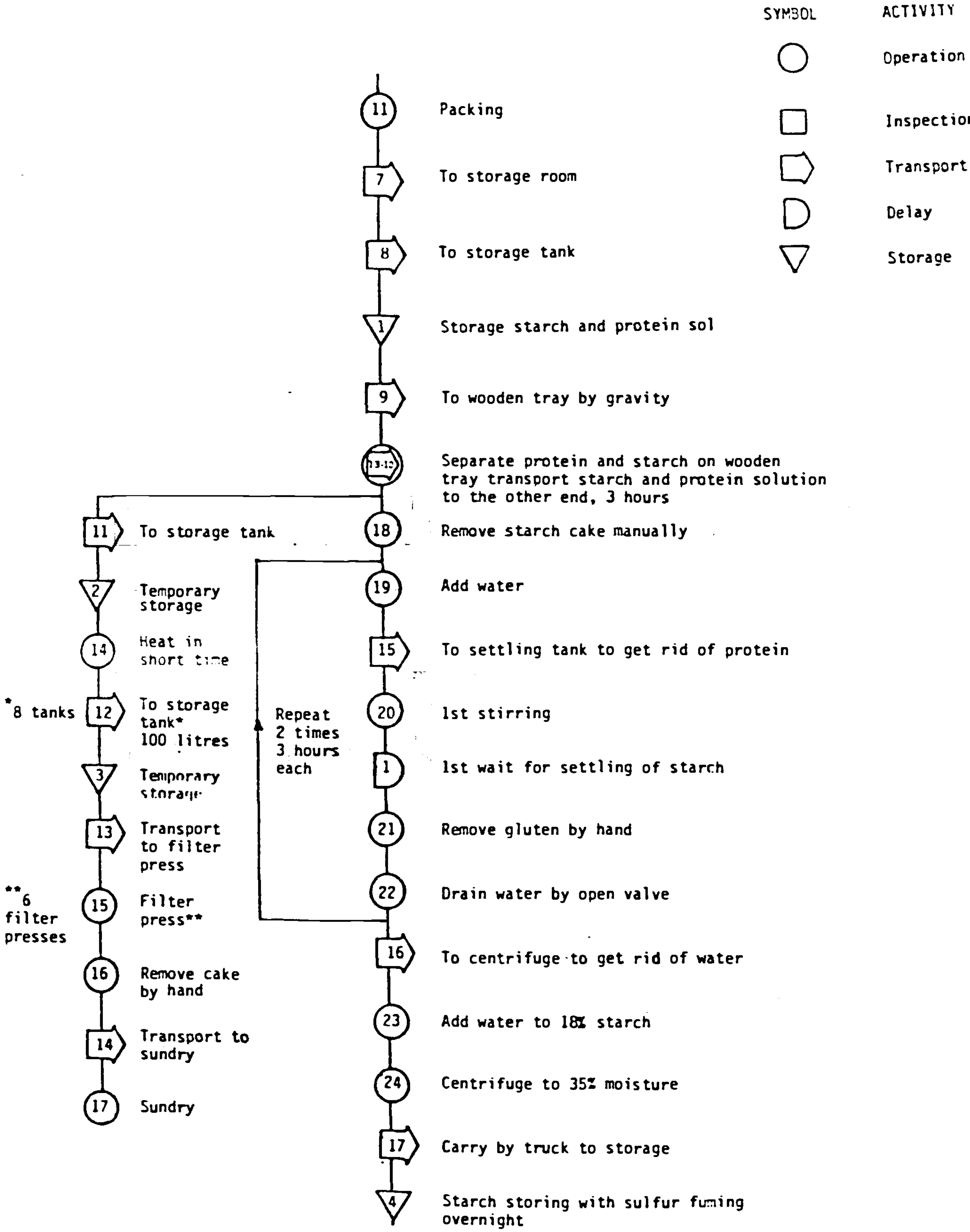

Figure 2 Process flow chart--Portion of starch noodle process, TISTR, Bangkok, Thailand

conditions and possible mechanization opportunities

- equipment/machinery at each point noting function, efficiency, possible improvements
- layout showing direction of materials flow

Finally the researcher should prepare a mass balance across the whole process showing mass of total materials in and out of as many of the key operation points as is possible. This often leads to identification of immediately profitable process improvement opportunities to increase yields. With this information and these observations, it is possible to locate a number of critical points or operations within the process for detailed improvement work.

