Improving Small-Scale Food Industries in Developing Countries

IDRC-TS 48e

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Postal Address: Box 8500, Ottawa, Canada K1G 3H9
Head Office: 60 Queen Street, Ottawa, Canada

Edwardson, W.
MacCormac, C.W.

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Editors: W. Edwardson and C.W. MacCormac

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FOREWORD

This publication is a summary report of a workshop dealing with research approaches and methodology for process improvements in small-scale food industry enterprises of developing countries. The workshop, hosted by B.C. Research in Vancouver, Canada, took place from 13-24 June 1983 and was sponsored by the International Development Research Centre (IDRC). This was the third in a series of workshops on the process improvement topic. The first was held in Singapore in 1980 and dealt with the adaptation of quantitative research techniques normally employed by large-scale industries to the special situations of small-scale and family operated enterprises. A second workshop was held in 1981 in Bangkok where these techniques were presented to a research team at the Thailand Institute of Scientific and Technological Research as approaches to be tested in a process improvement project in noodle factories. Reports of both the Singapore and Bangkok workshops were published in IDRC's manuscript report series (IDRC-MR48e and IDRC-MR56e) and served as basic background documents for the Vancouver workshop.

The objectives of this workshop were:

- To review a variety of experiences in the application and evolution of a small enterprise-oriented process improvement methodology and suggest modifications and improvements;
- To examine problems, needs for research and development, and the interests and concerns of industrial researchers with respect to small-scale food industries in developing countries; and,
- To assist participating researchers to develop and apply more effective approaches to improving conditions in small food factories in their countries.

Participants from each of the nine developing countries represented at the workshop described their country's small-scale food sector, research and development services available, and the role and structure of their home institutions. Methodological approaches to problem-solving and techniques tried were explained. More advanced IDRC-supported projects in Thailand and Singapore were examined and discussed in some detail. Descriptions of the processes and problems encountered in typical small-scale food factories of each country were used as case studies for small discussion groups to evaluate and prescribe strategies for process improvement research.

A range of methodological concepts and techniques were presented by invited resource persons with experience in advanced industrialized country situations. In addition, a local small-scale fish-processing factory was visited where participants had an opportunity to practice some of the techniques presented and discussed. In the end, no fixed methodology or single set of techniques applicable to developing country small enterprise situations could be defined. Rather, a flexible approach evolved to combine the techniques presented in the following pages according to the specific requirements of each problem situation. The meeting was held at the facilities of B.C. Research, a nonprofit research organization with considerable experience in problem-solving and assistance to small businesses in the food and other industries in the province of British Columbia. Ample opportunity was given at the meeting for participants to learn from this experience and to understand the organization and function of this industrial and service institute.

Because the nature of the workshop presentation involved considerable duplication and preliminary findings, this report takes the form of an amalgamated summary of content rather than the more common proceedings format incorporating individually authored papers. The content of this document was contributed by all participants and it is hoped that it will serve as a useful source of ideas and experience for small enterprise process improvement research and development practitioners.

E. Weber
Associate Director
Agriculture, Food and Nutrition Sciences Division
IDRC

PARTICIPANTS

William Edwardson, Agriculture, Food and Nutrition Sciences Division, International Development Research Centre (IDRC), Apartado Aéreo 53016, Bogota, D.E., Colombia

Ricardo Garcia, Instituto Centroamericano de Investigación y Tecnología Industrial (ICAITI), Apartado Postal 1552, Guatemala City, Guatemala

Olympia N. Gonzalez, Food Technology R&D Program, National Institute of Science and Technology (NIST), Kahong Koreo 774, Manila, Philippines

K.G. Gunetileke, Ceylon Institute of Scientific and Industrial Research (CISIR), P.O. Box 787, 363 Bauddhaloka Mawatha, Colombo 7, Sri Lanka

A.M. Khorshid, Agricultural Research Center, Grain and Bread Research Department, Field Crops Research Institute, Giza, Egypt

David A. King, B.C. Research, 3650 Wesbrook Mall, Vancouver, B.C., Canada V6S 2L2

Kenneth Liang Wai Yin, Singapore Institute of Standards and Industrial Research (SISIR), P.O. Box 2611, Singapore 9046, Republic of Singapore

Christopher MacCormac, Agriculture, Food and Nutrition Sciences Division, International Development Research Centre (IDRC), Tanglin P.O. Box 101, Singapore 9124, Republic of Singapore

Wiboonkiet Moleeratanond, Agricultural Products Development Division, Thailand Institute of Scientific and Technological Research (TISTR), 196 Pahonyothin Road, Bangkok 10900, Thailand

Graham K. Rand, Department of Operational Research, School of Management and Organisational Sciences, Gillow House, University of Lancaster, Bailrigg, Lancaster, LA1 4YX, England

Claudio Simian, Instituto de Investigaciones Tecnológicas (INTEC), Casilla 667, Avda. Sta. Maria 06500, Santiago de Chile, Chile

Jullett E. Simpson, North Clarendon Processing Co. Ltd., 20 West Road, Kingston 7, Jamaica

Chote Vimolchalao, Industrial Research Division, Thailand Institute of Scientific and Technological Research (TISTR), 196 Pahonyothin Road, Bangkok 10900, Thailand

Hussin Hj. Zakaria, Food Technology Division, Malaysian Agricultural Research and Development Institute (MARDI), P.O. Box 2301, Kuala Lumpur, West Malaysia

Observer:
I.H. Tomlinson, North Clarendon Processing Co. Ltd., 20 West Road, Kingston 7, Jamaica

Rapporteurial Support:
Christine Scaman, Department of Food Science, University of British Columbia, 2357 Main Mall, Vancouver, B.C., Canada V6T 2A2

Technical Editor:
K. Kealey-Vallière, Communications Division, International Development Research Centre (IDRC), P.O. Box 8500, Ottawa, Ontario, Canada K1G 3H9

INTRODUCTION

The postproduction systems program of the Agriculture, Food and Nutrition Sciences (AFNS) Division of IDRC supports research projects in developing countries that aim to improve various stages from harvest to consumption of local food commodities. Highest priority is given to requests from researchers in developing countries that focus on locally produced, nutritious foods commonly consumed by the poorer section of the population, whether rural or urban.

It has been suggested to IDRC that the small- and medium-scale food-processing sector in many developing countries has been neglected in terms of research and development. This sector is generally made up of family run businesses, which have evolved over the years, with little access to capital and technical services. It is also the main source of low-cost traditional food products, often based on local raw materials, which are important components of the meals of local consumers, and is an important source of employment and income.

In several countries, efforts are now being made to strengthen this sector to promote self-reliance through development of local industry with local skills to meet unique local market conditions and to ensure the availability of the indigenous processed foods. A solid base of indigenous small- and medium-scale industry could also provide for the development of larger-scale industries in the future.

The typical industrial extension services in many countries have little impact on the small-scale sector and often have little opportunity to make contact. They can usually only give advice. Without technical personnel and capital, the small family food business cannot articulate its needs, nor can it make use of the advice given. There is a need then for researchers and extension staff to interact directly with processors to help them specify their problems and needs and to work with them, within the constraints of their businesses, to suggest, test, and implement improvements. This is a new approach for most extension and research agencies in developing as well as developed countries.

A large-scale processing factory, for example, can call on specialists from its research and development, engineering, accounting, and marketing departments continually to identify areas for improvement in the productivity and profitability of the business and to develop and implement appropriate changes where warranted. Thus, the initial approach recommended at the first workshop in Singapore in 1980 was that developing-country researchers should adapt the approaches used by large-scale industry to the less-organized situation of small-scale processing companies. Individual small companies, although often producing similar products, have quite different constraints requiring different solutions. The approach, therefore, was comprehensive borrowing from the fields of industrial engineering, food processing, operations research, and systems analysis. It was suggested that researchers work in multidisciplinary teams to provide a greater variety of skills.

It was recognized that small-scale processors, like small-scale farmers, often aim to minimize risk in their operations. Therefore, the greatest opportunities for improvement may lie in improving efficiency and reducing losses in their current process as a result of organizational and operational improvements, rather than by imposing burdens of new capital investment. The much greater risks associated with introducing new products or implementing radical changes in technology or equipment should be avoided. The approach should also be systematic so that researchers will be confident that the suggested improvements will in fact be beneficial and that there is frequent interaction with management in information gathering and decision-making during the research activity. Thus, the realities and constraints will be understood and the risks minimized.

A second workshop in Bangkok, Thailand, in February 1981, developed these concepts further, and potentially useful techniques were analyzed in more detail with the Thai team preparing their plans for improvement of noodle processing in small-scale factories. The approach is based on quantitative measurement of factory operations, including both current and proposed conditions, and with interaction among management, factory staff, and researchers so that relevant, acceptable, and implementable project activities are undertaken in an efficient and cost-effective manner.

At the third workshop held in Vancouver, Canada, the Thailand and Singapore participants shared their experiences in working with and adapting this methodology in their local factories and their ideas for improving the approach. The other participants learned about the approach, criticized it, and suggested modifications or new concepts in an effort to develop a flexible array of skills to guide researchers systematically, quickly, and in an informed, well-directed manner, integrated with management goals, to improvements that foster development of small-scale traditional food industries.

A statement made by Professor Hawthorn at the Singapore meeting articulates clearly what is being attempted:

> Before we even start to think about research, appropriate technology, systems analyses, technical services, resource audits, etc., and long before we begin to talk about science we must try to understand the motivations of the business we are considering, the attitudes of the man who is running it, his level of education, his business worries, the family he has to support from it and his standing in his local community. We have to try, with sympathy, to understand his problem from his point of view, and also the needs of the people who work for him. Every business is different and there is no universal remedy which can be applied to them all. There is no point in telling him to buy a new machine if he is already up to his neck in debt. But if we understand the underlying prerequisites for success we may be able to gently guide him in directions which will gradually lead to a

> more hopeful approach to his problems. If we recognize at the outset that modern food technology is not necessarily the road to instant success, but merely a catalyst in an overall process, we shall start on the right lines.

This must be done while building and maintaining credibility of researchers through action in individual factories and coming up with results that offer real, tangible benefits for that business. This is certainly not easy and will only occur through the accumulation of experience in working on a range of real factory problems. It is to be expected that where this experience does accumulate, perhaps such small-industry research activities will be incorporated into present institutional services in developing countries. This will not only foster continued interaction with small industries and provide a realistic training ground for young researchers, but will also suggest research priorities in other fields such as product development, process development, packaging, and more fundamental fields at the research institute, which will be based on the real needs of the sector as perceived by industrially oriented researchers. It was an objective of this meeting to continue discussions on the need to develop approaches for small-scale food industry improvement.

STATUS OF FOOD-PROCESSING INDUSTRIES AND RESEARCH SUPPORT

Participants from the nine developing countries represented (Chile, Egypt, Guatemala, Jamaica, Malaysia, Philippines, Singapore, Sri Lanka, and Thailand) provided the workshop with an overview of the status of the food-processing sector in the national economy along with a brief description of past and present support to the food industry by national institutions. The following is a brief summary of the presentations (detailed statistics relating to specific countries are included in Appendix A).

With the exception of Singapore, the food-, beverage-, and tobacco-manufacturing industries in these countries represent a significant sector of the economy. However, it is a diverse sector, characterized by firms of vastly differing size, investment, number of employees, value added, processing of domestic and foreign agricultural commodities, and operating in national or export markets or both. The larger companies generally have significant foreign ownership; process domestic agricultural products (produced on large estates or relatively large farms) or products imported from abroad; are relatively capital intensive, employing modern, often imported plant and equipment; use technically skilled labour; have their own in-company research and quality-control facility (or purchase such services as required); and are usually not a market for the production of the smaller- and medium-size food-processing operations. The small- and medium-size firms, however, are locally owned, process domestic agricultural and fishery products, are relatively labour intensive, use mostly unskilled labour, and have no in-plant research and quality-control service nor can they afford to pay for such services.

Although in most of the countries one can find statistics on the registered domestic and foreign-owned food businesses, it is very likely that many of the small and cottage-level even in-home food-processing operations are not included in the statistics. This is usually due to their small size, often seasonal operation, and because they are located in nonmetropolitan areas. In general, as traditional food-processing activities, their existence is known to food scientists, food technologists, and governments. Detailed knowledge of their actual processes and the associated technical economic and managerial constraints is not. Their actual contribution to the economy in terms of a market for local agricultural produce, value added, and employment cannot be accurately measured, but it is significant due to their numbers alone, their production of traditional foods for the majority of the population, and their usual tendency to process locally grown commodities.

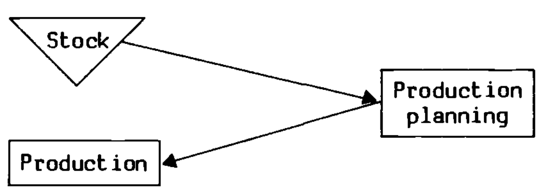
In all of the countries represented there are national institutes, government programs, and, in some cases, distinct government policy aimed at providing a wide range of financial, managerial, technical, and even research support services for the food and beverage industry. However, given that the larger businesses tend to have a good understanding of the scientific and technical principles underlying the technologies they use and have the skills and resources available to articulate their perceived problems, plus the need of many of the national institutes responsible for providing research and technical services to partially or completely cover all their costs from contract work, the bias is still toward providing these support services to the larger companies who go directly to the institutions concerned and who can pay for the services provided. This has often resulted in national, food-research scientists having little or no contact with small-scale food businesses and, therefore, no opportunity to become familiar with the traditional food processes or to conduct specific research for their improvement.

This means that most traditional food processing largely develops through the ad hoc introduction of individual pieces of new equipment rather than through a continous systematic analysis of problem identification, experimentation, and process evaluation involving both researchers and small business owners/managers. The exception to this has been Singapore, Thailand, and, recently, Chile, which have undertaken, in cooperation with the International Development Research Centre (IDRC), specific research projects aimed at improving selected traditional small-scale food processes. Further detail and explanation of the research activities, i.e., methodology, and results of the Singapore and Thailand projects will be given throughout this report.

UNDERSTANDING PROBLEMS OF A SMALL-SCALE FOOD-PROCESSING BUSINESS

Process improvement in a small-scale business is not just a technological or engineering function that can be carried out in isolation from all other business functions. Too often scientists or engineers think that the business can be represented like this:

However, if a mung bean noodle manufacturing business is considered, for example, it must be remembered that noodles cannot be produced unless mung beans are available to start the process. Therefore, a production-planning function is necessary to ensure that enough stock is available. Thus, the diagram can be extended to:



Furthermore, it is not sufficient just to plan the stock levels: the mung beans must first be purchased, so a purchasing activity is necessary, which will interact with the supplier(s). It will also be necessary to consider what happens after the noodles have been produced: they need to be marketed and distributed to customers.

Thus, a business is not just a process, it can more accurately, although still simply, be represented as in Fig. 1. This diagram shows the interactions among the various activities that together comprise the basic functions that occur in any business. All these activities may be managed directly by the owners, as typically found in small businesses, or the industrial activities may be delegated to other staff, or as in large companies to distinct departments. The researcher must be aware of the particular structure of the business that is being investigated, with the decision-making procedures used, to evaluate fully the implications of any improvements that may be suggested.

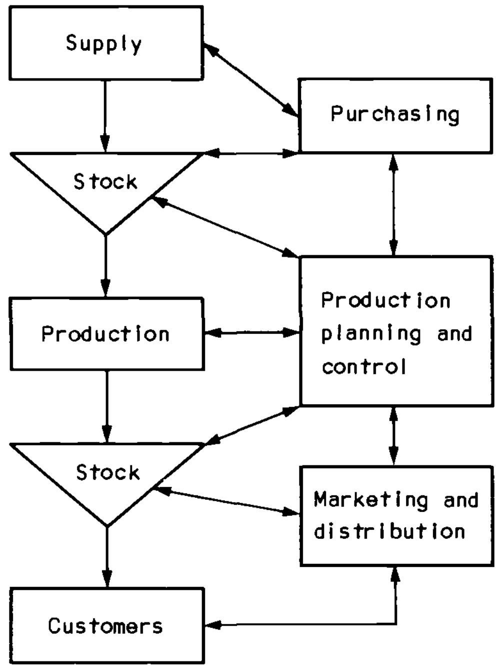


Fig. 1. The simplified business model showing the interaction among different functions.

SYSTEMS ANALYSIS

The focus of systems analysis is the recognition that the different functions of a firm, as illustrated in Fig. 1, cannot be isolated from each other. In systems terminology, each system that may be considered is merely a subsystem of a larger system and will interact with other subsystems. Therefore, to evaluate any process improvement, it is necessary to identify all significant interactions caused by the change and evaluate their combined impact on the organization as a whole and not merely to determine the effect of the improvement on the area of the firm in which the problem originally appeared (Fig. 2).

Systems analysis tries to ensure that all the interactions have been considered. For example, from a sales point of view, it may be desirable to introduce a new variation of a particular product. However, from a production point of view it may be that the new variety is difficult and expensive to produce and causes inconvenience because machinery must be stopped to change from one variety of product to another. Financially, there may have to be an increase in stocks to support the sale of the new product. All of these aspects would need to be taken into account.

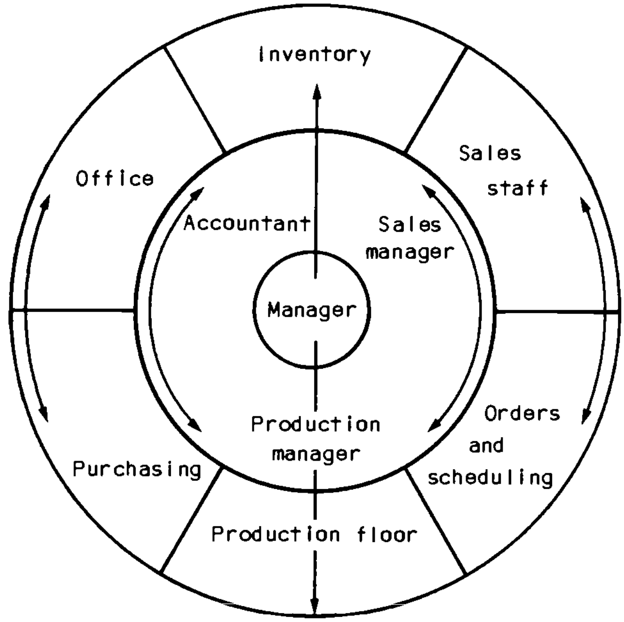


Fig. 2. Interrelationships within a business structure (arrows indicate the information flow).

Systems analysis also provides a diagnostic technique to help unravel the particular problems of a small firm. Several standard problems are often encountered in small firms and these can be analyzed by systems analysis using "minimum activity" charts that describe what usually has to happen before a business can function smoothly (Fig. 3).

Underlying all of the activities listed in Fig. 1 is that the research analysis is being applied to a private, individual commercial business. In most developing (and in some developed) countries, the majority of food processing is performed by small, private family businesses. These are generally characterized as having very limited investment resources; their total purchase of raw materials and their output is small compared to the total market and, therefore, they cannot influence or control the prices they pay for raw materials or those they receive for the sale of their standard products to a general, not a specialized, market. Therefore, the profit margin (the difference between the price of the product and the costs to produce it) is small, and their total profit depends on keeping the production costs low and the production volume high.

The structure of the individual firm and the specific market environment in which it operates will largely determine how the system could be analyzed in economic terms. For example, if research is aimed at significantly improving a quality standard for a product or at the development of a new product for which there may be a specialized but relatively higher-priced market, then least-cost criteria may not be the most important factor, but instead minimization of risk

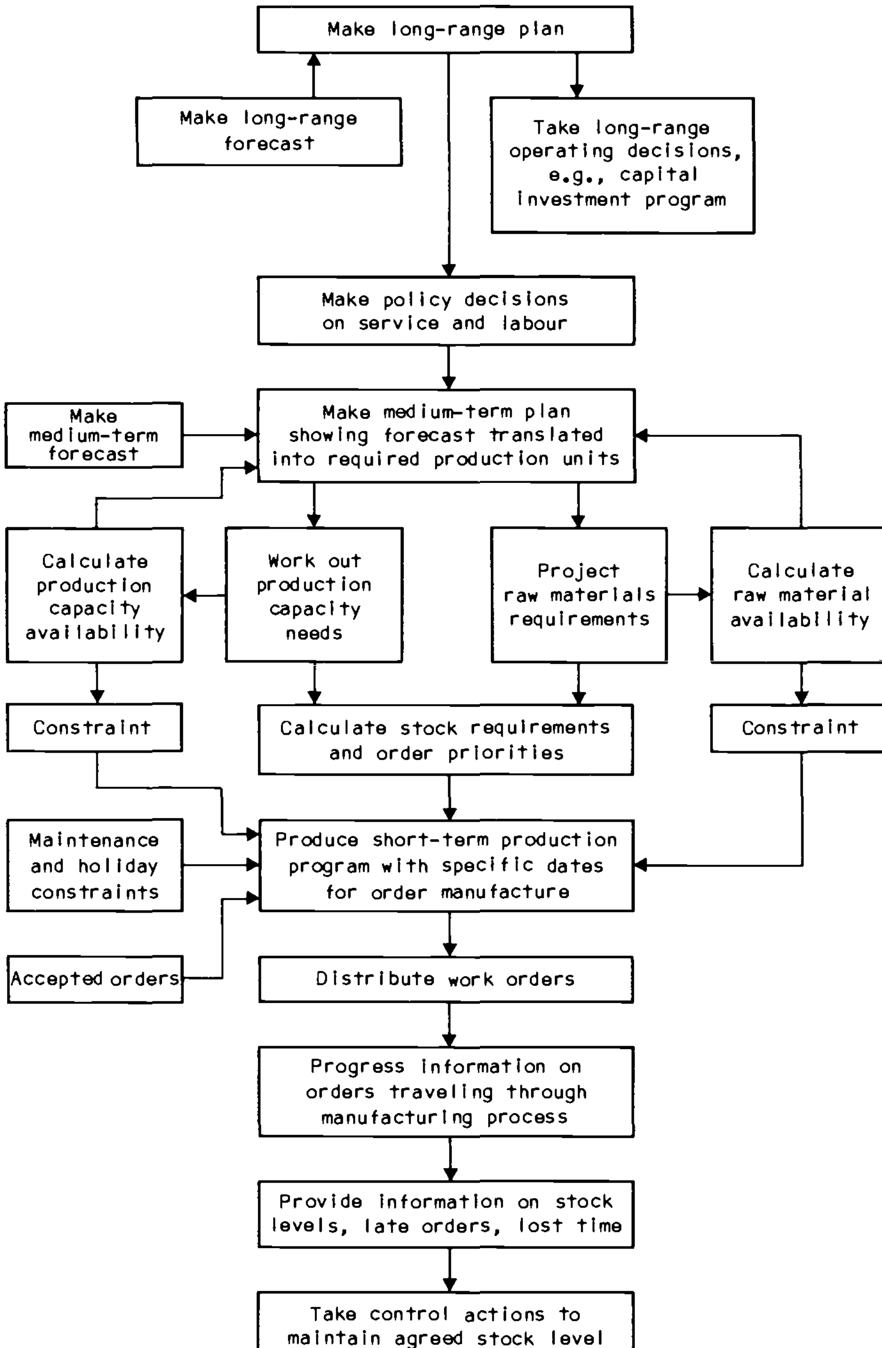


Fig. 3. Minimum activities model for production planning.

through product and market diversification should be considered. A factory owner may place a high priority on reducing the labour input into the process and may, therefore, be willing to accept, in the short-run, relatively costly new equipment because he or she believes that in the long-run it will save money in wages and in costs to train new employees.