4. <u>Selection of operations with greatest potential for improvement</u>

With a list of potential operations within the process for improvement, and a range of options for this improvement, the order of prioriting for attacking these should be set. A systematic, rapid, yet objective way of assessing these areas is by quantitative screening.

Each of the areas for improvement is judged on its potential contribution to specific factors, important to the company. These factors might include profitability, product quality, working conditions, yield, product cost, investment capital required and so on. Several company staff and researchers are asked to rate all areas of potential improvement on all factors. This may seem a rather strict and formalised procedure but it is extremely valuable in forcing each individual to think in quantitative terms about the implications of any process improvement. In the group situation, screening can spark off an active and very worthwhile discussion among members with different backgrounds and different points of view. Very often such discussions lead to observations which would not be made by an individual working in isolation. An example of screening is shown in Table 3 (p. 14).

Screening leads to a list of process improvement alternatives in order to priority on the basis of potential contribution to the company. Work should now begin on each of the improvement options in order of priority.

5. Systematic research

With the specific operation or problem area identified, a pragmatic research program is required to find a satisfactory solution or improvement strategy. Wherever possible, most of the research should be carried out in the plant to ensure that the solution fits and is implementable. This is obviously essential if the problem area is, for example, equipment which is operating out-of-specification, developing in-plant quality control, investigating material-handling problems, etc.

In order to minimise disruption to normal production schedules, the research should be carried out efficiently in terms of time, necessitating a compromise between scientific rigour and the need to get a solution identified and implemented quickly. Fortunately, several systematic techniques have evolved for this situation, largely from the fields of experimental design and operations research.

The major areas relevant to process improvement are:

a) Formulation design

b) Process optimization

Table 3 SCREENING OF OPERATIONS FOR PROCESS IMPROVEMENT--STARCH NOODLE FACTORY

Improvement strategy	(25) Low capital investment	(30) Better product quality	(20) Reduced production costs	(20) Simple technology	(25) Time for research	(10) Minimum labour disruption	Total Score
1. Material handling	25	15	20	20	20	10	110 (1)
2. Control sulphur	20	30	10	12	22	5	99 (4)
3. Cold storage conditions	15	30	10	18	25	8	106 (2)
4. Dough consistency	22	25	10	10	15	5	87 (5)
5. Increase yield	10	10	20	5	15	3	63 (6)
6. Study of effect on noodle/starch quality	25	28	15	18	12	6	104 (3)

c) Quality control analysis

d) Plant layout analysis

e) Production planning analysis

Details of these techniques are presented in IDRC-MR56e, and in standard texts.

a) Formulation design The product formulation is not satisfactory. Modifications are required, or new raw materials or ingredients have become available. This is an area which is often approached in a rather haphazard manner by modifying one ingredient, then another and so on. Although this approach can lead to successful results there are some very useful techniques which can form the basis of a more systematic and faster approach to formulation. These techniques come generally under the heading of statistical experimental design, requiring only a basic knowledge of arithmetic backed up by a desk calculator. The techniques identify the contribution each ingredient makes to a formulation. They help the researcher gain a better understanding of his formulation and generally save time and effort in reaching an acceptable product. These techniques include screening experiments, factorial designs, mixture designs, and linear programming. In more detailed work, experimental design can be used to derive equations which predict the effects of changing specific ingredients or process conditions.

Most of this work can be carried out in the laboratory with final formulations only requiring runs through the process to check if any problems occur. The need for new quality control procedures, and the effect on costs should also be taken into account in the selection of new formulations.

b) Process optimization Specific parts of a process can often be run more efficiently to improve product quality, save time, cut labour costs or save waste. There are three basic approaches to process optimization:

i) To carry out laboratory or pilot plant trials varying the processing conditions using experimental designs to achieve the optimum. The advantages of this approach are that it is inexpensive, requiring only small quantitites of raw materials and limited labour, and does not interfere with factory production. The major disadvantage is that optimum conditions in the pilot plant or laboratory may not be optimum after scale-up to factory operation.

ii) To halt factory production and use factory equipment to carry out processing trials. Although this overcomes the problem of scale-up, it can be costly in terms of factory down-time, raw material usage, and labour. Time can be saved by using efficient experimental designs.

iii) To carry out experimentation in conjunction with normal factory operation. This has definite advantages in that it does not require factory down-time and does not hold up production. A real criticism might be the possible loss of large quantities of production if experimentation leads to rejection of the product. Fortunately, there are ways of minimising the likelihood of this happening. The specific technique which is used for in-line experimentation is called EVOP--evolutionary operations. This procedure encourages a gradual and systematic change in process conditions in a direction which improves product quality.