A small business may receive benefits of scale if output can be increased, but this greater amount of product output must be marketed. Instead of expanding just one product, diversification may be required. This diversification may also help to overcome problems caused by seasonality of some food products. However, the more diversification that occurs, the more complex the operation becomes and the more "down time" the factory experiences. All the factors have a direct effect on cash flow.

Again, it is important to remember that no aspect of a business can be segregated from the others. A business operation must always be looked at as a set of interrelated systems. This is especially true in a small-scale business. It may be difficult, however, for one person to coordinate all of the different systems within a business. Some small company managers may not realize that certain aspects of the business exist, so there is a need to bring about this awareness in an organized, systematic manner.

CONTACT WITH SMALL-SCALE BUSINESS

Researchers from the various institutions represented at the workshop discussed their different methods of contact and information sharing with small-scale businesses. It was felt that to make the first contacts with small-scale business it would be necessary to advertise the services available to the industry at large. Training courses that offered visiting experts, but preferably featuring local experts, have been used to promote interest. Other methods included visiting local businesses personally and surveying the characteristics of a particular food sector or processors' association.

B.C. Research, for example, has organized seminars focusing on specific problems faced by different small-scale industries together with direct technical staff assistance. Through this method they have established contacts within the industry, built up a reliable reputation, and increased the awareness of what services are available. In Singapore, the most effective contact has been made through voluntary response to their improvement program stimulated by media coverage, but it has been difficult and slow to obtain these contacts. Usually, only young, often well educated, managers are motivated to seek improvements in their businesses. In Thailand, surveys were made of the individual factories and personal contact was made to help determine what problems individual firms were experiencing. Surveys were also made of the members of the Federation of Bakers in Chile. Cooperation among the bakers, however, varied greatly. Generally, the best results have come from initiating contact on an individual basis. Once initial credibility has been attained with one company through positive improvement, the reputation of the research group will spread in the industry and more people will initiate the contact themselves.

Experiences in certain countries showed that the mass media, such as radio, television, and newspapers, plays an important role in stimulating the development of small-scale food industries. The participant from the Malaysian Agricultural Research and Development Institute (MARDI), for example, reported that the announcement of the availability of a package technology for soybean curd processing, complete with its cost-benefit implications, on radio and television resulted in not less than 300 inquiries within a period of 3 months. This soon led to a steady stream of potential and existing processors coming to learn about the technology concerned. A follow-up study by the institute indicated that about 25 such industries had been set up within a period of 2 years. As a result, the institute soon became recognized as an important centre for food processing technological expertise. This led to a reemphasis of the institute's work toward helping small-scale industries.

FACTORY VISITS

First-hand experience must be gained by visits to the particular factory. Such visits must be planned carefully beforehand, especially understanding the goals to be achieved by the visit. The size of the research team must first be determined. It should not be too small, more than one person is almost essential, but it should also not be so large that it overwhelms the management. Ideally, three researchers with different backgrounds in, e.g., food technology, economics, engineering, etc. should form the team.

Techniques Used to Describe Business Operations and Identify Problem Areas

Checklists

The research team must be prepared to collect information systematically. A useful way of obtaining a basic understanding of what is happening in a firm is to ask questions. A convenient means of doing this is to use checklists so that the strengths and weaknesses in strategic operating areas within the firm are revealed. Appendix B contains a checklist of questions that was developed during the workshop. These are only a guide and are expected to lead to further questions evolving during the visits.

The purpose of these questions is to help the researchers identify the potential problem areas in the business. At a detailed level, it may be possible to draw an actual activity chart, which can be compared with the minimum activity chart, as in Fig. 3, to identify gaps in activities as problem areas. At a more straightforward level, it will be possible to discover the strength of the links between the different activities that are shown in Fig. 1. For instance, if questioning reveals that not much thought is given to the supply of raw materials it is possible that a stock control study would lead to improvement. Or if the manager is not certain about what prices the customers are prepared to pay it may be that a marketing study would lead to a substantial reduction in distribution costs. Appendix B also contains examples of data-collection forms that have been used by researchers from the Thailand Institute of Scientific and Technological Research (TISTR) in their visits to factories in Thailand. The completion of such forms will help researchers to collect quickly the basic information about a business and, in particular, quantitative data on the process. Often several visits are needed to obtain adequate detail of specific areas in the plant.

Charting

In studying a food business it will usually be necessary to gain a detailed understanding of the production process. The most appropriate way to do this is to draw a chart. At the initial recording stage, only an overall view of the process is required, and this will help to indicate how detailed further records should be. Such a view is provided by the outline process chart (OPC). A more comprehensive picture, covering more than the key activities of a job can be presented in the flow process chart (FPC), which is particularly suitable for recording maintenance and other indirect work.

In certain cases, the OPC may serve as the basis for examination of the process without further recording. However, the OPC is more often used as a skeleton around which an FPC is built. The OPC does not record exactly what is involved in these production activities, nor how they are accomplished. An alternative to amplifying the entire OPC is to select one or more of the operations and inspections that are sufficiently complex to require clarification. These are then made the subject of further detailed charts. After examination in the early stages of research, the OPC is used again to provide a skeleton summary of the proposed new method. This will incorporate the broad modifications to the process, which will later be detailed in an OPC.

The FPC records not only the "key operations" involved but inspections and the "make ready" and "put away" operations, as well as "delays," "storages," and "transports." An example of an FPC chart is used in the Thailand case study and details of how to construct a chart are also included in Appendix B.

Bar charts can be used to express the sequence of operations in any process on a time scale. This method was used to demonstrate the benefits that were available from the variety of process improvements the Thai researchers, for example, intended to undertake in their factories.

Much information is available on the subject of bar charts (or Gantt charts as they are usually called) in any number of industrial engineering textbooks. Bar charts, generally used to assist in scheduling production activities, can also be useful in identifying the bottlenecks that occur in a process. The simplified example in Appendix B shows what can occur when a process is improved through the reduction of the bottleneck operations time. It is important to note that the separate operations cannot be considered in isolation.

Work Sampling

Work sampling is a method of determining the proportion of a typical work period occupied by various human and machine activities. It is a valuable tool in determining lost time and unproductive work as targets for improvement. By a system of sampling based on statistical concepts, it provides an inexpensive and accurate way to gather facts about an operation, process, machine cycle, or any other form of work.

Briefly, a work sampling study is carried out by observing an employee or a machine in operation at random intervals during the day and recording exactly what is occurring at the instant the observation is made. These observations are summarized daily and the like observations grouped. After a number of days of observing the work cycle the observations will begin to fall into a pattern that should indicate the proportion of total time occupied by each activity during the period of the work sampling study. Consideration of the activities using up most time can assist in identifying bottlenecks or opportunities for increasing production, better utilization of labour, etc. The method of carrying out a work sampling study is given in Appendix B.

Pareto's Law

The appreciation of the basic concepts involved in "Pareto's Law" can be of use. It states that "in any series of elements to be controlled, a selected small fraction, in terms of numbers of elements, always accounts for a large fraction, in terms of effect." For example, once a chart is drawn, or work sampling is completed, it may be possible to identify one or two parts of the process that take up a considerable proportion of the time. Making a small percentage saving on these operations will make a greater impact on the process as a whole than a similar percentage saving on an operation that is in any case not time consuming. Similarly, analyzing production costs in this way will reveal the most costly activities for attention.

Economic Analysis

The responsibility for obtaining information on economic and financial characteristics of the business (and in undertaking subsequent economic screening assessment and technology evaluation) should, where possible, be with someone trained in the field of microeconomics. In most cases, this would be an economist, but many other professions with major training in engineering, particularly industrial engineering; food scientists; operations researchers; business management specialists; accountants; etc., can have the required academic training to do the work. However, whatever the background of the person responsible for the microeconomic analysis, that person should be a full-time, active member of the research team. The economic analysis, is not something that can be "done in a vacuum" from the rest of the scientific/technological research of the other team members.

The economist on the research team must contribute to the research team's holistic understanding of the food process operation, i.e., its determinants and constraints are often economic or financial ones, not just technological. The role of the economist is not just to be independently given a set of experimental data on the existing process but to be involved in the original experimental design as well as the evaluation of experiments with new technology.

Before making the first factory visit, the team economist should keep in mind that in most cases the small- and even medium-size traditional food-processing business will be completely privately (most likely family) owned where the owner is the manager, and the sources of funds for investment in process improvement come from money borrowed from the bank or family or previous profits.

It is very unlikely that a small-scale food-processing factory will be able (or willing) to provide the research team with a detailed breakdown of the costs of producing its products. No doubt the owners/managers will have some cost information available, particularly for material and labour inputs and product prices and they will have their own perceptions as to what makes up the average total cost of producing one unit of output. But it is unlikely that an annual financial statement or detailed periodic (weekly or monthly) cash-flow statement will be available. However, a relatively detailed, and hopefully accurate, definition and description of the total costs of the existing process will be necessary before the research team can make decisions regarding priorities for technical research for process improvement and in evaluating alternative technical solutions to a specific processing problem.

At this stage of identification and classification of costs, to describe the business financially, the important questions to be answered are: what items are costs; where are the costs incurred in the process; when are these costs incurred; how are specific values placed on these costs; and how should the costs be apportioned?

- What items are costs? -- The following are the normal costs incurred in food processing: plant and equipment (buildings and machinery); material costs (raw materials, packaging materials); labour costs (wage labour and salaried labour); water; electricity and fuels; vehicles and/or transport costs; taxes; and equipment maintenance.
- Where are the costs incurred? -- Costs are incurred either directly (are specific to one activity) or indirectly (are not specific to one activity). For example, fuel for drying noodles or labour for bottling soysauce can be directly charged to those activities, but the annual cost of the building has to be charged to all major components in the process and is, therefore, classified as indirect. Most attention should be paid to direct material, labour, plant and equipment, and fuel costs as well as indirect plant and equipment costs. This will be important when making estimates of the comparative marginal costs and benefits of a new technology compared to the existing process.
- When are these costs incurred? -- Besides being classified into direct and indirect costs, costs are separated into fixed and variables costs. Fixed costs mean those costs that are incurred regardless of the level of output. As long as the firm remains in business these costs will have to be met. Examples of fixed costs are plant and equipment and vehicles. Variable costs mean costs that vary directly with output, although not necessarily in the same proportion. Material costs, fuel, and labour are common examples.

The distinction between fixed and variable costs is important because, as long as the price of the product covers the variable costs of its production plus interest on the capital, it will make sense for the factory to stay in business. The reason is that if it closes down completely all of the fixed costs would then be lost.

- How are specific values placed on these costs? -- The first three questions are fairly basic, but the fourth one, how are specific values placed on these costs, is more involved. For example, for the plant and equipment, if the factory building is owned by the food processor, then an annual depreciated charge is normally calculated as an allowance for replacement at the end of its assumed life. If the factory space is rented, then the annual rental charge is used. For equipment, the annual depreciated price is used. Depreciation for either plant or equipment is most often calculated according to the straight-line method. Under this method the annual depreciation is computed by dividing the original cost of the asset, less any salvage value, by the expected years of life. This method is the easiest to compute and understand. Often this is the method most widely used. It is also true that most processing equipment depreciates more rapidly and sooner than the straight-line method would indicate.

During the factory visits, for materials costs, labour costs, fuel costs, etc., receipts for payment within the last 6 months (probably from the owner's own personal accounts) should give reasonably accurate estimates in terms of both quantity and price. The information on quantity from receipts should of course be supplemented with detailed sampled observations of the actual processing to relate quantity of inputs used to quantity of products produced per unit time.

For equipment maintenance, information should be obtained by questioning the owner, doing research, making observations or using past experience on equipment breakdown and/or maintenance over a period of several months, or by using a rule of thumb of 5-15% of the purchase price of the equipment depending on its age and complexity. Information on taxes is difficult to obtain from the owner. The economist, after making estimates of the annual total returns and total costs, will have to apply what is considered to be the normal business profit tax rate to the difference.

• How should the costs be apportioned? -- The procedure for apportioning the indirect costs to the major processing components is often a difficult and time-consuming task (in addition to deciding if a cost is fixed or variable and setting values to cost items). Most small- and medium-scale food-processing operations in developing countries are not likely to have indirect costs other than for the plant's annual depreciation charge or rent, owner's own salary, power for lighting, etc. These, however, can be significant in some cases. The most important of these will be the charges for plant and some equipment. Here some simple general guidelines can be applied. In the case of plant and equipment, the cost can be allocated proportionally based on the proportion of total floor space devoted to each major processing component. The same is true for general power costs for lighting. It is recommended here that the team economist not devote a significant amount of his or her time to the question of apportioning indirect costs except for the items just mentioned. The increase in accuracy is likely not to be worth the effort and use of the limited time available.

The foregoing applies in the case of a factory producing a single product. However, once the possibility of more than one product is considered (e.g., in a bakery), the determination of average total cost per unit of output becomes very difficult and the interpretation of the result must be looked at carefully regarding the decision to decrease production of some products and increase production of others. Table 1 illustrates a hypothetical example of a small bakery producing four products.

In this case, the bakery produces four products, A-D. Direct variable costs are allocated directly to each product and the overhead cost (fixed costs that cannot be directly allocated) is apportioned on the basis of either sales revenue or units produced. The important points to note here are that the total revenue (TR) and total cost (TC) facing the firm are the same regardless of the method of apportionment chosen and the total profit in each case is $5800. Every product makes a positive contribution to the fixed cost, yet by attempting to apportion the fixed cost by TR, the value of product C is brought into question and the firm will consider dropping it. Under the apportionment method of units produced, both products C and D appear to be making an overall loss. By dropping these products the firm would still have the total fixed cost to bear, $10 000, yet, it would have lost the contribution being made by C and D of $5000 ($2000 + $3000).

Table 1. Contribution to fixed costs and fixed costs apportionment ($) for a small-scale bakery producing four products.

	Products				
	A	B	C	D	Total
Price	100	80	50	20	
Number of units produced	120	150	200	300	
Total revenue	12000	12000	10000	6000	40000
Variable costs per unit	60	40	40	10	
Total variable costs	7200	6000	8000	3000	24200
Contribution	4800	6000	2000	3000	15800
Fixed costs					
Apportionment on basis of sales revenue	3000	3000	2500	1500	
Profit	1800	3000	(500)	5800	

Note: Total figures are rounded to the nearest 10.

It could be argued from looking at the data in Table 1 that even on the basis of the difference in price and variable costs, products A and B should be expanded and C and D reduced because the difference is 40 for A and B and only 10 for C and D.

Once the costs are identified and classified, it is useful to prepare a general annual cost statement for the factory. Table 2 gives an example of a hypothetical small-scale food-processing firm.

From the table one quickly sees the importance of making sure that the process has a minimum of raw material wastage in processing

Table 2. Total costs of production from 1 January to 31 December.

	Quantity	Unit price	Cost/ revenue	% of total cost
<u>Annual operating costs ($)</u>				
Variable costs				
Raw material processed	2000+	80	16000	47
Packaging materials	10+	100	1000	<1
Fuels (gallons)	12000	3.50	42000	12.3
Labour (hours)	23000	3.00	69000	20
Water (gallons)	20000	0.05	1000	<1
Shipping	265	25	6625	2
Fixed costs				
Salaries of management			12000	3.5
Salaries of technicians			8000	2.4
Plant depreciation (or rent)			12000	3.5
Machinery depreciation			15000	4.4
Maintenance			7500	2.2
Interest on borrowed capital			2700	<1
Lighting			1500	<1
Property and business tax			1000	<1
Office materials			300	<1
Total cost			339825	
<u>Annual production and revenue ($)</u>				
Production sold	315000	1.25	393750	
Change in inventory	2000	1.25	2500	
Total value of production			396250	

<u>Selected economic indicators</u>

Gross profit (before taxation) = 396250 - 339825 = 56425
Rate of return on operating cost = 56425/339825 = 16.6%
Rate of return on investment = 56425/150000[a] = 37.6%
Production per labour hour[b] = 31700/23000 = 13.8
Value of production per labour hour[b] = 396250/23000 = 17.2
No. of units of production per tonne of raw materials = 317000/2010 = 157.7
Amount of labour required per unit of production[b] = 23000/317000 = 0.073
Cost of labour per unit of production[b] = 69000/317000 = 0.22
Amount of raw material per unit of production = 0.0063+ (or 6.34 kg)
Cost of raw material per unit of production = 0.51

[a] Based on total initial investment in fixed assets. In this case, equipment only, assuming straight-line depreciation and an average life of 10 years for the equipment.

[b] Wage labour only.

and in storage of the final product (because this is the marginal cost centre) and is able to use as much as possible all of the raw material input in the final product. For example, if the efficiency of use of the raw material in processing per unit of final product could be improved by 5%, this would have a potential gross savings of $8000, equal to 2.4% of existing cost. In a small business, which survives on volume output and a small profit margin, a 2.4% reduction in cost is significant. Another example from Guatemalan rural coffee drying illustrates the relative costs of each process operation (Table 3).

Table 3. Costs incurred for rural coffee processing in Guatemala (Q 1 = U.S. $1).[a]

	Q	Cost/unit product	%
DIRECT PRODUCTION COSTS			
Labour	1093.73	42.26	30.24
Supervision	192.50	7.44	5.32
Electricity	125.72	4.86	3.48
Fuels	157.67	6.09	4.36
Water	70.04	2.71	1.94
Maintenance	75.00	2.90	2.07
FIXED CHARGES			
Depreciation of bed dryer	20.33	0.79	0.56
Rent	500.00	19.32	13.83
Overhead[b]	463.38	17.90	12.81
GENERAL EXPENSES			
Administration	138.84	5.36	3.84
Transportation to Palín (central collection centre)	779.13	30.11	21.54
TOTAL COST	3616.34	139.73	100.00

[a] Details of this process are provided in the Guatemalan example in the section on Country Workshop Reports.
[b] Includes warehouse keeper, watchman, and other expenses.

The second step in getting an initial annual costs and returns analysis of the factory is a statement of revenue. Generally, this is much easier than estimating or calculating costs. Table 2 shows these for the same hypothetical factory. For the sake of simplicity, revenue consists of only two items: value of goods sold and the value of the change in inventory of unsold finished goods. This shows a gross profit (before tax) of $56 425.

The next step is a general analysis of these results vis-à-vis some economic criteria. Such analysis can be made by the research team to identify areas where gains can be made through improving specific aspects of the process as a "yardstick" or measure to compare the general financial performance of the factory after certain technical improvements have been made and to compare a specific factory with the performance of another or more similar factories (in this way the researchers can isolate areas in the process where there is a high probability of improving factory performance because a better performance already exists in other factories). Again, Table 3 shows some of the major criteria that can be used.

Defining Problem Areas

It is essential that as the problem becomes more focused and ready for final definition (through the application of the foregoing procedural steps) a summary of the criteria to be used to confine the limits of any investigation can be established. This summary, i.e., the "terms of reference," describes, in a succinct manner, the basic framework around which analyses will be structured and against which results may be assessed as they are finalized. The main objective is to set down the major parameters within which all work will be done.

The terms of reference needed for any procedure under investigation must consist of at least the following five items. These must be capable of being verified in all ways (organizationally, economically, technically, etc.). This means sufficient factual data must have been developed and be available to permit them to withstand the most rigid scrutiny. It is useful to consider a basic terms of reference as including:

- Purpose -- A statement of the objectives of all work to be done.
- Scope -- A statement of the limits of the work that will meet the needs of the study purpose.
- Outline process chart -- The chart that describes the process under investigation in a clear schematic outline and at an appropriate level of scale.
- Key activity identification -- This activity is the vital step around which all other activities in the process are built.
- Statement of achievement -- This is a simple, brief sentence that describes the "end result" brought about by the "key operation."

In every process there are operations that control all, or a major portion, of the whole. These are called key operations and may be defined as: those operations that, if eliminated, will eliminate all, or a major portion, of the entire process. All other operations are to prepare for doing the task(s) described by the key operation or closing down work after it occurs. To simplify terminology these other operations are called "make ready" and "put away" activities. The key operation is called the "do operation."

In the food processes there may be several key operations to be considered, so that an ordering of priority among them may be necessary. This may be a useful approach in some problem situations, but other approaches drawing from checklists, cost analyses, and other information may also be appropriate in identifying priority activities for improvement.

As an example of the identification of a "key operation" a factory operation has been chosen that describes the packaging of papadams (a crisp, legume-based snack food) in a small Sri Lankan plant. This is a portion of an actual case study presented at the workshop. In Fig. 4, the key operation is the one where the papadams are placed into the plastic bag by the operator. If this action is altered, the entire process will change. For example, if it is decided to package the product mechanically, or ven not to package it at all, for whatever reason, then major changes will be required in the existing process. In this case, if the packaging operation is eliminated then the whole process from quality inspection and weighing through to heat sealing and boxing becomes unnecessary. All the operations before packaging are "making ready" to package and all subsequent operations are "put away" or closing off the process.

The "statement of achievement" is not a description of what is done during the operation but is a clear picture of what has been achieved by taking this action.

Using the papadam packaging process as an example, the key operation is "place in plastic bag." This is the action taken but is not the requirement that must be met. The requirement is to protect the papadams so that they will maintain a quantity and quality level demanded by the marketplace. There are obviously other ways to do this but the way that has been chosen is through the use of a plastic bag. The immediate "end result" (or achievement) brought about by the activity described in the key operation is, therefore, the containment of a measured quantity of papadams (100 g). "Required quantity of papadams are contained" could represent the statement of achievement. It must not state the objective of the activity. This answers the question "why" the activity is carried out, e.g., "market shelflife is obtained," is not the achievement -- it is an objective of the achievement. It must answer only "what" is achieved not why, who, how, where, or when it is achieved. This approach allows exploration of ideas of how else might the achievement be made as a means of identification of possible improvements.

PROBLEM IDENTIFICATION IN THE SMALL-SCALE BUSINESS

After initiating contact with a small-scale business, visiting, describing, and analyzing its operation, the problems encountered will be either managerial or technical or both. Figure 5 illustrates the sequence of events that occur from the time any situation is considered for improvement. This sequence of events may be applied in great detail up to a broad general approach depending on specific circumstances. The diagram provides a useful guide that permits those involved in the improvement activity to orient themselves from time to time and understand the progress they have achieved and what remains to be done in any problem-solving activity.