One of the real advantages of EVOP is that it can be designed to involve factory staff, particularly operators, thus encouraging interest in the process and a will to improve the product. The approach is illustrated in Figure 3 (p.18).

c) Quality control analysis Many companies rely on random checks of the finished product to make sure everything is fine before product release. The company may be losing money when batches are rejected or, because of inadequate weight control, by giving away product. Quality control is absolutely vital to ensure product quality, reliability, and therefore security of supply to markets.

Quality control should be treated as a regular activity in the production process and involve:

i) testing throughout the process--raw materials input, within-processing operations, final product and product in-store, to allow for earliest possible correction to minimise losses;

ii) systematic planning, with a sound statistical basis, if possible, so that cost-effectiveness can be estimated.

Procedures are available for monitoring the process capability at different points in the process as well as important raw materials and product quality characteristics by statistical sampling. Quality control limits and charts can then be set up for all the key process and product variables. Statistical concepts of the risks of accepting or rejecting lots with particular quality levels and associated costs can also be utilised in conjunction with processing tests of the effect of these lots on processing and final product, to select the quality standards and procedures best suited to the company.

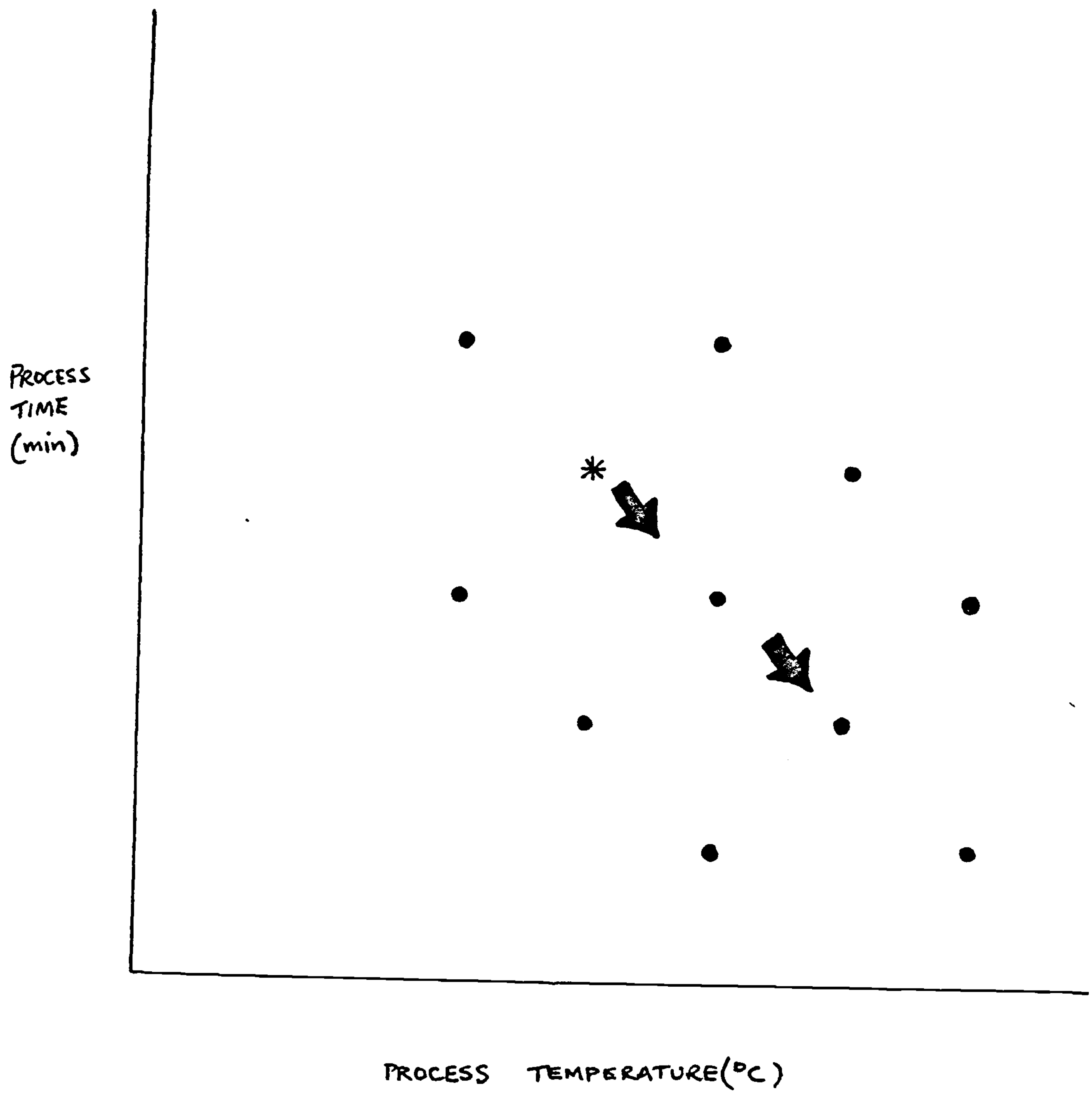

FIG.3. ILLUSTRATION OF EVOP FOR IMPROVEMENT OF PRODUCT QUALITY WITH SLIGHT VARIATIONS OF PROCESS TIME AND TEMPERATURE

d) Plant layout analysis Food processing plants are often the result of haphazard developemtn. Pieces of equipment have been slotted in and building added on over the life of the plant. Very often, the resultant factory layout is far from perfect. Working conditions may be unpleasant, there may be delays in the process, and low yields, caused by the layout. It would be impractical to suggest a total plant reorganisation for most companies, but a practised and critical eye can spot areas where improvements can be made without major upheaval. This, combined with certain systematic techniques, can lead to a marked improvement in plant layout and associated productivity or allow opportunities for expansion. One such technique which, although best suited to new plant design, can be applied to layout improvement, is Simplified Layout Planning. This rests on three fundamentals:-

i) defining relationships among various functions or activity areas

ii) defining space required for each activity area (amount, kind, shape)

iii) adjustment of these into a layout plan.

e) Production planning analysis This is to determine when to produce the various products and in what quantities to meet expected demands. Associated with this is capacity planning. Excess capacity leads to low productivity, whilst inadequate capacity leads to poor customer service and a reduction of potential profits. Capacity planning is made difficult by the uncertainty of demand and the seasonal nature of raw materials supply.

Techniques such as linear programming, simulation, and forecasting can be used to assist identification of appropriate capacity and production plans.

6. Implementation of improvement strategy into company operations

Often little thought is given to this stage of a project. Consequently results are either not implemented, or badly implemented. Consideration should be given as to who should carry out implementation and how the implementation might be done.

Three possible scenarios for implementation are:

a) Relevant management implements improvements directly based on project recommendations. This is usually least effective since some 'bugs' inevitably remain.

b) Researchers implement their own recommendations into the company, making sure that all 'bugs' are worked out and confirming that objectives are met. This approach requires a weaning stage for relevant management to take over.

c) Joint implementation by researchers and relevant management. This is normally most effective., allowing for 'bugs' in improvement strategy to be ironed out, so as to fit into total company operation and management.

There are three main methods of implementation:

a) Parallel running--where the improved system is run alongside the old, which allows for full-scale operation and debugging in a real situation. Direct comparison with the old system is also evident. This is expensive and is really only possible in companies with multiple lines and spare capacity.

) Pilot project--a small pilot scale process is set up to produce the product, demonstrate the new process, etc. This allows collection of more data, market testing or limited marketing, until the stage is reached where the company is convinced and decides on a full-scale investment. The danger here is that the pilot plant may not be truly representative of the operational/management requirements at full-scale, even though these factors have been considered in the research.

c) Immediate full-scale implementation. This is the most often used. Provided the research team have comprehensively studied and evaluated the improvement in the company context, the risks here, while great in some projects, may be minimised. There usually has to be a commissioning stage to allow the whole improvement strategy to settle and fit into the total company system, removing any remaining 'bugs'.