Figure 5 also illustrates the major segments in the initial problem identification process: the identification and gathering of facts that are known or available and the screening and reasoning procedure that defines priority areas for improvement and that requires the specification of terms of reference that will determine the scope and development of the study, which leads on to identifying a systematic,

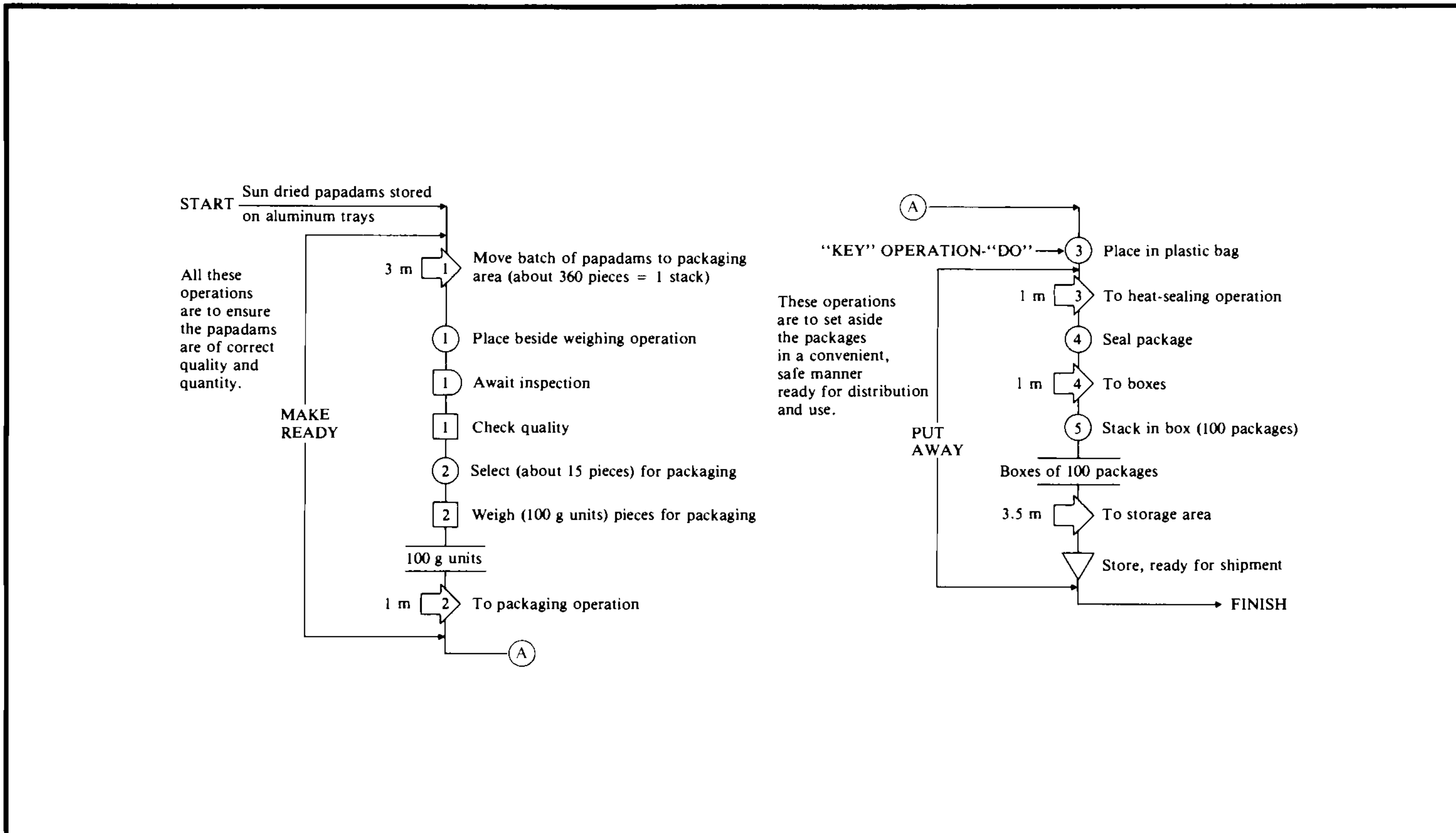


Fig. 4. Identification of the key operation in the packaging of papadams.

structured approach to finding solutions. The researchers' point of contact with the business and early factory visits offer the identification of problems or symptoms. The researchers' task is to make a diagnosis from these symptoms; as much information as possible is needed about the business.

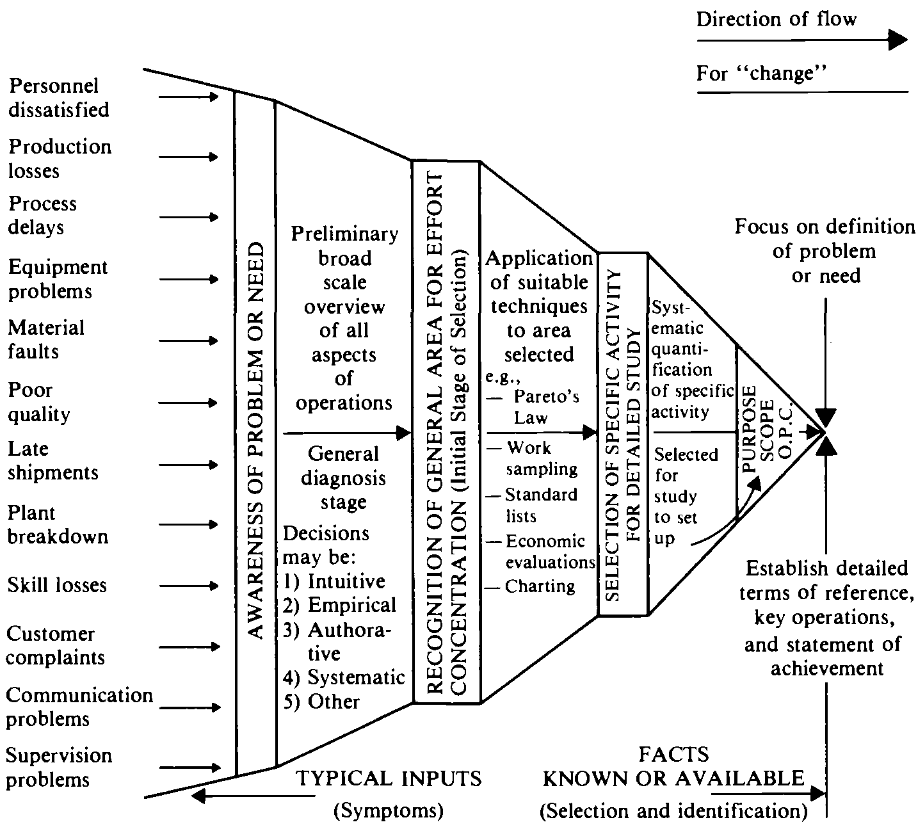


Fig. 5. Structural framework for the problem identification process.

This initial study will identify a series of constraints that will influence the improvement strategy because 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.

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 their objective.

Generally, the objective will be increased profitability, cost reduction, or both. This might be accomplished, for example, through a reduction in energy requirement or cost, reduction in waste treatment load, or reduction in labour requirements. Pareto's law can be of value to select these areas for attention (classification of the activities, products, and ideas to identify the vital few and the trivial many). In a company with several products, 10-15% of the total number will account for perhaps 80% of the company's profit. It is important then to identify those few products or processing activities, individual machines, etc. that have the greatest impact on total company profits, costs, and problems, and so concentrate research efforts in these areas. Several methods are available (Table 4).

In many instances, of course, the researcher 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 this specific problem is solved, time is not taken to identify other opportunities for improvement within the company and thus reduce vulnerability in the future. In any case, after clearing it with management, the problem area with opportunity for greatest improvement is chosen for detailed study.

Description of Processing Operations

Where the area of attention is an individual product or process line, the next step is to draw up a detailed process flowchart that shows all the steps in the process in their logical sequence (Fig. 2). 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 conditions and possible mechanization opportunities;
- Equipment or machinery at each point noting function, efficiency, and possible improvements; and
- 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 for as many of the key operation points as is possible. This often leads to identification of opportunities for process improvement that would immediately and profitably 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.

Screening

After a series of factory visits, interviews with management, and data gathering at the factory, a list of problem areas or opportunities for improvement for the plant can be derived from analysis of such management areas as production scheduling, inventory, the major

Table 4. Some procedures for identifying priority areas for process improvement.

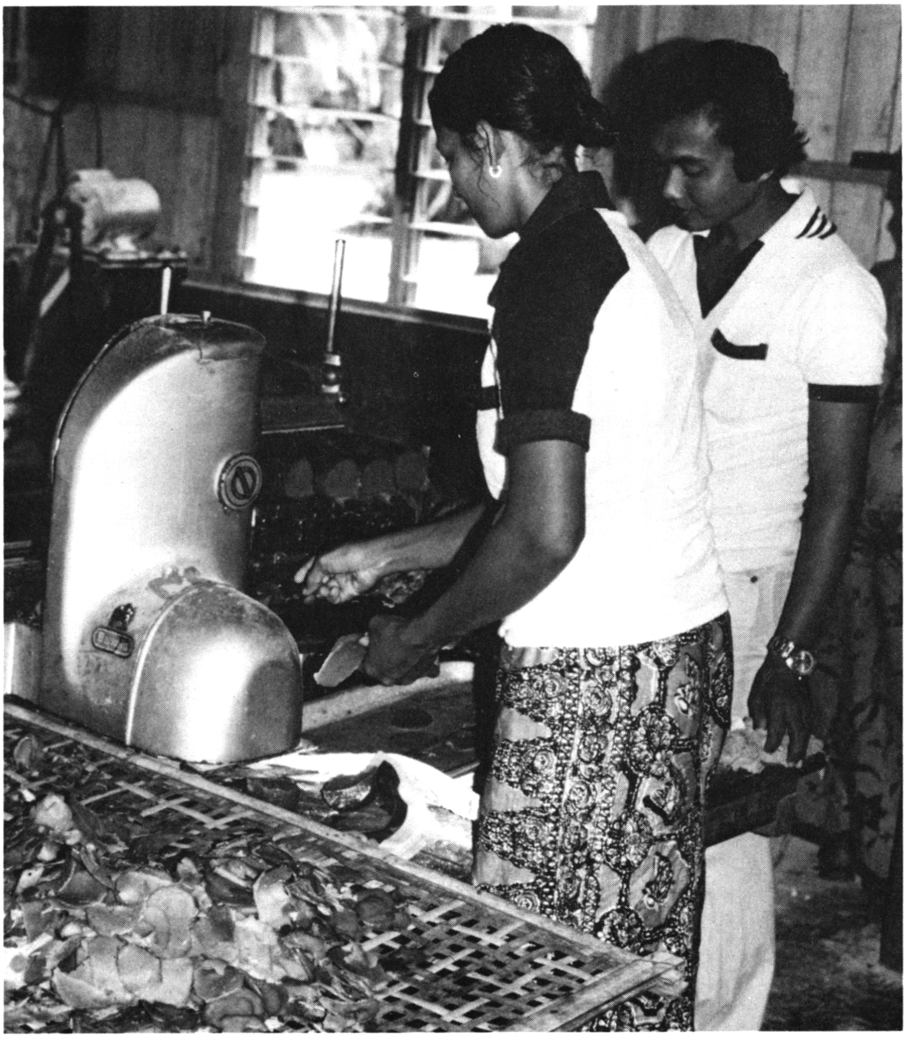
Method	Description
1. Profitability analysis	Calculation of contribution to annual profit for each product
2. Cost analysis	Contribution to production cost/ standard cost of each cost centre
3. Energy audit	Contribution to overall energy cost/ requirement of each unit operation/ product/company activity
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 overall maintenance cost/time for each machine
7. Work sampling	Time spent/labour use at each operation

cost centres in the operations where possible benefits to profitability exist, or through identification of technical operations in the process where improvements might be beneficial.

The next step is to arrange the activities in order of priority and determine which activity would be the most beneficial to complete first. It is important to involve the manager in this procedure so that a mutually agreeable research activity is selected, e.g., by defining criteria important to the business, i.e., factors, objectives, and constraints that will determine whether the improvement will be implementable in the plant and the degree and type of benefits expected.

Each possible activity can be assessed against each of these criteria to select the one with the highest potential for initial improvement work. The typical criteria used are: improve quality, increase capacity, reduce operating costs, minimize capital costs, assess effects on labour requirements, increase profitability, minimize research costs, assess availability of raw materials, etc. These criteria are discussed by the research team with the manager, so that the most critical factors are chosen. Often they are ranked in importance and a weighting is assigned to each to reflect the relative importance of the various criteria to the management's goals.

Each alternative area for improvement is then rated against each



In small factories, some mechanical operations are important such as this dough-slicing operation in a fish cracker plant in Malaysia.

criterion and a total rating is obtained. This rating may be a simple yes or no, e.g., does it conflict with the criterion, or a ranking, or a score on a 10-point scale or within the maximum weighting? There are several approaches. The degree of detail used depends mainly on the level of decision needed from this quantitative screening exercise. At an early level, ranking or scoring is sufficient because essentially qualitative data is being used to select an area for more detailed investigation. At a later stage in the improvement work where, for example, specific equipment options may be screened, more quantitative data on costs, maintenance, throughput, and training

Table 5. Sample of the final screening table for a small-scale bakery using ranks (1 is most favourable).

Improvements	Criterion						Total
	Increase revenue (1)	Reduce operating costs (2)	Contribution to overhead (3)	Capital cost requirement (4)	Research cost (5)	Effect on quality (6)	
A. Reduce baking time	7	1	7	3	3	7	28
B. Reduce labour requirement at mixing	7	3	7	5	4	6	32
C. Reduce level of rejected product	3	7	3	4	5	1	23
D. Reduce bottlenecks	7	2	7	7	6	5	34
E. Consider introduction of new products	2	7	2	6	7	2	26
F. Consider increasing the price of products	1	7	1	1	1	2	13
G. Reduce distribution costs	7	7	7	2	2	2	26

issues, for example, can be taken into account in more detail in a more critical screening exercise.

As an illustration of ranking, following visits and discussions in a small bakery, analysis of the information indicated certain opportunities for improvement: reduce baking time, reduce labour requirement at mixing, reduce level of rejected product, reduce bottlenecks at packaging, consider introduction of new products, consider increasing the price of products, and reduce distribution costs. After discussion with management, the following list of criteria reflected the objectives and constraints that affect the desired improvement in their order of importance: increase revenue, reduce operating cost, contribution to overhead, capital cost requirement, research cost, and effect on quality.

Each improvement idea was ranked for its estimated degree of favourable impact on each criterion. It is useful to involve a group of people, including the manager, in the screening activity. The average rank of the group's individual scores should never be used as this tends to smooth out differences among options so that a clear choice cannot be made. Instead, following discussion of each individual's score, a group concensus rank should be agreed on. Where possible, estimates of costs, profits, and technical and marketing issues, etc. should be brought into the discussion to aid rating. As shown in Table 5, the most appropriate improvement area for initial work was identified as "F," investigation of opportunities for increasing the price of the bakery's products, which involves new marketing approaches, what level of price increases might be possible, etc.

Problem-Solving Techniques

Brainstorming for Ideas

No one model is suitable for all generation of ideas to solve the priority problems identified, however, brainstorming is perhaps the simplest and most popular technique used. A team should be assembled of probably 6-12 participants. Some should have a good knowledge of the problem and previous experience of brainstorming. The problem should be outlined to the team so that the members can ask questions to clarify the matter. The next step is to restate the problem in a number of ways. The statement of achievement or problem situation should be written out. Members should then make suggestions or give ideas for achieving the objective or overcoming the problem, no matter how ridiculous they may be. The intense interaction that evolves allows one idea to spark off others until a long list is obtained.

The ideas should be edited by deciding on subject headings (e.g., financial, training, engineering, personnel, or perhaps, in another context, home, export, domestic, industrial). The ideas should be grouped under the appropriate headings and rationalized, i.e., combine them, eliminate, clarify, extend, and add additional ideas from the group. Then, if not already done at the defining stage, the acceptability criteria should be established, to allow a screening process, similar to that outlined earlier, to select what seem to be the best ideas (probably no more than 5%) usually by a smaller team.

EXPERIMENTATION: INVESTIGATION FOR IMPROVEMENTS

After the specific operation or problem area has been identified for improvement in the processing plant, or particular ideas suggested, a pragmatic research program is required to find a satisfactory solution. This implies some degree of experimentation or investigation. Wherever possible, most of this research should be carried out in the plant or at least involve the manager in the decision-making to ensure that the solution is appropriate and implementable.

To minimize disruption to normal production schedules, research should be efficient in terms of time, necessitating a compromise between scientific vigour and the need to define an improvement quickly. For technical work, support activity at the laboratory may also be appropriate. Investigations should be systematic to reduce risk for the researcher, and fast so that the processor is not frustrated by endless studies awaiting useful results. Fortunately, several systematic techniques are available to the researcher.

Successful experimentation is usually a result of careful forward planning and systematic working toward a predefined goal. Therefore, the following steps are suggested:

- Problem definition -- A brief statement should be made of what the experiments are to achieve, e.g., yield and quality of dried fish is to be improved.
- Setting objectives -- Know exactly what is to be found out during experimentation, e.g., to define the optimum conditions for fish drying.
- Experimental planning -- The experimenter must first define the output variables, i.e., those factors that change as a result of altering the process; in fish drying, the output variables might include fish colour, yield, and rehydration capacity. The experimenter must decide which output variables are important and how these are to be measured. Next, the input, or process, variables must be defined, e.g., time, temperature, dryer load, etc.
- Experimentation -- The experimenter must now find out what effect the input variables have on the output variables, e.g., how does drying temperature affect fish colour? This is normally achieved by systematically varying each of the input variables and noting the changes in the output variables. Variation of each of the input variables can be extremely time consuming. Specific experimental design techniques are available to assist the experimenter in this regard.
- Execution -- Once the experimental plan has been finalized, it is important that the plan be adhered to exactly throughout execution of the experiment. Setting of input variables must remain unchanged -- even if the responses are not up to expectations.
- Analysis of results -- Care must be taken after each experiment to record and analyze the results before proceeding with the next

experiment. If a statistical experimental design is used then a full analysis should be completed to show the significance of the effects of each of the input variables. Graphical interpretation of results is often effective.

- Action -- If the objectives have been properly set then the experiments should always lead to some form of action relating to the objectives. Either the objectives have been met or further experiments are required. It is important that real and decisive action is taken in response to experimental results. Even more important, the process of experimentation and resultant action should be ongoing so that product and process improvement can be made in a progressive manner.

EXPERIMENTAL DESIGN METHODS

It is important, in most industrial situations, that experimental designs be easy to plan and execute and simple to analyze. Naturally, the value of the experimental results should not be sacrificed in an attempt to oversimplify experiments. There are a number of basic experimental design methods that do meet the criteria of simplicity of planning, execution, and analysis while still presenting the experimenters with extremely valuable information about their system. An outline of some of these methods follows, and case studies of the application of each method are presented in Appendix C.

Screening Experiments

One of the first steps in solving a development or production problem is to identify those input variables that substantially affect the response variables(s) under study. Frequently, the list of potentially important variables might range from 10 to 20. It is usually possible to eliminate some of these variables by previous knowledge or other nonstatistical screening methods, but often the experimenter is left with 6-10 variables to consider. Under these circumstances the problem may still be too large to solve using conventional factorial experiments. What is required in this case is an experiment that can detect the few main effects with a minimum amount of experimentation. There are several types of experiments that make these claims but one particular type, Plackett and Burman designs, has been successful in many industrial situations and is reputed to be the most efficient for screening large numbers of variables (Appendix C illustrates a case study of this technique).

Factorial Experiments

Factorial experiments are commonly used to guide researchers efficiently to the most suitable conditions for a number of factors in the process. The most typical situation allows for each factor to be set at two levels -- a high and a low level where two factors are considered, 2×2 or 2^2 or four experiments are required, for three factors $2 \times 2 \times 2$ or 2^3 or eight experiments are run, and for four factors 2^4 or 16 experiments are run.

At least two runs of all the experiments are necessary for statistical significance testing, but it may only be necessary to estimate the direction in which to shift process conditions without statistical calculation. For example, a 2 x 2 factorial experiment on soaking conditions of mung beans for improved starch yield indicated conditions at D (Fig. 6) to be best, so another experimental run around D was carried out that found E to be best. The time was considered impractical, so a final experimental run, FGHI, showed that H gave a good yield improvement. If relative differences among experimental points are not clear cut then statistical calculations are necessary to determine any significant effects and interactions to guide future improvements. Appendix C illustrates a detailed factorial experiment on cowpea dehulling.

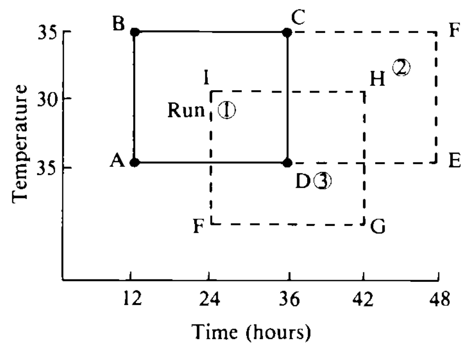


Fig. 6. Representation of treatments in 2^2 factorial design for effect of time and temperature of soaking of mung beans on extraction yield of starch.

Evolutionary Operations (EVOP)

EVOP is an experimental design technique that can be used to evaluate and improve a process while production is proceeding with minimum interruption to the production line so that the final product can still be acceptable for sale. Data analysis is not complicated, and the results are rapidly available to the people who need them most, the production personnel.

The technique works by making small changes to specific process variables above and below current levels (as illustrated in Fig. 7) and assessing the effects on product quality, yield, etc. resulting from these changes. By systematically changing these process variables a gradual improvement in the product may be achieved and new processing conditions are defined. The procedure is similar to factorial experiments, but much less dramatic changes are made and it is much more suitable for in-process investigation. Again guidance in the direction of improvement is sought.

Several cycles of running the process under the five process conditions are repeated. If there is no significant difference in yield or quality, it would be appropriate to increase the size of the increments in one or both directions. The process would then be repeated until a significant difference emerged. Each time enough cycles are completed to justify changing the treatments, another phase of the EVOP procedure begins. (Appendix C illustrates a case study of this technique.)

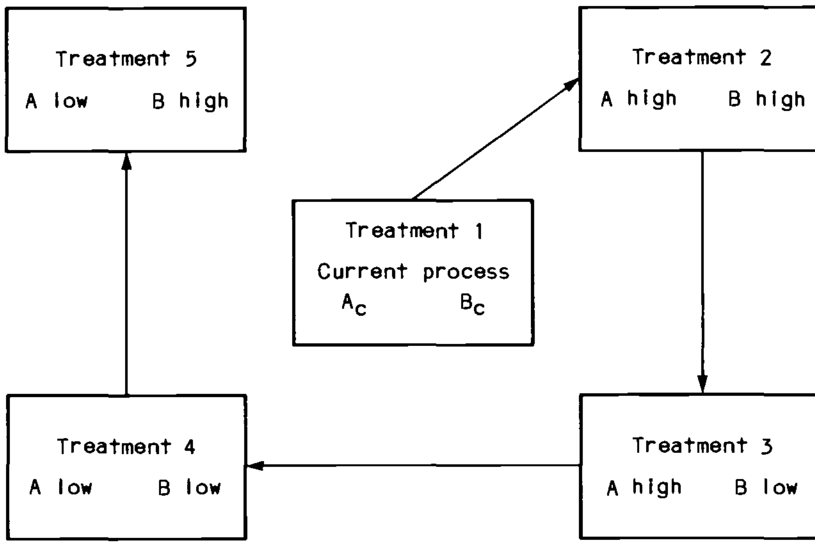


Fig. 7. Evolutionary operations procedure (EVOP) for two variables.

Mixture Experiments

In cases where new formulations of product ingredients are sought as an improvement -- whether to reduce costs, incorporate alternative ingredients, or improve functional or acceptability characteristics -- factorial designs are usually unsuitable. It is impossible to vary one ingredient or component while holding all others constant. As soon as the proportion of one component is altered so is that of at least one other component because the sum of all components is always 100%. To cope with this situation a set of experimental plans, called mixture designs, has been developed. Mixture designs for a three-ingredient mix can be illustrated by Fig. 8. The level of each ingredient is measured as the perpendicular distance from its axis.

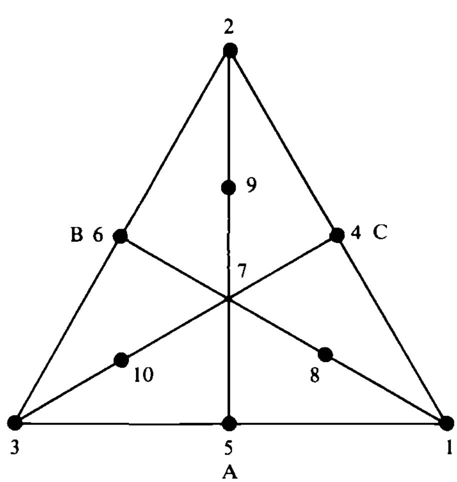


Fig. 8. Three-ingredient mixture space.

A full and balanced representation of the potential mixture of the three ingredients can be obtained by taking mixtures at the vertices (points 1, 2, and 3), at the midpoints of each axis (4, 5, and 6), at the centre point (7), and at the midpoints from the central point to each vertex (8, 9, and 10).

Mixtures represented by these 10 points will give full information about mixture possibilities. Response variables such as sensory score and cost will allow selection of the most useful mixtures. Fewer runs may be carried out if the experimenter is willing to accept less information about the mixture system or alternatively the possibilities may be limited by constraints on the level of use of one ingredient. One of the advantages of mixture designs is the relative ease of making subjective judgments for product improvement from a visual appraisal of the responses throughout the mixture space. This does become rather difficult of course when the number of ingredients exceeds four. Linear programming methods will be more useful in these more complex mixtures. (An example of the subjective application of mixture designs is presented in Appendix C.)

Linear Programming

This type of investigation is used when the factory manager has a limited availability of resources, whether they are raw materials, equipment, finances, or labour, and he or she wishes to allocate them so that some objective of the business is optimized, e.g., maximize profit minimize cost, maximize throughput. Typically, this technique provides rapid identification of optimum strategies for improvement such as in blending of more than three ingredients, production scheduling, selection of products to be produced for particular marketing conditions, allocation of distribution routes, etc. Appendix C illustrates a simple example in food formulation investigations and another variety of linear programming, called the transportation algorithm. This can be used to help production planning of seasonal products.

Inventory Investigations

Investigation of inventory decisions often offer attractive opportunities for improvement in food-processing businesses, due to the changing availability of raw materials, their prices, limited time available for storage, and costs of ordering and delivery. Consideration of optimum strategies will usually result in cost savings and suggest organizational improvements in this area over the somewhat ad hoc approach often found in small companies. Appendix C illustrates a typical example of this problem and simple analytical tools for its solution.

ECONOMIC ISSUES

The economic analysis in "problem identification" provides for an early identification of where opportunities may be for economic improvements and can indicate what general value or benefit may occur for a given level of improvement in certain general areas, i.e., efficiency of raw material use and labour productivity. However, it does not tell you specifically where in the process particular problems are and what their associated costs are to the overall business. This usually requires further detailed study through in-plant experimentation or analysis of certain (or all) components in the existing process for a specified period. A common technique is process costing.

Process costing is used in those industries where large quantities of homogeneous or very similar units of product are produced throughout the production day and it is often not possible to identify jobs or batches of production for cost purposes. The emphasis in process costing is on the accumulation of costs for all work units during a given period of time, usually every month. At the end of each period the cost per unit of goods produced is determined as an average unit cost for the period. The average cost per unit is used to value completed units and unfinished work.

When costs are assembled by processing activity in a process cost system, a separate "goods in process" account is used for the costs of each major activity. For example, a firm manufacturing a product that is processed in turn in three major activities will collect material, labour, and overhead costs in three "goods in process" accounts, one for each activity, and the costs will flow through the accounts as in Fig. 9.

In the factory, the product starts with Activity 1 where the first process in its manufacture is completed. After this, the product is transferred to Activity 2 for its second process and then on to Activity 3 for the third and final process. After completion of the third process, the product is completely processed and packed and is transferred to the finished goods area.

Note that each activity's material, labour, and overhead costs are charged to the activity's "goods in process" account. Observe also how costs are transferred from activity to activity, just as the product is transferred in the manufacturing procedure. The cost to process the product in Activity 1 is transferred to Activity 2, the sum of the costs to process it in the first two activities is transferred to the third, and finally the sum of the processing costs for all three activities, which is the cost to manufacture the product, is transferred to "finished goods."

Because there are no individual jobs in the process cost system, accounting for material and labour costs in such a system is much simplified. Material invoices may be used. Because most employees spend all their working time in one or a few activities, an end-of-the-period summary of the payroll records is usually all that is required in charging labour to the activity.

A basic objective of a process cost system is the determination of unit processing costs for material, labour, and overhead in each processing activity. This requires that: (a) material, labour, and overhead costs be accumulated for each activity for a cost period of 1 month, for example; and (b) a record be kept of the number of units processed in each activity during the period. Unit processing costs are then determined by dividing costs by units processed.

A supervisor is generally responsible for a count of each day's production. Either way, at the end of each cost period a report is prepared for the activity showing not only units processed during the

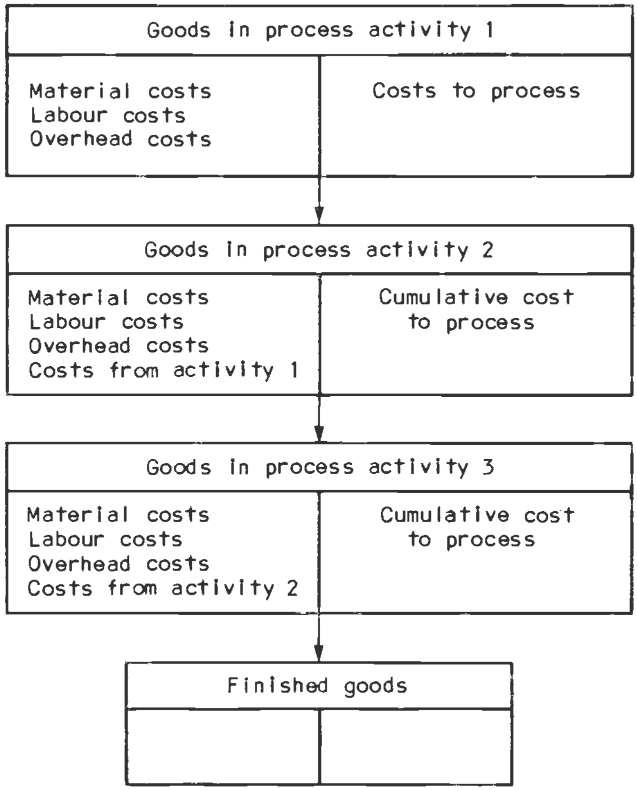


Fig. 9. Costs assembled by processing activity.

period but also any partially processed units at either the beginning or end of the period. Analysis of these average costs per process activity can suggest the most costly activities that could be focused on for improvement. Additionally over a longer period stability or trends in costs can be examined to identify activities needing more control or investigation. An example of this application in the rural processing of coffee in Guatemala is shown in Table 6.

Appendix C gives a simple example of process costing for a two activity process-grinding of legumes followed by mixing, which, for a process that consists of several more major activities, as will almost always be the case, the techniques remain the same except that they are repeated and continued in sequence for each major processing activity.

A limitation of using only process costing is that costs incurred were actual or historical costs, accumulated after the process operations have taken place. This in itself is valuable because it indicates where costs are incurred and which are the most significant and

In some situations, the processing takes place outdoors close to the farming area as shown here in coffee processing in Guatemala. The use of natural resources such as water for transport and sun for drying are important process factors.

those that are unstable but it does not give a standard measure of efficiency for which this 1 month of operation can be compared. Actual costs are a result of a mixture of high and low efficiency. To overcome this problem, and to assess processing efficiency, a system of "standard costing" is used.

Standard costs are the costs that should be incurred under normal conditions in the various activities leading to production of a product. They are established by means of engineering and accounting studies made before the product is manufactured or often during production. Once established, the actual costs incurred during subsequent production can be compared with these standards to assess whether and how they vary from standard.

Usually, great care and the combined efforts in accounting,

Table 6. Coffee processing costs by operation in Guatemala (24-day monitoring period) (Q 1 = U.S.$1).[a]

Operation	Q	Cost/unit product	%
Receiving	64.35	2.49	1.78
Depulping	224.92	8.69	6.22
Washing	158.59	6.13	4.39
Drying in patios, San Lucas (rural site)	498.24	19.25	13.78
Drying, mechanical, San Lucas	312.55	12.08	8.64
Drying, patios, Palín (central site)	76.01	2.94	2.10
Drying, mechanical, Palín	163.35	6.31	4.52
Transportation to Palín[b]	779.13	30.11	21.54
Other costs[c]	1339.20	51.75	37.03
Total cost	3616.34	139.75	100.00

[a] Details of this process are provided in the Guatemalan example in the section on Country Workshop Reports.

[b] Mostly dry parchment coffee for its final processing.

[c] Includes rent, supervision, administration, and maintenance (except for patios and dryers).

engineering, and management are required in establishing standard costs. Time and motion studies are often made of each labour operation in a product's production to learn both the best way to perform the operation and the standard labour time required under normal conditions for performance. Investigations are also made of the quantity, grade, and cost of each material required, machines and other production equipment are monitored to achieve maximum efficiencies and to evaluate the level of standard costs for each cost centre.

However, regardless of the care exercised in establishing standard costs and in revising them as conditions change, actual costs incurred in producing a given product or service can vary on occasion from standard costs. When this occurs, the difference in total cost is likely to be a composite of several cost differences. For example, the quantity or the cost, or both, of the material used may have varied from standard, and the labour time or cost, or both, may have varied. Overhead costs may have varied also. When actual costs vary from standard costs, the differences are called variances.

When variances occur, they are isolated and studied for possible remedial action or improvement. For example, if the standard material cost for producing 2000 units of product A is $800 but material costing $840 was used in producing the units, the $40 variance may have resulted from paying a price higher than standard for the material, or a greater quantity of material than standard may have been used. However, if more than a standard amount of material were used because the material was of a grade below standard, causing more than normal waste, responsibility would return to the manager for buying a substandard grade. Appendix C gives a detailed example of the calculations of different cost variances and how they are usually interpreted. These more detailed studies of costing in the production process can take place before or during technical investigations to assess the effects on production costs in the improvement activity.

Up to now, the economist in the team should be able to provide the research team with a generalized total costs and returns statement of the processing operation, to be able to indicate the relative degree of efficiency that the process operation (and its various major key activities) is running at, and to assist in identifying causes for the process (or its key components) not operating at standard efficiency. This information is often discussed by all the research team members and the owner of the factory, which, combined with the other technical data and views of the owner/manager, should allow the research team to make a decision as to what are the immediate priorities for developing improved processing techniques and/or equipment to improve processing efficiency and increase processing profitability. Therefore, the economist has assisted in the important task of describing the economics of the existing technology and in establishing the subsequent research projects' research design.

EVALUATION AND IMPLEMENTATION OF IMPROVEMENTS

COSTING FOR DECISION-MAKING

Another important function of the economist in the total research study of the processing operation is to provide an economic basis as a criteria to evaluate and recommend alternative technological solutions that his or her technology colleagues have identified to overcome processing problems. The words "a" criteria and "recommend" are used because economic assessments by themselves are not the only basis on which to make a decision. The owner/manager may have different opinions than those expressed in the economic analysis with regard to risk, future costs and benefits, social criteria, and different opinions with regard to the expected technical performance of the new technology recommended. Because of this, the concept of "sensitivity analysis" will be important.

The economic evaluation of technological options is important for two reasons. First, many technological choices to solve a particular processing problem are mutually exclusive, i.e., only one can be employed and, therefore, the one that seems to offer the best net increase in future profit should be chosen. Second, many technological options are not mutually exclusive as they deal with individual processing activities in the production system and cannot be employed independently. However, investment capital is almost always limited. Therefore, generally, the capital must be invested in a specific set of technological options that gives the highest net profit to that investment of limited capital.

There are two broad types of economic analysis that can be used for the purpose of decision-making: marginal analysis and cost-benefit analysis. Marginal analysis is generally applied to "short-run" evaluations of alternative methods of producing products, and/or alternative volumes of products, and/or alternative types of products.

In marginal analysis, only the additional costs and revenues that are associated with the alternatives are included, generally, only variable (direct and indirect) costs and revenues are included. In other words, fixed costs are not included because they are incurred regardless of the technological alternative and regardless of the level of output. The marginal concept is an important one with regard to a particular production process. In general, it can assist in production decision-making in four areas: maximum level of inputs, maximum level of production, least cost combination of inputs, and combination of products.

A common and useful tool used in calculation for marginal analysis is the partial budget. As changes are introduced into a particular process, the partial budget identifies and places values on the specific effect of the change. This way the partial budget acts as a short-cut and saves on researchers' time as unchanged items in the process are not included as they do not affect costs and revenues.

In cost-benefit analysis, the time factor is taken into account where the direct and indirect costs and revenues incurred for each alternative improvement are not always in the same year and, therefore, the analysis considers the time value for money, either as an expense or as income. Fixed costs can also be included in this form of analysis.

In situations where the proposed technical/organizational changes to a food-processing business involve decisions on significant changes in plant and equipment and, therefore, result in associated costs and returns (as a result of these changes) occurring over a period of more than 1 year, the use of partial budgets and marginal analysis is usually not appropriate. It becomes necessary to use a technique to assist in the investment decision-making process that will determine the value of all fixed and variable future costs and revenues in terms of their present value. In other words, if we know or expect to have to make payments in the future and/or receive income in the future, what value should we place on these in terms of their value today if we had to make these payments today or if we were to receive that income today?

There are three main measurement methods that can be used in cost-benefit analysis: (a) Net Present Value (NPV) method -- what is the present value of the difference between all future costs and revenues. The criterion of the NPV measurement is that if NPV is < 0 investment would be profitable, if NPV is >0, investment would not be profitable, and if NPV = 0 it would be a break-even situation. (b) Benefit-Cost Ratio (BCR) method -- benefit-cost ratio is defined as the ratio of the total present value of benefits to the costs. There are two kinds of BCRs: net and gross. The criterion of this measurement is that an investment with a BCR greater than one or the highest among alternative investments is feasible. (c) Internal Rate of Return (IRR) method -- in using the NPV and the BCR methods one encounters the problem of choosing the appropriate rate of discount for discounting future costs and revenues. The internal rate of an investment (k) is the discount rate that makes the present value of the net cash inflow equal to zero. It represents the average earning power of money used in the investment. If k is greater than the appropriate opportunity cost of capital, the investment is feasible. Appendix C gives an example of marginal and cost-benefit analyses.

IMPLEMENTATION OF THE IMPROVEMENT STRATEGY INTO COMPANY OPERATIONS

Often little thought is given to the implementation stage of a project. Consequently, results are either not implemented or are implemented poorly. Consideration should be given as to who should carry out implementation and how the implementation might be done. The ideal and most successful approach is to have the research team work closely with management. Three possible scenarios for implementation are:

- The relevant management implements improvements directly based on project recommendations. This is usually the least effective manner because some problems inevitably remain.
- Researchers implement their own recommendations into the company, making sure that all "bugs" are worked out and confirm that objectives are met. This approach requires a weaning stage for relevant management to take over.
- Joint implementation by researchers and relevant management. This is normally most effective, allowing for "bugs" in the improvement strategy to be ironed out to fit into the total company operation and management.

There are three main methods of implementation:

- Parallel running -- Here 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.
- Immediate full-scale implementation -- Immediate full-scale implementation is the method most often used. Provided that the research team has comprehensively studied and evaluated the improvement in the company context, the risks here, although great in some projects, may be minimized. There usually has to be a commissioning stage where the researcher is still available to monitor the whole improvement strategy to ensure that it fits into the total company system and deals with any remaining problems.

It has been suggested that the degree of involvement of company management throughout the project and, hence, management's commitment, correlates with the degree of success in implementation. This also holds for seeking some contribution to the costs of the research from the relev^nt management, whether the research is within a large company structure or involves an external food research organization. Although one would think that managers should welcome research for which they do not have to pay, this is seldom the case. Only if they pay for it can they be sure that the research is serving their, 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.

RESEARCH COSTING

The value of some investment research is difficult for researchers to communicate to small companies and again depends on understanding the motivations and thinking of the management. Researchers need to be particularly careful to estimate the costs, even crudely, for the various improvements they may be considering, what are the impli-

A common operation in small factories is to use sun drying such as at this fish cracker plant on the east coast of Malaysia.

cations in additional investment and cash flow (cost-benefit or marginal analysis) for the factory and the research cost itself, etc. Thus, a research and implementation program can be planned and costed that will be a worthwhile investment for the factory. The problem still remains to communicate to the owner/manager, in terms consistent with his or her goals, the value of investment in research.

As a cash contribution is not often possible from small companies, at least in the initial stages, other means of contributing to the cost of research costs should be considered, e.g., providing extra labour, materials for the trials, or perhaps transportation for research staff as a contribution to the cost. It may be appropriate to start the research activity with a low-cost initial phase, negotiating further phases, perhaps requiring greater financial commitment, with the manager after results of the previous phase are available. If the managers have been involved in the low-cost initial research, they may be sufficiently confident in the results of subsequent work to risk more and locate the necessary funds from their own reserves, relatives, or money lenders. Normally, most credit agencies are not able to finance research activities particularly for small companies. Credit is usually based on the cash flow of the particular factory.

The other important aspect of financing research is the contribution from the research institute. Many research institutes now must recover a portion, if not all, of their costs from this type of industrial research. Costs are considerable, and often have been insurmountable for small businesses. The phased approach could overcome this, as well as some contribution from outside agencies. However, ultimately it has to be perceived by research institutes/universities that a portion of their staff time, facilities, and budgets could bring about identifiable development of the small food sector. Thus, researchers should plan research activities carefully, maintaining total cost records, including staff time. They should determine and record the impacts of results in small industries, not only the cost-benefit for each factory worked in but cost-benefit for the institute's research activity. With such cost records, together with benefits, which might need to be followed for a considerable time, it could be possible to plan, budget, and justify future research programs for small-scale food industry improvements at the research institutes.

INTERACTION WITH MANAGEMENT

An understanding of the motivation of the management and the realities and constraints of the individual factory situation is essential to ensure that any research will be relevant and implementable. The facts of small businesses are stark, and the consequences of failure through misjudgment of capital needs, raw material availability, equipment complexity, market demand, cost of marketing, and, particularly, the capabilities of the entrepreneur, can mean serious financial losses, perhaps even business ruin.

It is important then to approach any small business with sympathetic understanding and a sincere intent to listen to and learn about what the owner perceives as his or her advantages and limitations. It is easy for researchers to suggest improvements, but these may be beyond the comprehension of the owners or, equally likely, they may understand perfectly but be unwilling to apply them for reasons of their own that they do not wish to explain.

This understanding between factory owner and researcher is perhaps the most difficult aspect for researchers to achieve satisfactorily. Some researchers, depending on their personality and the personality of the owner/manager, will find it easier than others to discover the situation of a particular factory. However, by a systematic, step-by-step approach all researchers can build up a qualitative and quantitative description of the factory situation and constraints. Through continual interaction with the management, only beneficial improvements will be identified, developed, and implemented. Experience accumulated through working in a number of factories over the years will suggest successful approaches and techniques that can be applied by researchers in future work.

This has been the experience of cropping systems researchers working with small-scale farmers over the last 12 years. IDRC has supported and continues to support research in this field in many parts of the world. The situation of the small-scale food processor parallels that of the farmer who aims to optimize food production and profits and minimize risk within the constraints of land size, market prices, and cultural practices, with the available resources -- seeds, fertilizer, labour, and capital. Researchers have developed and are still adapting a research methodology that involves working with farmers in their fields, documenting their existing practices, testing improvements acceptable to the farmers in their fields, and determining the most improved procedure as perceived by the farmers and the researchers. The improved pattern is considered acceptable only after it has been successfully managed by farmers in the area. The key to the approach is involvement of the farmers and their opinions in the decision-making.

A similar approach is no doubt appropriate for improvement of small-scale food industry systems. The approach taken by researchers should involve owners/managers of the small company at all stages of the activity. It has to be remembered that each factory situation will be different, with a different set of constraints, even though products may be similar. It is necessary to foster interaction with management in each of the following areas associated with improvement strategy:

- Definition of the factory's need for improvement;
- Establishing credibility with management and an interactive relationship;
- Survey of the factory situation and definition of constraints;
- Management involvement in decision-making on particular improvements to be made. Should the researchers' ideas be overruled by management's own perception of priorities?;
- Carrying out research activities in the plant;
- Deciding on whether or not results should be implemented;
- Planning for implementation and evaluation of impact;
- Provision of economic data for decision-making throughout the activity;
- Spin-off training of management through association with research; and
- Contribution to research costs.

APPLICATIONS IN DEVELOPING COUNTRIES

The practical application of the foregoing methods and procedures were emphasized at the workshop through the presentation of actual cases studied during factory visits.

In this section, two completed case studies presented by the participants from Thailand and Singapore are detailed. Following these reports are brief presentations with a summary of the working-group discussions for the remaining seven country studies.

CASE STUDY: THAILAND (TRANSPARENT NOODLES)

Methodology

A successful methodology is developing at the Thailand Institute of Scientific and Technological Research (TISTR) in obtaining contact with factories, isolating problem areas, evaluating possible solutions, and then implementing them. The approach involves the formation of a project management team, which allows input from a number of disciplines (Fig. 10). It has been found useful to have a range of skills in the team allowing for comprehensive problem-solving techniques.

The initial contact with the company has been made by the management of the company itself or has been initiated by the staff of the working team. A series of steps has been followed to establish this initial contact (Fig. 11) including:

- Gathering information on factories surveyed or compiled from various literature and local knowledge, etc;
- A number of factories are selected and contacted through a personal visit, letter, phone call, or other appropriate means;
- Each factory is visited to obtain general information that could be used to isolate problem areas and to inform the management of benefits that cooperative work with the institute could bring;
- This general information is then compiled and evaluated by the team, and factories that have potential are chosen;
- Time is allowed for the factories to approach the institute, and, if such an approach is made, a prompt response is given; and
- A second visit may be made by the institute if contact is not forthcoming by the factory, and potential improvements will be suggested in individually visited problem areas, but this approach must be made carefully.

Once contact has been established, a plan is formulated and a schedule is designed for improvements, possibly requiring more visits

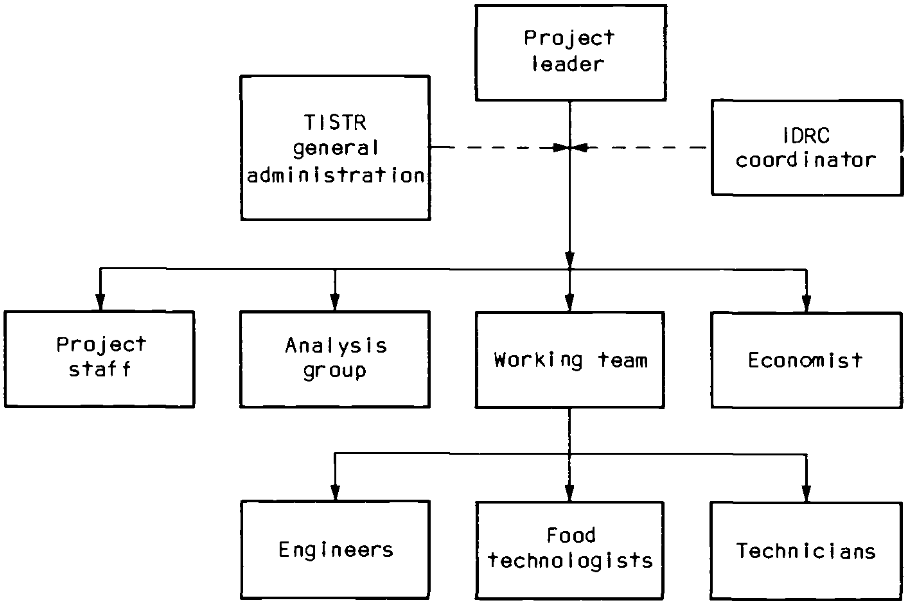


Fig. 10. Project management diagram (Thailand).

to the factory. A series of forms has been developed to aid in gathering and recording information in an orderly fashion during factory visits (App. B). After the factory visits, the working team compiles information according to the survey sheet and the work study record sheet and draws up a process flowchart (App. B) and timetable (Fig. 12). These forms are frequently used for reference in subsequent studies. It is interesting to note that a worksheet for cost analysis of the factory is not included, but such information is incorporated in the other charts. In this manner an economic analysis can be obtained from the recorded information and indirect contacts because management may often be unwilling to discuss such financial matters until they have developed some confidence and trust in the research team.