It has been suggested that the degree of involvement of company management throughout the project and hence their commitment, correlates with the degree of success in implementation This also holds for seeking some contribution to the costs of the research from the relevant management, whether the research is within a large company structure or involves an external food research organization. Although one would think that a manager should welcome research for which he does not have to pay, this is seldom the case. Only if he pays for it can he be sure that the research is serving his, rather than someone else's best interests! This is a difficult area for government and university researchers, who may aim to serve the greater good of society, but if there is no implementation, there is no benefit.

III Process Improvement in developing countries

Industrial researchers, supported by IDRC, are attempting to develop this interactive and systematic approach in their process improvement activities in small food companies in developing countries. At this time active projects are underway in Singapore for soya sauce factories, in Thailand for starch noodle factories, and in Chile for bakeries.

In the Singapore project, a soy sauce factory is replacing a batch of 40 individual 90 litre crockery jars with a single fibreglass tank for the fermentation operation. This is one of the improvement areas being tested and evaluated, taking into consideration the limitation in floor space and material handling facilities. Initial indications are that management is happy with the increased yield obtained, although the product could not be classified as first-grade as that produced by the traditional process. The research team is working to prepare a program for changing over to bulk tanks, with attention given to the associated requirements for new pumping, filtering and bottling equipment, and new job specifications. This must be a phased program, in line with the owner/manager's financial constraints. He also wishes to maintain at least one line of production using the traditional fermentation in small crockery vats, for customers of his first-grade quality sauce.

In Thailand, the team is working with mung-bean noodle manufacturers and has identified the improvement of starch yield in the extraction process as a major opportunity for process improvement for the first factory in which it is working. After visiting the plant several times and preparing flow charts, they have simulated the process at their pilot plant. They have, with difficulty, been able to obtain data in the factory to prepare a crude mass balance across the process and compared this with that achievable in their simulated plant. It appears that opportunities exist to increase yield by approximately 10 per cent by modifying the flow rate of slurry over inclined starch tables. Efforts are now under way to obtain co-operation of the factory management to allow detailed mass balance and process experimentation in the plant.

In Chile, the project has just begun to measure the variability of wheat flour quality used in small bakeries in relation to the yield of bread obtained. The objective here is to set standards for flour quality and to develop procedures for improving yields and profitability with the raw materials and bakery equipment available at the bakeries.

In these projects and in others being developed, improved operating procedures are tailored to the needs of commercial plants, by carrying out the greater part of the research in the factory, involving factory staff and managers. At the same time, the experiences of the multidisciplinary research staff over several factory and problem situations will contribute to the development of appropriate applied research methodology to support indigenous food industry. It is anticipated that such a methodology will become institutionalized in their industrial research institutions, so that continuing interaction of small companies and applied researchers is fostered.

IV Conclusions

It will be appreciated then that the researcher working in industrial process improvement requires a broad-based approach, borrowing from the fields of industrial engineering, food processing, operations research, and systems analysis. The approach is based on quantitative measurement of operations with interaction between current and proposed conditions, and between management, company staff and researchers, so that relevant and implementable projects are undertaken in an efficient and cost-effective manner. Within larger companies, a team of relevant staff from different departments would be organised to interact and work on the various activities. Given the background knowledge of their company or access to this by the various staff, several of the steps in this systematic approach could be handled quite rapidly, since the group can easily assess how the improvement might fit and where and how benefits would accrue. In companies without adequate staffing or research capacity, particularly in the large number of small food businesses, outside consultants from the private or the government sector, may be called in. A group approach is again necessary. The group should then take the time to interact with the company staff in order to completely understand the company environment in which they are to work and to maintain relevance. Often, the technical consultant only sees with <u>his</u> eyes and advises or works on the relevant topic in isolation from the total system. This comment applies even more to the university researcher, who rarely develops an awareness of the real operating and commercial system. Government and industry researchers are trained at universities. It is understandable, that without some exposure in their training to applied industrial research on real company problems and improvement in on-going operations preferably with in-plant experience, their approach to research often is inadequate. I maintain that a proportion of training and research at universities and government research institutes should have this real-life industrial and systems focus. This would ensure that a proportion of industrial researchers become available to work for the development of the food industry in an efficient, pragmatic, and cost-effective manner.