Each member of the team is responsible for collecting information on different parts of the process. Often several visits are necessary to document fully the business and its processing activities. Adequate time is required for the evaluation of the compiled information by the technical group so that the entire process is completely understood. (A typical diagram of a transparent noodle factory is shown in Fig. 13). This is essential before any improvements can be made. Screening of possible tasks is then carried out carefully, because this is the foundation upon which all subseqent work will be based. Extensive group discussions are held by the members of the research team to study the complete process and to develop different improvement ideas.

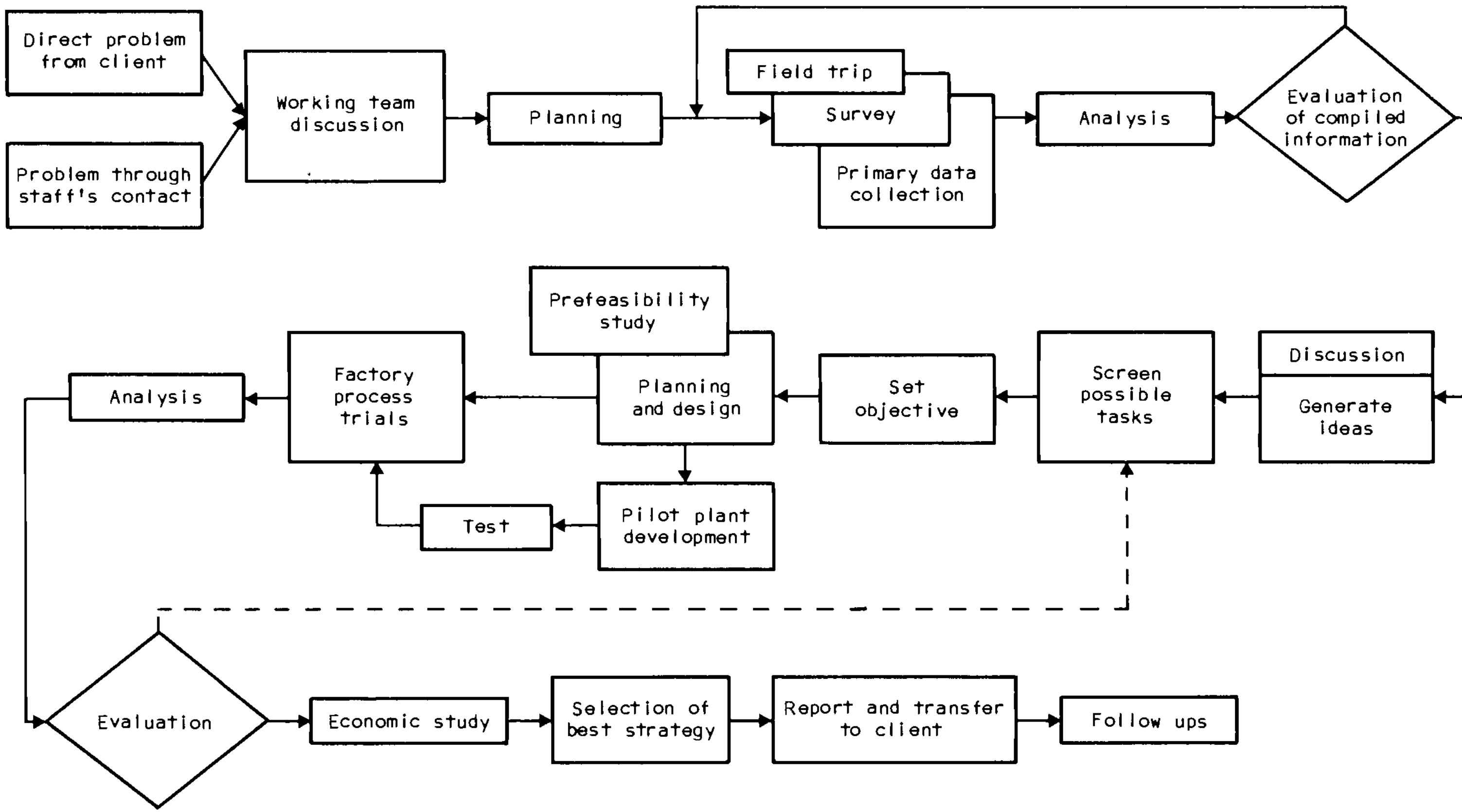


Fig. 11. Process improvement activities (Thailand).

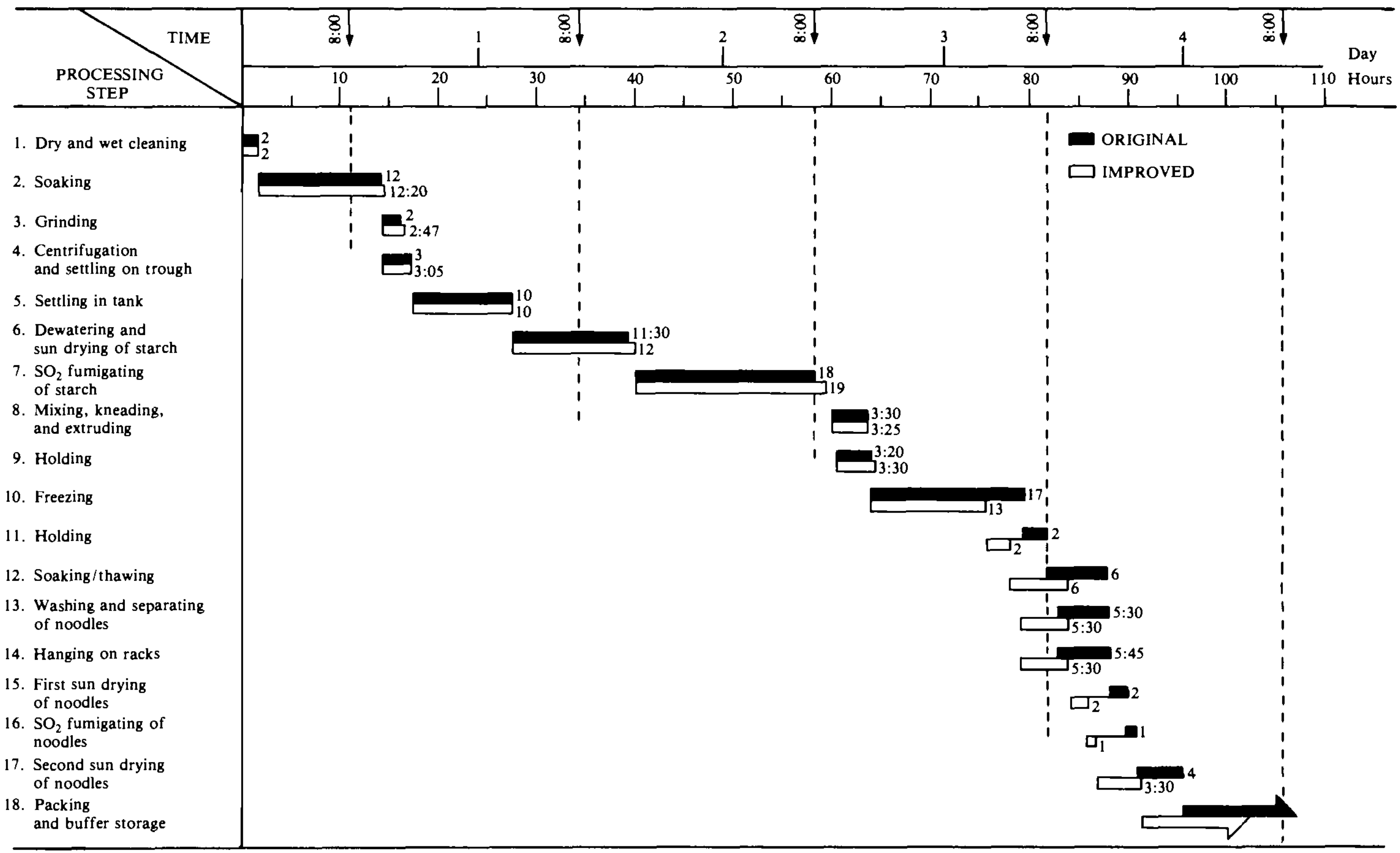
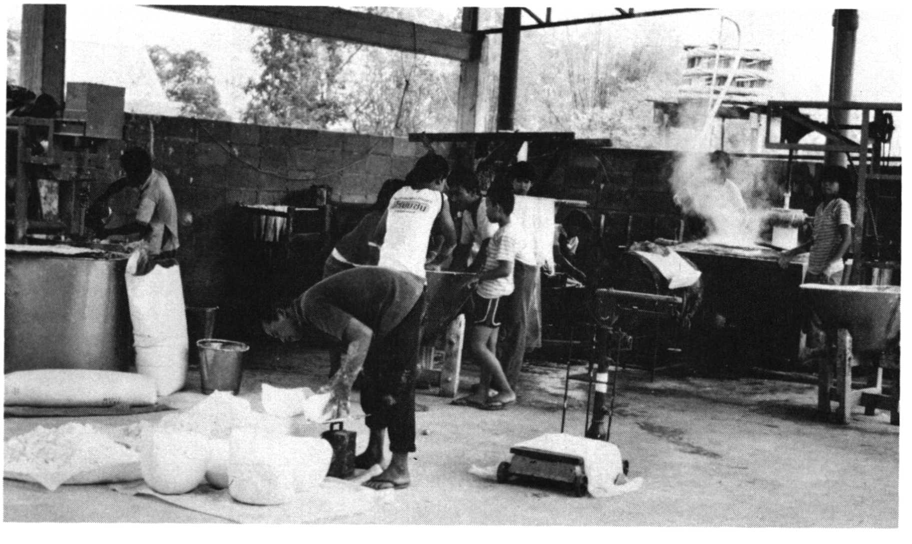


Fig. 12. Bar chart of the original process schedule and the improvement in the freezing stage schedule.

Screening is then done by a process of scoring or ranking the alternatives until consensus is reached after discussion of the scores given by each team member. This is followed by determining priorities from among the alternative improvement ideas. After the best improvement area is chosen the working team discusses the plans for improvement that include experimental design, factory trials, laboratory experiments, and method of analysis; preparation of instruments, apparatus, and equipment; and assigning schedules and responsibility for each member of the team.

Methods of evaluation can be used in determining the area in which to concentrate. For example, in one transparent noodle factory, the freezing operation was chosen as an area for improvement because it was identified as being the most energy-intensive operation (Pareto's Law) after evaluation of energy consumption throughout the process. In the energy analysis it was estimated that freezing consumed 68% of the total energy. However, management and its concerns should be considered at this stage. An improvement in an area that management is showing interest in or one that will have an obvious and dramatic improvement change associated with it in a short period of time, will establish credibility and confidence in the research team. Once this is accomplished it will be easier to work on other improvements with the manager in the future.



Some of the processing operations in a typical Thai noodle factory.

During the factory trials, the working team tries to encourage a good relationship with the factory owner and gain his or her confidence. All particulars of the research investigation are held in confidence by the members of the research team and methods used in other factories are not discussed. At the implementation stage, the working team sets up the improved method in the plant and transfers it to the manager personally by working with him or her through the activities that have adjusted or changed to ensure that the manager understands

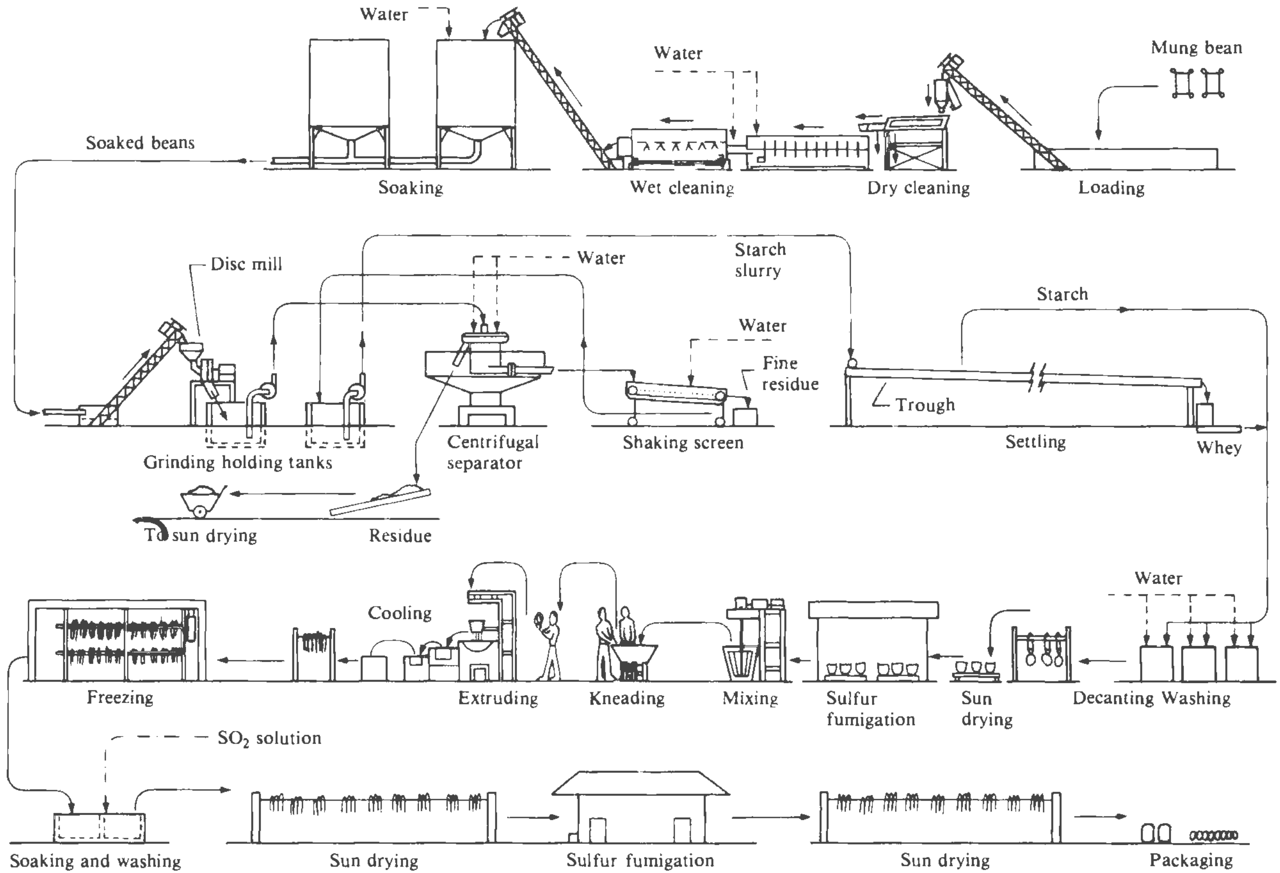


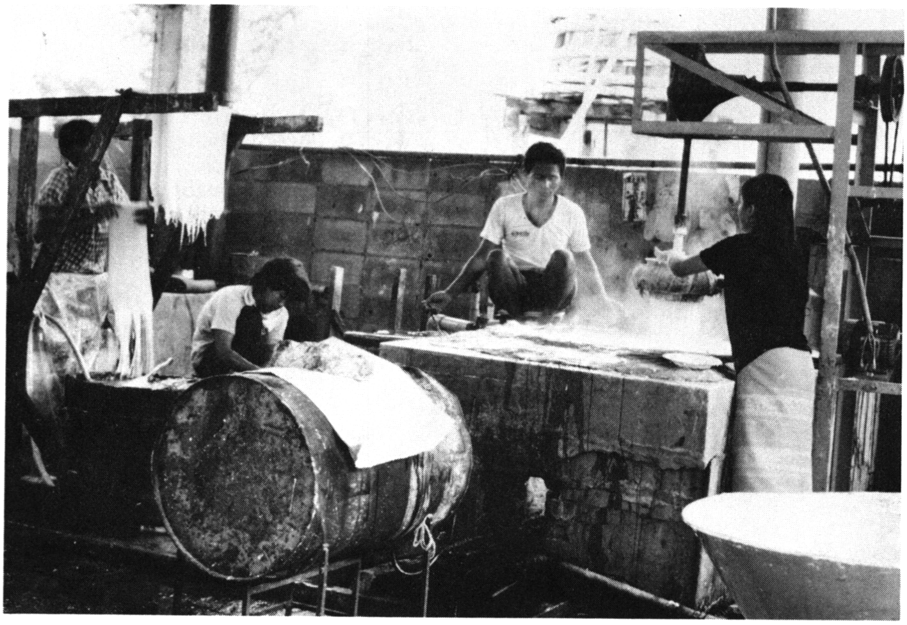
Fig. 13. Processing in a transparent noodle factory (Thailand).

them thoroughly. For example, the working team draws up a chart illustrating the improved method in comparison with the existing method (Fig. 12) as a team record with a simplified format for implementation and transfer in the factory. Once improvements in a process are made in one factory, it has been found that other similar factories are more approachable as word of the improvements spreads.

As an example, in 1980, initial contact with TISTR was made informally by the owner of a small transparent noodle factory. At the time, the owner had problems with his horizontal stone disc grinder and with extracting protein from effluent (Fig. 13). The owner did not contact TISTR again until February 1982, when he requested TISTR assistance because of the poor quality of his noodle product. An active association with another noodle factory that involved pilot plant experiments at TISTR, however, made it impossible to work with this new factory at that time. Two months later, the factory was revisited. Arrangements were made for a consultant to visit the factory for further discussion on possible improvements.

The working team was able to convince the factory owner of the potential value in cooperating with TISTR for factory process improvement. Consequently, it was agreed that:

- The working team would collect all relevant information on the product, raw materials, processing steps, and quality control, but TISTR would not intervene in company management, marketing, or finance unless the factory asked for such input.



Extrusion and washing stages in a Thai noodle factory.

• Process data and improved processes implemented in the factory would be kept in strict confidence. The results of the whole process improvement that would be reported and distributed to other interested factories and institutions would not identify any particular factory.

• Because present transparent noodle processes are generally known, and TISTR was then carrying out process improvement with one larger-scale transparent noodle factory, the smaller factory had no risk but could profit from the results of that process improvement project experience.

• No research service fee would be charged, but raw materials in factory trials and new equipment to be installed would be provided by the factory owner. Other expenses would be paid for by TISTR.

After 2 months of preliminary negotiation the factory owner decided to cooperate with TISTR in this process improvement project. The working activities were planned and the factory process improvement began (Fig. 14 and Table 7).

Possible Problem Areas and Improvement Analysis

After studies at the plant were done on estimating mass balance and chemical composition of materials used in the process, the working group analyzed the results. All the possible problem areas were identified through the use of screening criteria such as simplification of the process, limiting capital investment, limiting operating costs, increasing capacity, improving product quality, improving working conditions and time for research, and the owner's priorities. After lengthy discussion, the working group identified potential problem areas and listed them in order of their priority (Table 8).

Process Improvements Experimentation

The working group planned to improve on the existing process used in each of the five problem areas in their order of priority. Therefore, the working group invited the owner to discuss and rearrange the priority of problems if there were any differences of opinion. The owner agreed to the priorities that had been assigned after discussion of the reasons and the benefits that would be obtained. Experiments were carried out as planned to use two turbo centrifuges instead of only one (because the factory possessed a second centrifuge that was not being used), and to modify the operating specifications of the turbo centrifuges such as speed, power used, and the size of the rotating basket. When the dual turbo centrifuge operation conditions were evaluated it was recommended that management reduce the power requirement to 5 hp and speed of rotation to 500 rpm and use 120 mesh screens in both centrifuges.

The owner modified his equipment accordingly and when he was ready for a trial run, the working group collected data on the improved processing. The analysis results of starch yield before and after the process improvement are shown in Table 7.

After the first priority improvement analysis results were carried out, the working group invited the owner to discuss the results. The owner was satisfied with the improvement because of the higher starch yields achieved in the trial run. It was then agreed that work

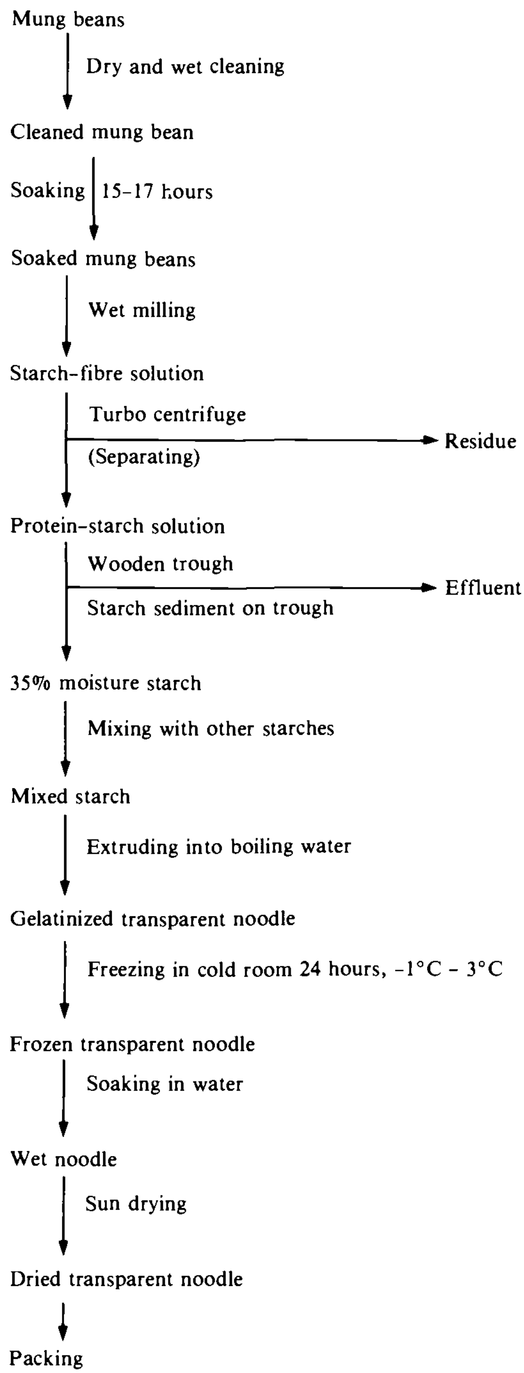


Fig. 14. Process flowchart for a small-scale transparent noodle factory (points at which data were collected are identified in Table 7).

Table 7: Analysis results of starch yield before and after process improvement.

Description	Before improvement				After improvement			
	MC[a] (%)	Starch (%)	Total product (kg)	Starch content (kg)	MC (%)	Starch (%)	Total product (kg)	Starch content (kg)
Mung beans	12.43	48.18	1100	530	12.65	45.57	1156.5	527
Soaked bean	66.10	18.74	--	--	62.89	22.84	--	--
Slurry discharged from grinder	94.09	3.17	18000	570.6	93.38	3.34		
Residue	86.26	6.83	1953	133.4	86.95[b] 88.81[c]	4.85[b] 5.09[c]		
Starch solution	96.36	2.08			95.71[b] 98.83[c]	2.22[b] 0.58[c]		
Effluent	97.83	0.03	8640	25.9	98.59	0.36		
Dewatered starch	49.45	48.87	510	249	47.92	49.00	598	293
Yield (%) (dry basis)		26.76				30.83 (4.07)		
Recovery (%) (starch)		46.98				55.60 (8.62)		
Recovery (%) (as is)		46.36				51.71 (5.35)		

[a]MC = moisture content.
[b]First turbo.
[c]Second turbo.
Note: Values within parentheses are the percentage increase.

Table 8. Possible problem areas and identification of potential priority areas in a small-scale transparent noodle factory (Thailand).

PROBLEMS	POSSIBLE SOLUTIONS
1. Inefficient dry and wet cleaning.	a. Dry cleaning -- use two plate screen shaker; wet cleaning -- use paddle washer, manipulator.
2. Inefficient transportation of soaked bean to grinder.	a. Use belt conveyor instead of workers.
3. Process to separate starch slurry from ground bean solution to obtain more starch yield.	a. Add one more turbo centrifuge.
4. Process to separate protein from effluent.	a. Boil effluent for few minutes and filter boiled effluent.
5. Process to dewater starch cake to obtain 35% MC (moisture content).	a. Use batch-type horizontal basket centrifuge.
6. Need to store residue fibre for longer time especially in rainy season before sun drying.	--
7. Need to process transparent noodle for longer shelf life (more than 2-3 months).	a. Not decided yet because of many factors involved such as quality of starch sulfur treatment, quality of water used in process, etc.
8. Cold room leakage and poor performance of cooling temperature in cold room area.	a. To modify and improve performance of the existing cold room or new cold room design.
9. No consistency in mixed starch.	a. Design and construct an instrument to measure dough consistency before extrusion.
PRIORITY PROBLEM AREAS	**REASONS**
1. Process to separate starch solution from ground bean solution to increase starch yield.	a. Process is simple. b. Low investment because the owner already has one extra turbo centrifuge.
2. Equipment used in dry and wet cleaning.	a. Present dry and wet cleaning is not efficient. b. Improve product quality because at present starch has many impurities and starch colour turns brown.

PRIORITY PROBLEM AREAS (Cont'd)	REASONS (Cont'd)
3. Cold room leakage and poor performance of cooling temperature in cold room area.	a. Lower operating costs if cold room leakage is solved.
	b. Improve product quality if temperature spreads equally all around the present cold room.
	c. The owner has bought an evaporator and a condenser to construct a new cold room.
4. Process to dewater starch cake from settling tank to obtain 35% MC.	a. Process is simple but owner has to buy one new basket centrifuge.
5. No consistency in mixed starch.	a. Improve in product quality.
	b. Low capital investment but this instrument might have to take time for research on this kind of starch.

could proceed on the second and third priority steps. Activities were planned as follows: investigate screen shaker, wet cleaning manipulator, belt conveyor, and cold room temperature (2 weeks); calculate and specify details on new equipment dimensions, accessories, and machinery needed with a mechanical engineer (1 week); sketch a detailed specification on a blueprint (1 week); construct and install equipment by factory owner (8-10 weeks); operate new equipment and cold room and take data (2 weeks); analysis of results (2 weeks); and unit process improvement evaluation (4 weeks).

Now, the first three activities are finished. Copies of each detailed drawing of the equipment and cold room were sent to the owner in March 1983. By late May 1983, the working group contacted the owner and learned that the equipment installation and cold room construction would be completed by the following month.

CASE STUDY: SINGAPORE (SOYSAUCE FERMENTATION PLANT)

Soysauce is a condiment taken by the entire population of Singapore and is used both as a seasoning in cooking and as a dip. The industry is characterized by the large use of space and slow turnover of product. Because of limited land resources, the return per square metre of land devoted to soysauce fermentation industries is very low. Earlier work at the Singapore Institute of Standards and

Industrial Research (SISIR) was aimed at developing a strain of fungus that would accelerate fermentation. More recent work has continued on the design of large fermentation tanks in place of the traditional small porcelain jars to minimize use of space and labour in a cooperating small factory in Singapore.

The factory contact was made through a survey of small-scale soysauce plants at the initial stages of the research project. A flowchart of the project as shown in Fig. 15 and Table 9 details the process of identification of key operations for possible improvement in the factory. Larger-scale fermentation was seen as a major priority for the factory concerned.

Larger-Scale Fermentation of Soysauce

In Japan and Taiwan, soysauce is fermented in tall fibreglass tanks. The production yield of the sauce per unit of land area is about 10 times that of the local ones and is fermented at a low temperature of around 20°C. No sunlight is allowed to enter the airtight fermentation tank. The taste and aroma of their sauce is very different from that produced in Singapore. Therefore, the local sauce producers do not want to use Japanese or Taiwanese methods to make the sauce because their customers would not like the aroma and the taste of the product. However, they wanted to produce sauce in a large tank to save land area and labour. Several attempts were made by manufacturers directly but with no success, due mainly to pest infestation problems. Thus, there was a need to carry out research and development work in this area.

From the chemistry point of view, the aroma and the taste of the sauce produced locally must be related to interaction with sunlight and air, whereas the Japanese and Taiwanese soysauce excludes these two ingredients and, hence, has a different aroma and taste. In designing a large fermentation tank for local manufacturers, the use of sunlight and air must be included. A tank with a transparent cover and a gap between the cover and tank body could achieve this. With this fermentation tank the workers do not have to remove the cover to allow sunlight and air to come into the tank and then replace the cover when it rains. Presently, a considerable amount of time is spent on covering and uncovering several thousand jars every day and this operation must be repeated three or four times a day because it rains frequently.

The factory manager was a university graduate and had an open mind. He was interested in having research carried out in his factory to evaluate this idea and was willing to provide labour, land, and processing facilities. We then discussed with him the size of the tank that was most suitable to his production. He indicated that his factory was cooking two batches of beans twice a week. Each batch of beans weighed 540 kg dry weight. He felt that it would be ideal to have a tank that was big enough to hold one entire batch. At the moment they used 40 individual crockery jars to hold each batch. A fibreglass tank was designed that held 3600 L when 80% full. It only took up 25% of the land area required by the 40 jars normally used.

A direct comparison between the large-scale method and the traditional jar method was made. The progress of the fermentation in the two vessels was closely monitored by the factory personnel as they

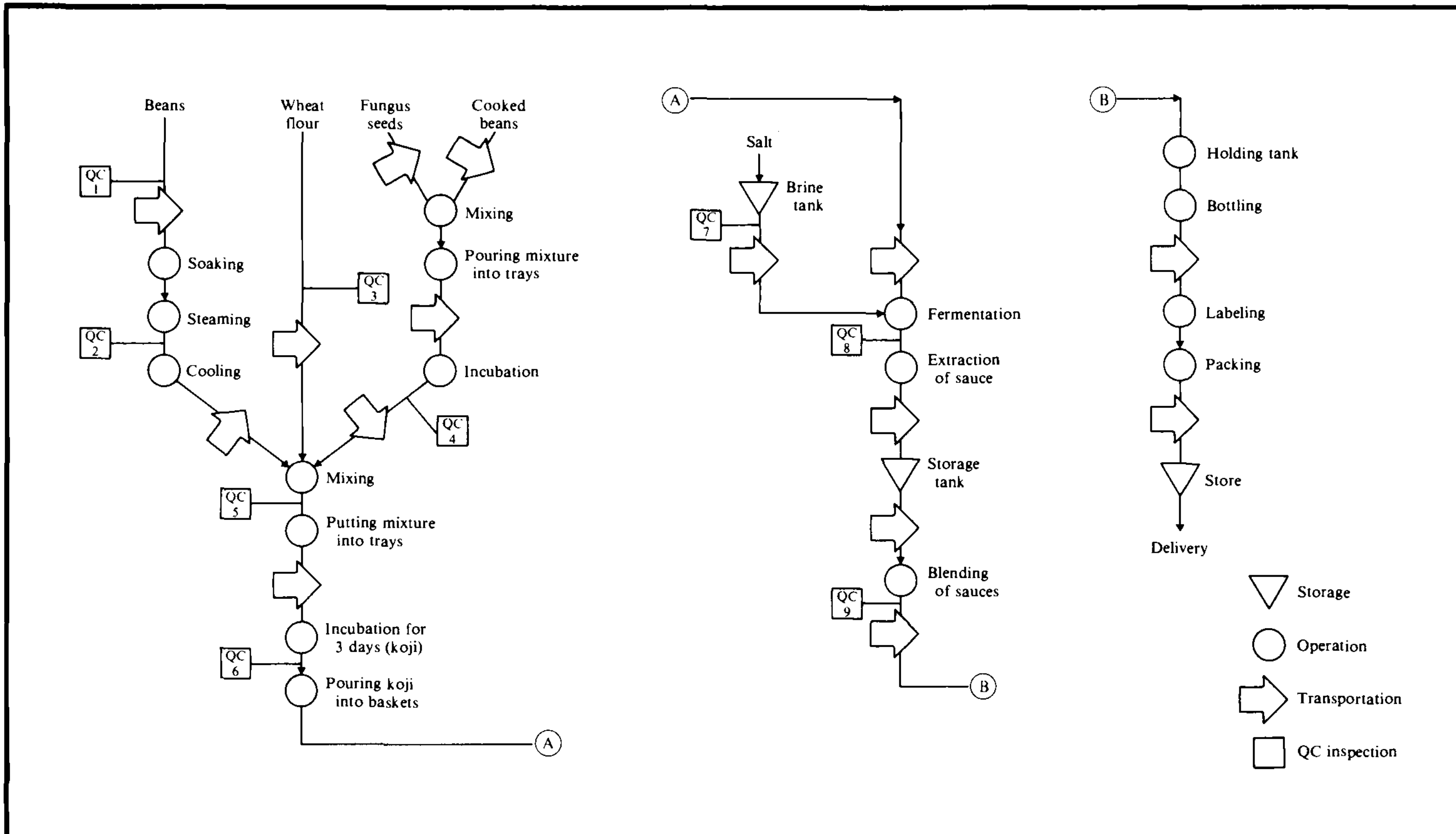


Fig. 15. Process chart and proposed quality control plan for manufacture of soysauce.

Table 9. Identification of key operations for possible improvement in the factory.

(a) DESCRIPTION OF OPERATIONS INVESTIGATION[a]	POSSIBLE IMPROVEMENT
1. Scale-up fermentation process.	a. Design large fibreglass tank. b. Utilize larger size earthen jars.
2. Improvement in product yields and quality.	a. Utilize factorial design technique for evaluation. b. Introduce quality control technique (implement weighing and process measurement).
3. Introduction of flow process chart (material) technique.	a. Identify existing material flow process and propose improved activities for the factory. b. Establish records of time standards for information.
4. Mechanization of filling, capping, and labeling operation.	a. Introduce conveyor belt for handling work in progress. b. Purchase customized design of a multipurpose machine for operation.
5. Improvement of factory layout and material flow process.	a. Apply string diagram technique. b. Develop drawing for new plant layout. c. Introduce battery reach truck.
6. Implementation of scientific approach to production control concepts.	a. Resources optimization - (labour/equipment). b. Illustrate job sequence by Gantt chart. c. Incentive payment scheme. d. Maintenance and replacement. e. Select and evaluate new equipment to increase output.

(Con't)

(a) DESCRIPTION OF OPERATIONS INVESTIGATION[a] (Cont'd)	POSSIBLE IMPROVEMENT (Cont'd)
7. Implementation of inventory control and budgeting technique.	a. Realistic control upon seasonal demand and seasonal production. b. Known, continuous demand and year-round supply.
8. Transport optimization.	a. Transportation problems.

(b) OPERATIONS UNDER INVESTIGATION AND THE SOLUTIONS SCORE[b]	
1. Scale-up fermentation process -- solution (a).	35
2. Improvement of product yields and quality -- solution (a) and (b).	20
3. Introduction of flow process chart (material) technique -- solution (a) and (b).	15
4. Mechanization of filling, capping, and labeling operations -- solution (b).	12
5. Improvement of factory layout and materials flow process -- solution (b) and (c).	8
6. Implementation of production control concepts -- solution a, b, and e.	5
7. Implementation of inventory control and budgeting technique -- solutions (a) and (b).	3
8. Transport optimization -- solution (a).	2

(c) HIGHER SCORES INDICATE HIGHER PRIORITY FOR IMPLEMENTATION TO THE FACTORY

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[a] The operations under investigation were then ranked in the order of importance and economical priority of implementation to the factory. The possible solutions were studied and evaluated based on their practicality in application to the client.

[b] Operations 6, 7, and 8 are not carried out due to restricted time and lower priority of implementation agreed by management.

Table 10. Results of the four best samples of soysauce.

Position	Sample jar no.	Raw materials	Fermenta-tion day	Fermenta-tion day in brine	Salt % w/w	Total solid % w/w	Total protein % w/w	Total sugar % w/w
1	8	HB HF HK	3	60	20	14	7.8	4.4
2	14	HB LF HK	5	60	21	12	7.8	4.4
3	12	HB HF LK	5	60	20	15	7.4	4.0
4	4	HB HF LK	3	60	20	14	7.4	4.0
5	N	NB NF NK	5	90	23	10	6.0	--

FLOW PROCESS CHART				
Material type	Summary			
SUBJECT: Soybeans Fermentation Plant	Activity	Present	Proposed	Saving
CHART COMMENCE: Jars in open courtyard	Operation ○	4		
	Transport ⇨	2		
CHART END: Pump soysauce to filling tank	Delay D	1		
	Inspection □	-		
RECORDED ON: 30 April	Storage ▽	1		
CHARTED BY:	Total distance (ft)	3547.5		
	Total time	2 days 2 hr 57.44 min		

Item no.	Description	Persons	Distance (ft)	Time (min)	○	⇨	D	□	▽	Remarks
										1 wooden pail for 1 jar (total 43 jars)
1.	Collect wooden pail and move to outdoor jar (two off)	1	80	0.54		•				Manually carried on shoulder
2.	Siphon off solution into two off wooden pail	1		4.44	•					Four siphon tubes for one wooden pail
3.	Transport two pails of solution to second outdoor larger jar	1	85	0.69		•				Second outdoor jar is near the building
4.	Empty pail of solution into jar	1		0.49	•					Manually carried on shoulder
5.	Repeat for next 41 jars to be emptied into second large outdoor jar		3382.5	126.28	•					
6.	Store soysauce solution in second large outdoor jar	1		2 days					•	Large second outdoor jar is near building
7.	Wait for pump to be moved to jar	1		15			•			
8.	Pump off solution from second jar through filter to filling tank	1		30	•					Whole tank of soysauce

Fig. 16 Charting techniques used for a soybean fermentation plant, showing the original and proposed operations with savings in process time.

could easily detect whether the reaction proceeded well or not. After the normal processing time of 4 months, samples of sauce taken from the fibreglass tank and from the jar indicated that the protein content of the sauce from the fibreglass tank was 71% of that from the

FLOW PROCESS CHART				
Material type	Summary			
SUBJECT: Soybeans Fermentation Plant	Activity	Present	Proposed	Saving
CHART COMMENCE: Jars in open courtyard	Operation ○	4	2	
	Transport ⇨	2	4	
CHART END: *Pump soysauce to filling tank*	Delay D	1	-	
	Inspection □	-	-	
RECORDED ON: 18 May	Storage ▽	1	1	
	Total distance (ft)	3547.5	332.5	3215
CHARTED BY:	Total time	2 days 2 hr 57.44 min	2 days 1 hr. 46 min	1 hour 11 min

Item no.	Description	Persons	Distance (ft)	Time (min)	○	⇨	D	□	▽	Remarks
1.	Collect pump and connect to valve of fibreglass tank in open courtyard	1	105	25		●				
2.	Pump off solution from fibreglass tank to large outdoor jar	1		30	●					
3.	Return pump to store	1	105	0.6		●				
4.	Store soysauce solution in the jar for 2 days	1		2 days					●	
5.	Collect pump and move to jar	1	62.5	15		●				
6.	Pump off solution from second jar through filter to filling tank	1		35	●					
7.	Return pump to store	1	60	0.35		●				

Fig. 16. Cont'd.

jar. With longer fermentation times the protein content continued to decrease, while the salt concentration increased with time. This may be due to relatively greater evaporation from the small jars. Before extraction, a brine solution is usually added to top up the vats.

Therefore, 1 week before the extraction took place, a brine solution of 20% concentration was added to the tank and the jars to make up the loss due to evaporation. The volume of sauce extracted from the big fibreglass tank was found to be 100% more than from the equivalent amount of small jars. This was partly due to more effective separation of sauce from solids by incorporating filter channels in the tanks.

If no brine solution is added to top up the tanks, the protein content would be similar to that from jars (which is diluted with brine). As the large-scale method saves 75% of the land area and a great deal of manpower (estimated to be about 75% also), it is definitely a much better process to produce the sauce than the traditional jar method. The cost of the fibreglass tanks is S$2150.

After the success of this experiment, the owner of the sauce factory said that he was going ahead to use this new method to produce the sauce in future. He has already begun implementing tanks at the rate of two per month.

Improvement in Product Yields and Quality

After discussion with the factory manager, it was decided that the improvement in product yields and quality would benefit both the financial position and the reputation of the company. The factorial design technique was selected as a suitable approach to define conditions to improve yields and quality.

While initially apprehensive about the value of the research method, the factory manager eventually agreed with our proposals after much disucssion and, subsequently, he made arrangements to allow experiments to be conducted at the factory site. Staff and materials were made available over 1 weekend to set up all the necessary treatments in 32 individual crockery jars. A special section of the courtyard was set aside for the experimental jars. A 2^5 experiment was set up, with two levels each of the five factors of soybean, wheat flour and koji levels in the mix, incubation time, and fermentation time. Fermentation times of 60 days were evaluated against the standard time of 90 days to evaluate the opportunity to increase production capacity. The first batch of the 16 results has been collected for the shorter fermentation time treatment.

The objective was to investigate the factors and their interactions that are more likely to improve the yield of the soysauce process. Table 10 presents a summary of the four best samples of soysauce obtained. The data in Table 10 indicate opportunities for reducing the process time to 3 days for incubation and 60 days for fermentation (presently about 5 days incubation and 90 days fermentation) (sample 4) with an increase in soy and wheat levels. Reduced salt levels are seen as desirable and higher protein levels over control indicate a satisfactory product.

During the meeting in Vancouver, considerable discussion took place over (a) the need to include economic evaluation of such changes in considering the overall benefit of such improvement in association with experimentation; (b) the value of graphical interpretation of results to identify improved conditions, although full statistical analysis will be necessary to evaluate whether effects of changes are significant; (c) future work needs to consider combining a large tank with the reduced process times. Overall, it was indicated that such planned experimentation effectively demonstrated to management that they do not always have to retain the traditional operating conditions to produce their products.

Investigation of Materials Handling Improvement

The flow process chart technique was used to monitor the movement of materials from the incoming stage of raw materials to the final stage of production. Activities of every work element and related time consumption were recorded in the chart. On each visit, a different section of the process was studied (recorded on separate charts). It took 3 weeks to establish and verify data fully. The long, time-consuming activities would be isolated for in-depth studies and development of improved materials handling procedures. The proposed methods will then be compared with the existing method to assess the time saved by the new approach. The proposed method, if accepted, would be used for the recording of process sheets and the setting up of time standards for the process operations. In addition, the data of the existing method could be used for justification of the mechanization process in the factory and improvement of work efficiency. Work to date has indicated savings in process time by installing ramps in store areas to allow easier movement of goods, using wheeled rollers to move trays around, and relocation of the filling tank closer to the bottle handling area. Figure 16 illustrates a portion of the charting techniques used.

COUNTRY WORKSHOP REPORTS

In the latter half of the workshop, each participant from a developing country presented information on conditions in a typical small-scale food-processing company visited in preparation for the workshop. Small working groups were then set up, led by the participant, to apply some of the concepts of methodology, introduced earlier in the workshop, to this actual situation with which he or she was familiar. In the short time available, little ground could be covered, but given the different backgrounds of each participant these sessions were quite successful.

Discussions were often intense and often with technical details of possible improvements with which the essentially technical group were familiar. Group leaders, however, attempted, frequently with good results, to apply the major concepts of identifying problems, possible improvement approaches and screening, as well as the terms of reference approach, to ensure systematic, objective assessment for process improvement appropriate to each real small factory situation.

All of the participants appreciated these sessions because they had an opportunity to apply systematically some of the techniques and, for the most part, agreed that these methodologies were of value in their situation and were of general use across a wide variety of problems as encountered during these sessions. This section contains a description of each of the sessions based on notes prepared by each group as an illustration of the issues discussed.

MARRAQUETAS (BREAD) - CHILE

Location: Comuna de La Granja, South Santiago.
Products: Bread, mainly marraquetas and other types like hallulla and special bread.
Raw materials: Flour, yeast, water, salt, oil, lard, and additives.
Staff: Family based operation with members of the family in charge of direction, finance, sales, and processing management. Labour force of 13 workers.
Labour costs: $10.946/person/month.
Throughput: 2500 kg of flour/day to produce 3125 kgs of bread daily (67% marraquetas).
Product selling price: $45/kg (Cdn $0.73/kg).
Market: About 20% of the produce is sold within the immediate vicinity with the remaining 80% distributed to other selling points within South Santiago.

DISCUSSION GROUP

After detailing the aspects of the baking process of marraquetas, it was decided to follow the systematic analysis and develop the terms of reference. The major priorities were then selected.
Purpose: To examine the existing process of baking marraquetas to determine if improvements were possible to achieve greater economic benefit to both the producer and the consumer.
Scope: The study was to be limited to the bakery process from mixing of raw materials to shipping of the finished product.
Chart: Fig. 17.
Key operation: Baking.
Statement of achievement: Hot baked bread is available.

In generating potential improvements, the following questions were asked: eliminate or change the key operation? These questions had several alternatives called "prompts," e.g., eliminate -- not do it or avoid the need; change -- more of numbers or quantities or less; more than -- what is now plus something else; less than -- what is now less something done now; or other -- change to something different. What else could be done to avoid the need to make baked bread available to a market that wants hot baked bread 3 times a day? The answer could be to make marraqueta mix available to consumers and let them bake it themselves.

Each question can be answered in 5-10 different ways and raise 40-50 ideas that can be evaluated and accepted or rejected. The process should then continue to raise all the possible approaches that could be studied and then followed with the screening.

Some approaches were then analyzed with reference to important criteria for the screening process for the particular bakery, i.e., cost of research, profitability, available technology, etc., and the criteria were given relative weights.

After the screening process, specific priorities for initial research studies were identified. The importance of being more systematic in the research for possible improvement opportunities and in the evaluation process was stressed and was thought to be the best way to cover all possible alternatives. The approaches should then be transformed into specific projects before the screening process is performed. This workshop concentrated on systematically exploring means of generating ideas for improvements according to the terms of reference.

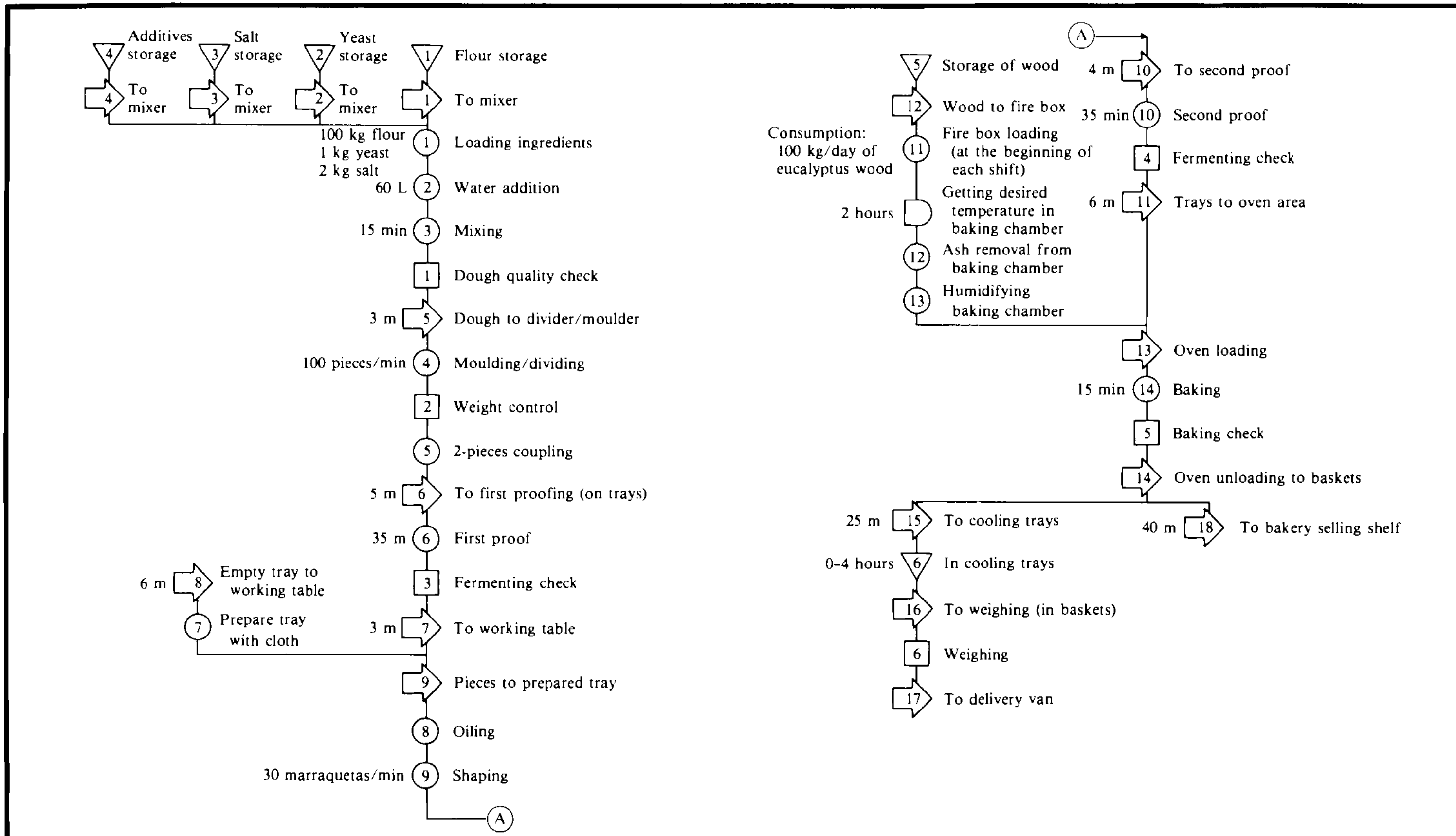


Fig. 17. Process flowchart for a marraquetas (bread) bakery in Chile.

PATIS (FISH SAUCE) - PHILIPPINES

Location: 86 km north of Manila.
Products: Patis and imitation soysauce.
Raw materials: Various fish species. (Salt price of fish P40.00/45 kg, salt P1.50/kg.)
Staff: Family based operation with five family members acting as directors and management, labour force of a maximum of seven employees.
Labour costs: P10.00 to P15.00/day.
Throughput: 100 banyera (4500 kg fish) a year to produce 500 L of patis puro (1st class) and 3000 L of patis especial (2nd class).
Product selling price: Patis puro: P17.50/bottle of 750 mL.
Market: Pampanga area -- cannot compete with known brands in metro Manila area or for export.

DISCUSSION GROUP

After flowchart work and the definition of terms of reference, alternatives were screened based on criteria defined as most important to the company. The criteria were given weighted values and the alternatives were rated on each of these criteria. As the company's main problems were financial, increasing productivity to generate more cash flow was given the highest score.

In the selection of approaches/alternatives using the screening table as a basis for discussion, among the alternatives with the most potential was partitioning and addition of more vats, which would allow for a continuous cyclic batch fermentation without adversely affecting product quality.

It is equally important, however, to look into the approaches relative to the problem on large interest payments. A new set of criteria on this aspect could be further evolved in consultation with the management and the research team.

Screening Table

Possible approaches	Criteria: Low capital investment 1 (50)	Low technology input 2 (30)	Increase revenue 3 (50)	Increase productivity 4 (70)	Time and cost of research 5 (20)	Total
1. Apply appropriate technology:						
pH	40	25	30	50	10	155[a]
Temperature	20	20	40	65	12	157[a]
Koji	30	15	35	55	9	144
2. Chopping fish	48	30	25	4Q	12	155[a]
3. Partitioning/addition of vats	15	30	35	50	15	145[a]
4. Delay initial payment	50	30	--	--	20	100
5. Lengthen loan period	50	30	--	--	20	100
6. Pasteurization	35	25	25	30	12	127
7. Blending	25	20	30	60	5	140
8. Better records	40	25	10	10	10	95
9. Animal feed	48	28	15	20	20	131

[a] Approaches with highest scores for further investigation.

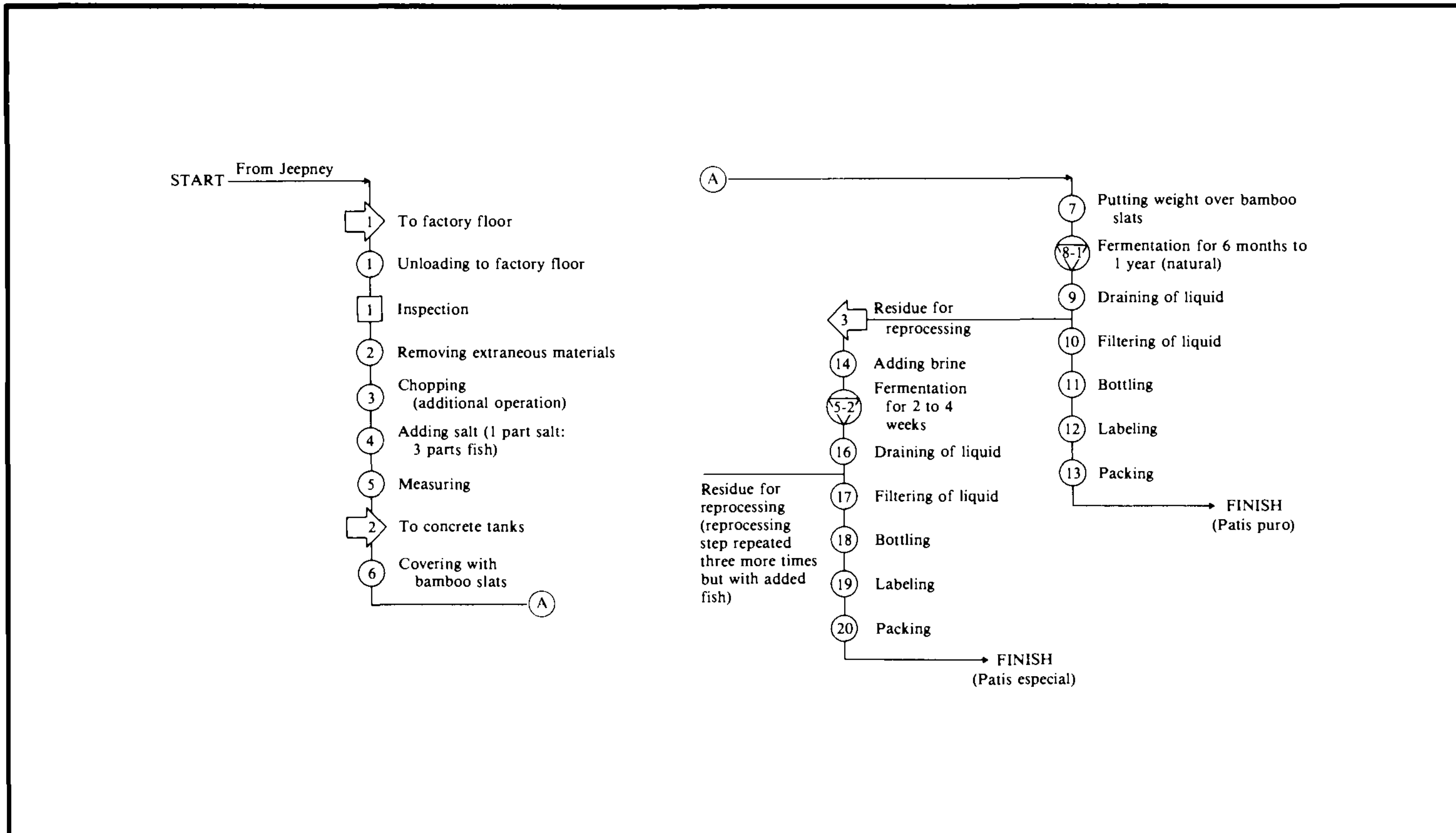


Fig. 18. Process flowchart for patis (fish sauce) production in the Philippines.

BALADY BREAD BAKERY - EGYPT

Location: Giza, Egypt.
Products: A two-layered flat bread called balady.
Raw materials: Wheat flour (82% extraction), sour yeast, salt, wheat bran, and water.
Staff: There is a total of eight persons working in the bakery: two to bake the bread, two to prepare the dough, two to divide dough pieces, one to flatten the dough pieces, one to transport the product inside the bakery, and the owner, who is responsible for controlling the work and selling the bread.
Labour costs: Labour costs for each 100 kg of flour include 52 piasters for preparing the dough, 86 piasters for baking, 46 piasters for dividing, and 23 piasters for transport.
Throughput: A total of 840 t of wheat flour per year (2.4 t/day) is required to produce 74 million loaves of 169 g each.
Product selling price: One piaster/loaf.
Market: Giza area.

DISCUSSION GROUP

Because of the rapid populanion expansion in Egypt the need to increase bread production has become a major concern. At present, bread production is subsidized by the government and the selling price is, therefore, very low. Because of traditional consumption habits and the fact that 30% of the bread is gelatinized dough, i.e., unbaked bread, only the crust is eaten by consumers and the rest is thrown away. This represents a major loss of scarce wheat. Other serious losses occur during the bakery process itself. The bread is also used as animal feed because it is so inexpensive resulting in a significant amount of loss as human food.

In terms of balady bread production, the group decided that improving the bread quality or providing a higher-quality bread as another product from the bakery might reduce the wastage and the amount of wheat importation. It was also felt that an increase in the selling price of the bread for an improved quality bread should also be considered. Among the opportunities for improvement in the yield of bread in the bakery that were discussed in the group were: various methods to increase the batch loaded into the small balady oven, decreasing the proving time, improving the dividing or apportioning procedure of the typical wet dough, reorganizing the bread cooling method, and consideration of packaging the bread to keep it fresh longer.

After screening for criteria of improving quality, increasing production, and decreasing production costs, it was agreed that increasing the bread diameter and the productivity of the oven were the main areas requiring immediate action.

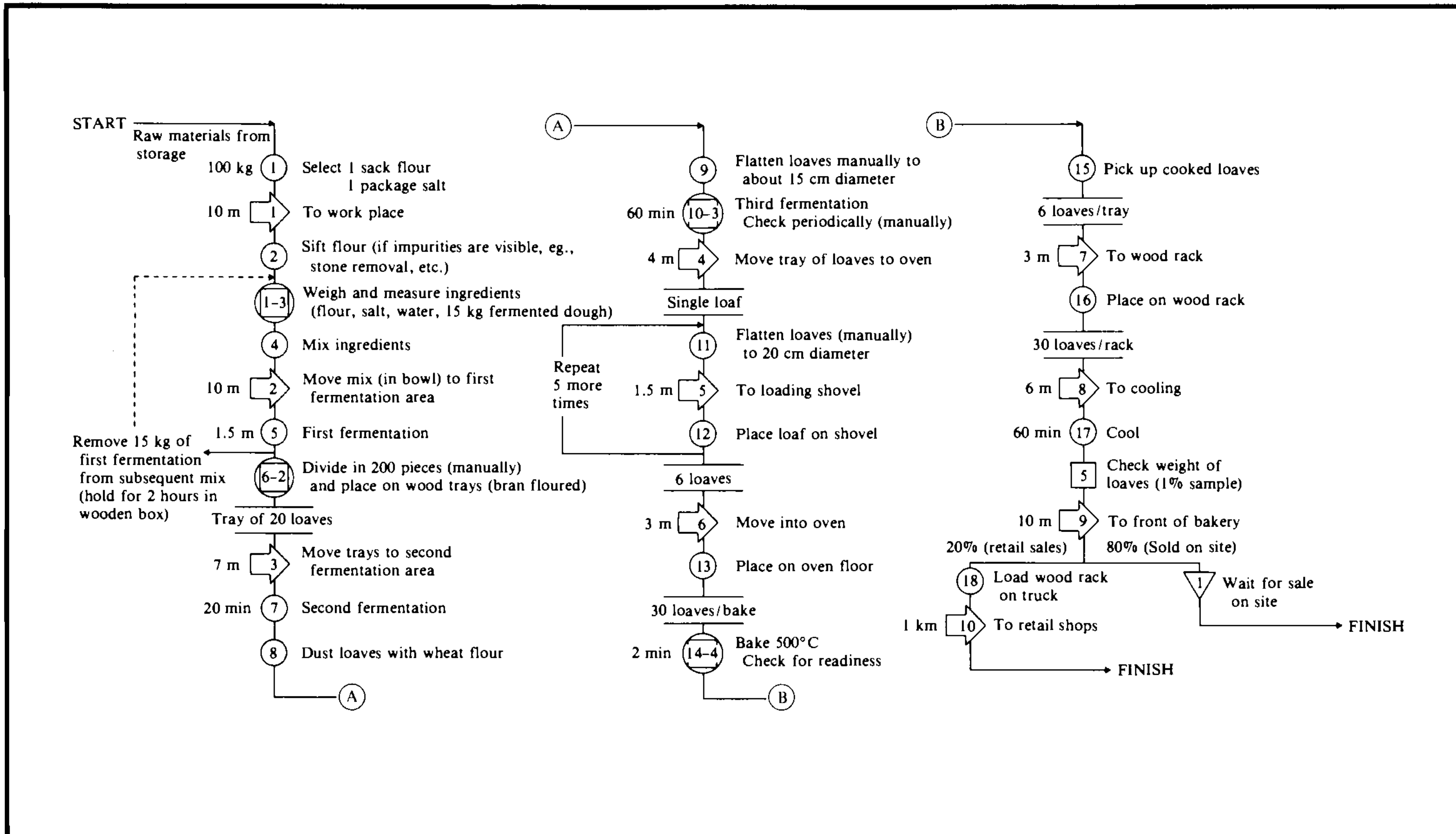


Fig. 19. Process flowchart of a "balady" bread bakery in Egypt.

CANDIED FRUIT - JAMAICA

Location: 90 km northwest of Kingston, Jamaica.
Products: Main product is mixed, candied fruit and peel, and the secondary line is canned ackees (tree fruit).
Raw materials: Seville oranges, paw-paw, cho-cho, and ackees.
Staff: The staff consists of a managing director (voluntary), plant manager, accountant/ company secretary, three administrative clerks, 20 permanent shop-floor workers, and 40 seasonal shop-floor workers.
Labour costs: J$56 000/year.
Throughput: 212 400 kg of raw material/year to produce 106 200 kg of product.
Product selling price: J$3/lb.
Market: Bakeries and final consumers island wide. Future export possibilities to the Caribbean Community of nations (CARICOM).

DISCUSSION GROUP

After redrawing the flowchart, the problem areas in the process were identified. The major bottleneck was seen to be the long time and floor space required for the syruping stage of the process. Thus, terms of reference were developed as a means of guiding improvement as follows:
Purpose: To examine the syruping process and develop a faster method of candying paw-paw.
Scope: All work will cover activities after fruit preparation through to final packaged product.
Chart: Fig. 20.
Key operation: Syrup fruit.
Statement of achievement: Desired sugar content is reached in fruit.

A short ideas generation session was attempted that indicated a range of opportunities for overcoming the problems of syruping, some of which included incorporating a drying stage and others that would eliminate the need altogether for syruping, because other presentation methods could be used to provide products with higher value than fruit, e.g., fruit leathers, jams, dried fruits, etc. However, the group refocused to suggest a range of improvements that might be incorporated in the present factory without changing the product.

A screening exercise was then conducted using a range of criteria judged important for the Jamaican company. Among these were minimum capital cost, reduction in production cost, implications for retraining staff, research time required, and effect on quality. The criteria were ranked and then each of the improvement ideas scored against them by concensus of the group.

This discussion group was particularly interesting because one of the participants had been associated with the rural processing company for several years, so comments and discussion simulated the type of meetings researchers need to have with managers of small companies in initially identifying relevant improvements.

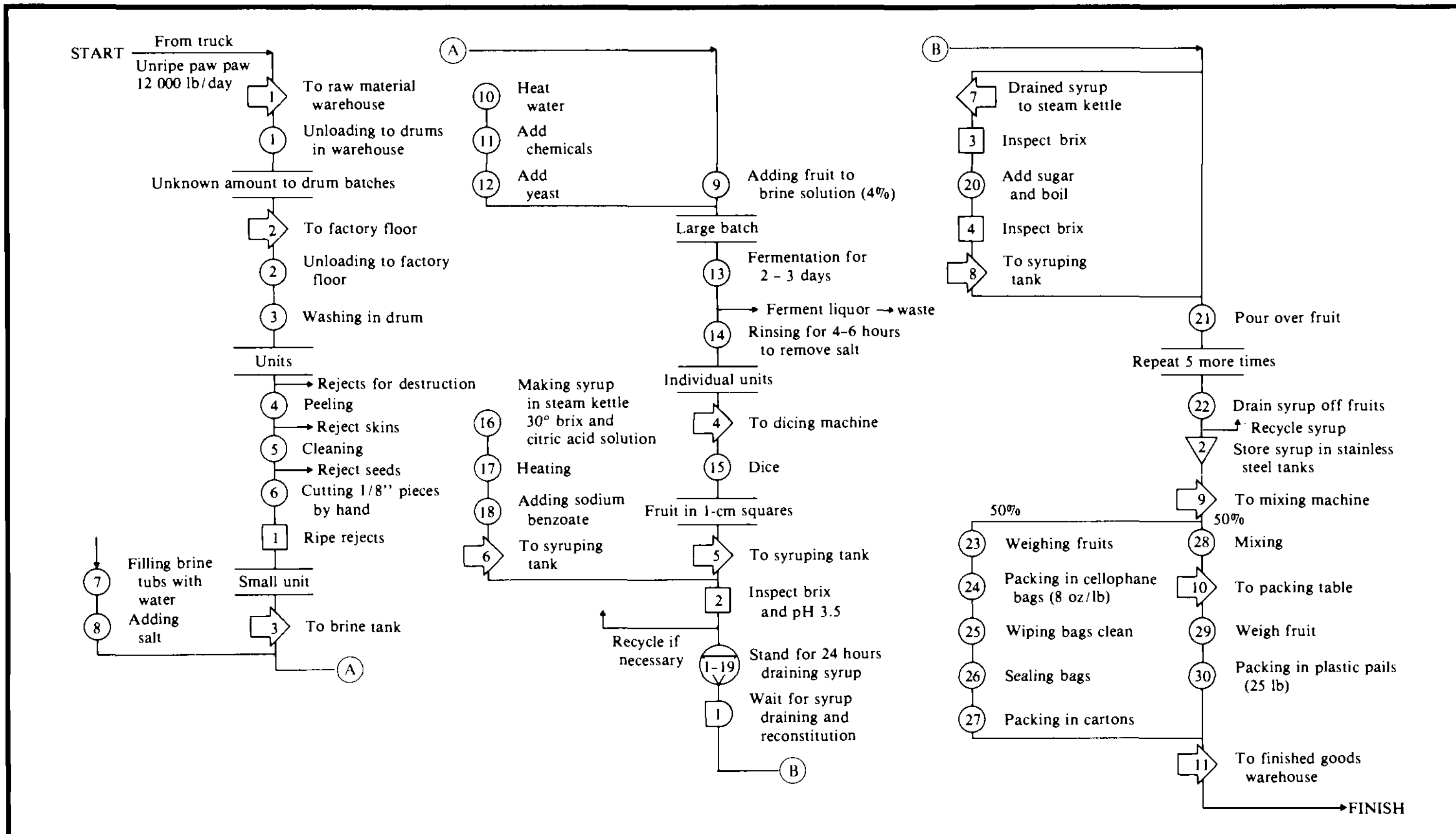


Fig. 20. Process flowchart for a candied fruit (candied paw paws) processing plant in Jamaica.

PAPADAMS (LEGUME-BASED CRACKER PRODUCT) - SRI LANKA

Location: 160 km from Colombo, Sri Lanka.
Products: Bread, biscuits, noodles, edible oils, rice, and gram flour.
Raw materials: Black gram flour, common salt, baking soda, and coconut oil.
Staff: Forty labourers and two supervisors.
Labour costs: U.S. $45/day.
Throughput: 500 kg of papadams per day.
Product selling price: U.S. $1/kg.
Market: Throughput Sri Lanka.

DISCUSSION GROUP

The same process of defining the terms of reference was followed in the discussion group for Sri Lanka:
Purpose: To find economic methods of expanding production.
Scope: Total production process.
Chart: The chart was modified as a result of discussion (Fig. 21).
Key operation: Three important key operations were discussed: (a) mixing flour and water to make the dough, (b) shaping the product (pressing), and (c) drying. In terms of the entire process, mixing was suggested as the key operation.
Statement of achievement: The dough is made available.

The problem areas, opportunities for improvement, and possible approaches were then identified and criteria for screening were selected and the approaches scored.

Based on the total scores, mechanical shaping was identified as the improvement with the best potential for overcoming low labour productivity and lack of uniformity of shape associated with the present wholly manual methods.

It was also noted that scoring should be tried again at a more detailed level when more information was available on the possible use of mechanical driers, because once productivity is raised through the improvements in materials handling, faster and more controlled drying would be the next area for improvement.

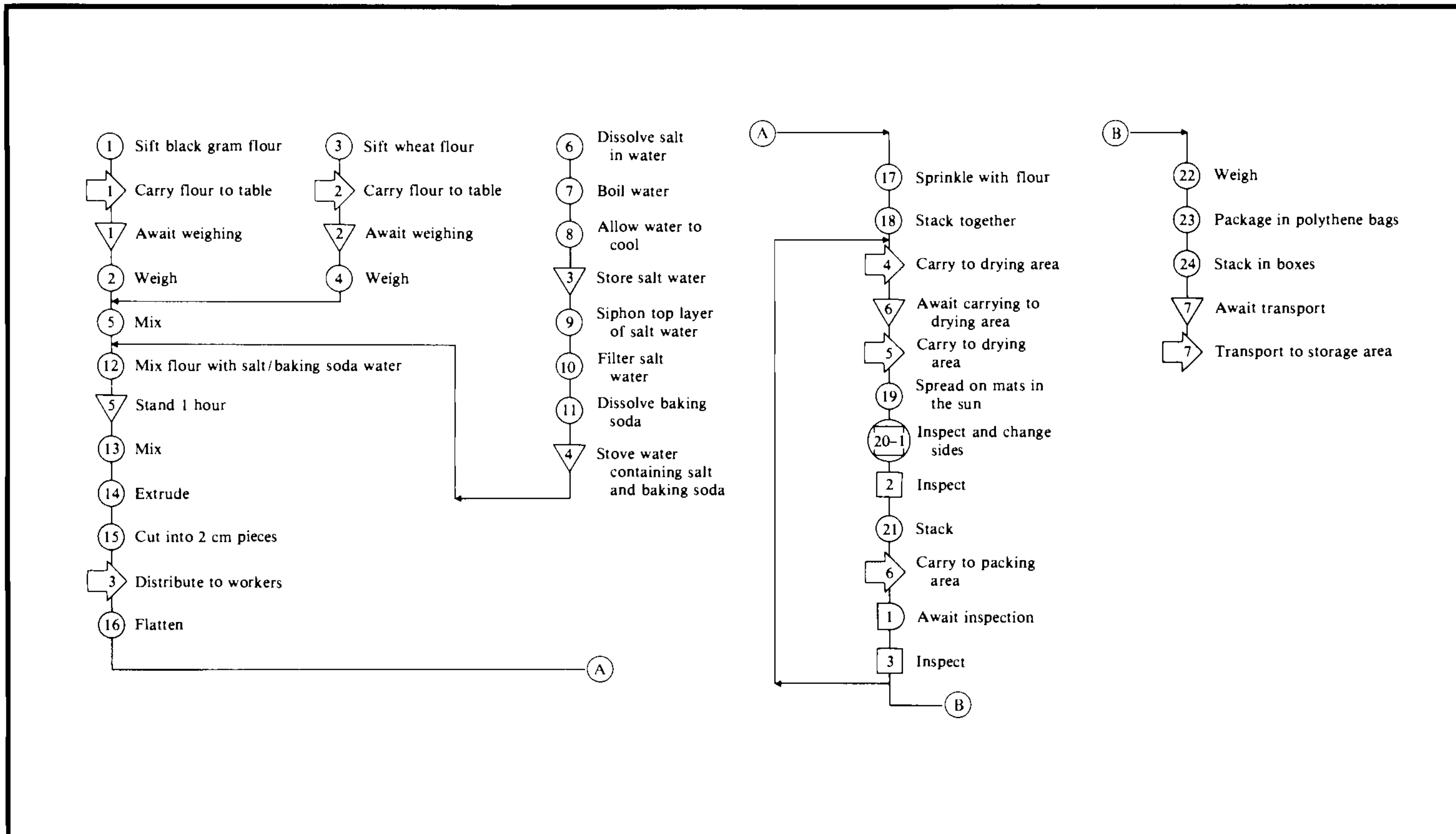


Fig. 21. Process flowchart for papadam (a legume-based cracker product) production in Sri Lanka.

KEROPOK (FISH CRACKERS) - MALAYSIA

Location: 560 km north-east of Kuala Lumpur situated in the east coast state of Trengganu.
Products: Mainly fish keropok.
Raw materials: Mainly two types of fish Clupea spp. and Chirocentrus spp.
Staff: One manager owner, one assistant manager, eight skilled and semiskilled workers, and 35 unskilled workers.
Labour cost: By contract arrangement -- average wage for skilled and semiskilled workers 250-350 M$Ringgit/month, and for unskilled workers $150-200/month.
Throughput: 925 kg of fish yielding 600 kg of keropok per day.
Product selling price: $1.00/300 g packet.
Market: Several major towns throughout Malaysia and Singapore.

DISCUSSION GROUP

The original flowchart was discussed and numbers were given to the stages of processing, together with the quantity of materials used, estimated time required, etc. A new flowchart was then prepared incorporating the suggested modifications. The following problems and improvement opportunities were identified: improvement in quality and presentation, improvement in packaging, expansion in production, uniformity in shape, thickness, etc.; drying during the wet season and sporadic rains; utilizing waste; reducing bottlenecks, such as the steaming process, rolling, etc.; product formulation; and combination of the mixing, extrusion, and slicing operations.

The identified improvement opportunities were mainly viewed from the following needs: to avoid spoilage of present products during storage, distribution, and at retail outlets; to improve product quality and appeal to increase market demand; to expand production to meet the expected increase in demand; to process during off-season to sustain market and to maintain the livelihood of the workers; and to have a better method of drying that will be independent of the climatic influences. The following criteria to assist in screening were also developed in the group: effect on quality, effect on yield, effect on cost of production, hygiene implications, capital cost implications, increasing production capacity, labour productivity, raw material availability, research time and costs, technical skills availability, and profitability.

The next step was to draw up a list of the improvement opportunities against these screening criteria. From the screening process, some possibilities for study were obvious. For each study area the process can be repeated as a range of options can be listed. For each option the capital cost, capacity change, research cost, technical skills, and other important inputs such as labour, raw material cost, etc. can be evaluated at a more detailed level. A Gantt chart would also be prepared for each study to indicate the time taken for research study of the various options to provide another basis of selection.

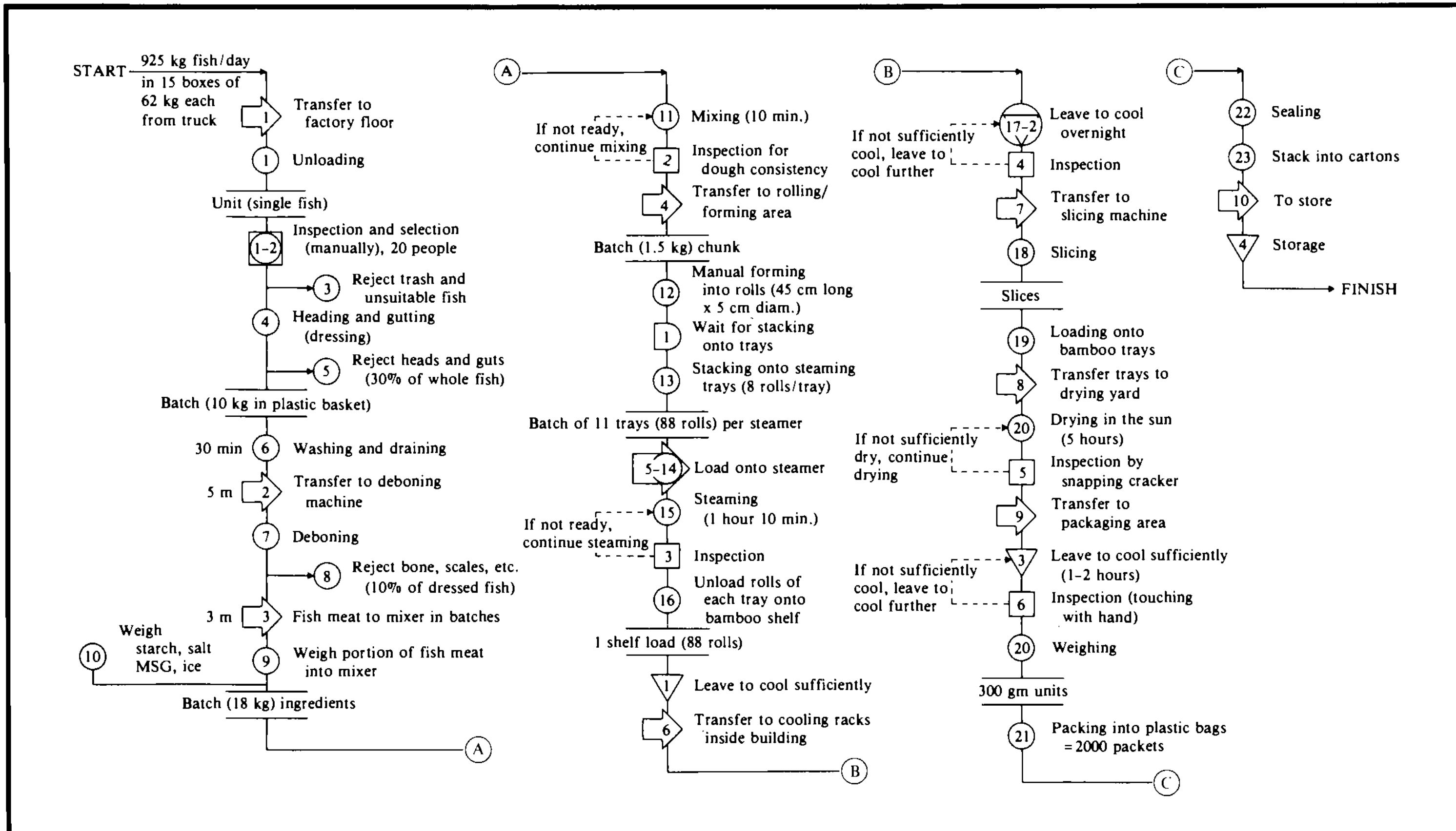


Fig. 22. Process flowchart for keropok (fish crackers) in Malaysia.

COFFEE PROCESSING -- GUATEMALA

Location: San Lucas Toliman, Solola.
Products: Coffee in parchment.
Raw materials: Coffee fruit.
Staff: One manager, warehouse keeper, watchman, and three permanent workers.
Labour costs: Ordinary: Q0.51/hour. Extraordinary: Q0.66/hour (Q 1 = U.S. $1).
Throughput: 4000 lb/day (1816 kg/day) of coffee fruit.
Product selling price: Fluctuates daily, about Q 75/100 lb (Q 1630/t).
Market: After parchment skin removal the product is exported to Europe, USA, and Canada.

DISCUSSION GROUP

First the process chart was redrawn according to the experiences gathered during the workshop. The process in this case was complex, but, general terms of reference were developed:
Purpose: Increase the profitability of the coffee processing operation by reducing costs and making better use of by-products.
Scope: The operation of all coffee processing plants of the cooperative.
Key operation: Because the process involved production of intermediate products at different stages, drying, pulping, and fermentation were all identified as key operations.
Statement of achievement: Pulp, mucillage, moisture, and coffee beans are separated; dried beans are made available; and most moisture and coffee beans are separated were suggested.

The key operation approach was difficult to apply, unless the process was broken up into its individual activities. Earlier, critical screening, perhaps involving relative costs of each activity, might highlight the activities requiring improvement. Detailed investigation of different ideas to meet the statement of achievement could then be carried out for the priority activities.

Discussion then focused on the practical application of the techniques. For example, direct contact with the Federation of Coffee Processing Cooperatives (FCPC) was suggested to solicit their participation in a research program with ICAITI, whose objectives would be determined by the FCPC. Information should be gathered about the operation of the coffee processing plants (beneficios) of the FCPC and management systems used. Working sessions with ICAITI researchers and the FCPC should then be held to identify problems and screen possible solutions. After an agreement is reached with the FCPC, the project should begin by collecting information relevant to the present costs and revenues of the process to be improved that will be compared after changes or innovations are implemented.

Data on industrial engineering studies conducted at a rural beneficio were also presented. Discussion centred around the difficulty in obtaining reliable data of this type in such a complicated, rural small industry. Data on labour utilization, process times, and costs were compared for the traditional separation process followed by open-air sun drying ("patio" drying) and for artificial drying using a bed dryer (2 t capacity) with air heated by burning mixtures of dried coffee pulp and firewood. It was shown that significant savings could be achieved and the process speeded up by employing the dryer with or without partial drying also in the patios.

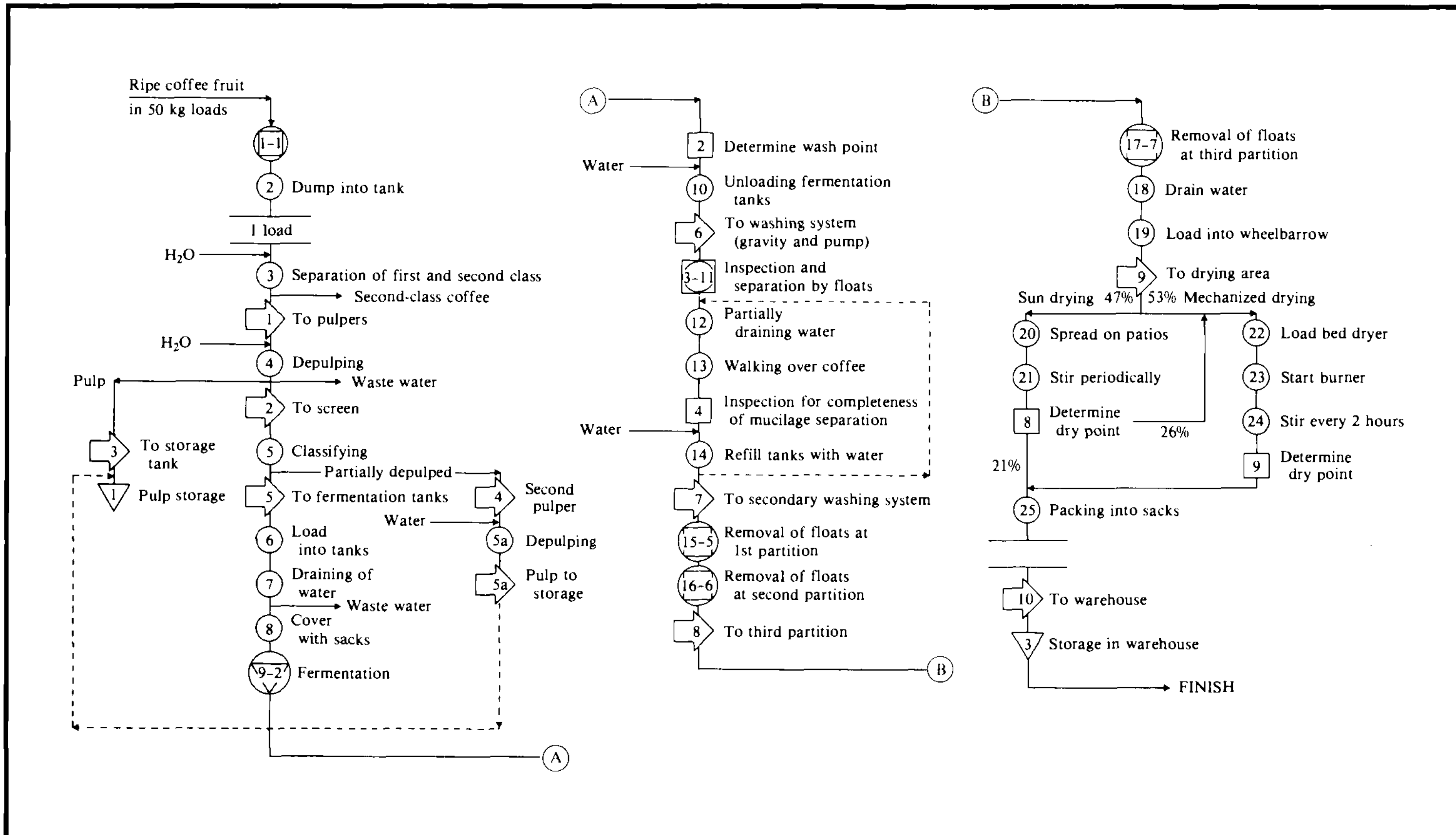


Fig. 23. Process flowchart of a coffee processing plant in Guatemala.

CONCLUSIONS AND RECOMMENDATIONS

All of the participants actively interacted during the workshop, enthusiastically at times, ensuring that the concepts introduced were adapted to relate more specifically to their particular situations. The factory visit was useful in attempting to apply some of these ideas and allowed a common experience to be shared by all, which led to useful interactions in return. The small processing unit visited, however, was sufficiently more advanced than that commonly found by the participants in their countries that some of the benefits in understanding anticipated with this type of field trip may have been limited. This emphasized the need to base future activities of this type at developing-country sites.

The individual working sessions led by each participant were particularly successful. These indicated each participant's grasp of the methodological concepts introduced as well as the advantages of group interaction in working together on defining problems, criteria for evaluation, and opportunities. However, insufficient data were available for detailed work in these sessions. If future workshops are based at an active, more advanced small-industry project, such as in Thailand, this deficiency could perhaps be overcome. It was apparent from their extensive input that because of their experience, the Thailand and Singapore participants understood the relevance and benefits of a systematic and sympathetic approach to problem solving in traditional food processing. Participants agreed that through accumulation of experience such as this, in a number of projects, and sharing it with other researchers in other project meetings that appropriate methodological steps and techniques could evolve. Training in specific techniques will be necessary to accelerate this.

Projects from participants from the Philippines, Malaysia, Guatemala, and Chile are anticipated to be presented to IDRC for potential support. It was suggested that a small working group of representatives of active projects be formed to meet at least once a year to review progress in methodology and highlight areas requiring assistance in the future development of this field. This could be a more cost-effective plan over the next 2 years or so than full workshops.

The major issue raised during the meeting, and requiring follow-up attention perhaps by the working group, was the concern over the costs of this applied research in factories incurred by research groups, with little likelihood of substantial financial contribution from the individual small factory owners. This financial consideration conflicts with the need to maintain confidentiality of information for the factory and could prevent wider dissemination of research results to similar small factories that could otherwise reduce research costs per factory. It is important, therefore, to propose imaginative possibilities to overcome this circle within the institutional, cultural, and financial constraints of each research group. IDRC can perhaps provide researchers with contacts in other small-industry research services groups who have successfully overcome this dilemma. It is planned to assist researchers in initiating projects in this field and to support the formation of a working group when a sufficient number of projects are under way. The working group can then suggest future activities.

The following are some of the specific conclusions and recommendations that were developed by the participants at the workshop:

- There was a general agreement that the small food industry is very important in developing countries, and, in some, the improvement of such industry has been included in the national plan. Although governments obviously have an important role in encouraging research in this sector, which is not always practiced, it was suggested that researchers must use their own initiative to make direct contact with industry perhaps through the existing food-industry federations to begin to work in this area. It may then be possible to justify continued development of this research area and relevant funding to government.
- The methodology that has been used in the past in the development of the small-scale food industry has proved to be inadequate. It was felt that the approach presented in this workshop, although not developed solely for this industry, could be adapted to provide a systematic method of evaluating and solving the problems of small-scale food businesses. Researchers may still be required to maintain flexibility and use their judgment in the application of these approaches.
- The most appropriate way for the methodology to be developed is through accumulation of experience in small-scale factories. Various suggestions were made to help accelerate this process, because it is necessary to develop both theory and practice. The exchange of experience between developing countries may prove useful, perhaps in the form of similar workshops held in developing countries. In countries where the predominant scientific language is not English, it may be necessary for reports, such as the one from this workshop, to be translated.
- Additionally, training requirements were discussed at length. It was agreed that training was best carried out during projects and that new and inexperienced staff could be introduced to methodology and techniques by working with experienced researchers in ongoing projects. Although this should be most effective in projects in factories in developing countries, intensive training in the application of specific techniques could be achieved by working in appropriate developed-country institutions on industrial problem solving. Two of the participants, David King and Graham Rand, indicated that their institutions could provide such training facilities. Alternatively, training could be based in developing-country situations with a visiting consultant from a developed-country institution, but this would require more preparation at the site and the assurance that the consultant can adapt his or her approach to the developing country context.
- The desirability of multidisciplinary teams was strongly emphasized. In many of the institutions represented at the workshop this was already encouraged, and many disciplines were available within the institution. In the other institutions, it was reported that there was no problem in involving engineers or economists, etc., from outside, for example, from universities.

• It was felt that, as much as possible, management and other staff should be incorporated fully into the research team. If this is not possible, their participation in key meetings (i.e., sessions where screening of problem areas is done) should be considered as a minimum level of involvement. This participation may serve to train the management in the methodology so that they may eventually solve problems on their own.

• When working in a large and diverse team, it may be difficult to achieve concensus on all points in the decision-making process. To overcome this, responsibility can be delegated to individual members for day-to-day decisions, who will then be responsible for their actions. Group decisions should be reserved for key points.

• It was agreed that it would now be possible to arrange regional workshops, which would make use of the experience of those from developing countries who had been involved in the previous workshops. It was expected that there would be less input than before from resource persons from developed countries.

• By keeping some form of communication between projects and considering the establishment of a small working group, the major issues in development of methodology, project management could be further developed. However, meetings at a research project site require a commitment with regard to facilities, time, and energy, and should, therefore, be kept to a minimum. It was suggested that, as an alternative to a meeting, progress reports from individual projects could be distributed regularly to maintain contact and awareness of developments. There is still room for the consideration of other alternatives to maintain momentum in development of the methodology and techniques.

• Ultimately, this research should at least be partly financed by the businesses that are helped, but it is recognized that, initially, as experience is gained and credibility established, there may be many serious problems with this approach. Financial help may be needed from a variety of outside sources, such as government or aid agencies. It should also be demonstrated to institutional directors that there are other benefits that accrue from the involvement of the institution in such work. For instance, the researchers will gain experience of local industry and make contacts that may be useful in the long term, for example, in defining useful research programs and practical advisory services to small food businesses.

• A method of recording the returns on the investment of R&D done by the institute needs to be incorporated into its projects. This information would encourage involvement of additional factories in similar projects, as they can be shown the monetary advantages. As well, the use of the institute's funds can be justified by a cost/benefit ratio and may increase support from government and encourage the establishment of small industry research services at their institute.

• To encourage dissemination of results and exchange of experiences, results of process improvement studies may be published in a variety of ways. Institutions may be required to report summaries of their work to government and may choose to advertise generally their work within their own countries. It was also suggested that there might be opportunities to publish discussions of methodology and examples of case studies in appropriate journals. Detailed technical financial data or identification of factories worked in should not be published to maintain confidentiality.

• A wide variety of techniques are available to make management in factories aware of the opportunities for improvement and have already been implemented successfully as discussed in "Contact with

Small-Scale Business."

- The amount of confidentiality that is required when working with factories will depend upon the state of the industry. A difficult situation arises when factories are competing for a limited market, such as the bakeries in Chile. Maintaining confidentiality for one factory may mean eliminating competitors from the marketplace. Yet it must be emphasized that it is better to make some advances in the industry than none at all.
- An approach to overcome this situation may be to solve a problem common to all factories, and then make this solution available to all interested parties together with appropriate implementation services. This approach allows each factory to maintain its individual process and possibly remain competitive because of their different products.

APPENDIX A **Statistical Tables**

Table A1. Chile: Number of industrial plants according to type and number of employees.

Type of industry	Cottage industries 1-4 employees		Small-scale industries 5-49 employees		Medium- and large-scale industries ≥ 50 employees		Total	
	No.	%	No.	%	No.	%	No.	%
Manufacture of food, beverages, and tobacco[a]	3548	30.3	3149	31.3	323	25.3	7020	30.5
Textile, wearing apparel, and leather industries	2273	19.4	2129	21.2	271	21.2	4673	20.3
Manufacture of wood and wood products, including furniture	2109	18.0	1571	15.6	128	10.0	3808	16.5
Manufacture of paper and paper products and printing and publishing	639	5.5	572	5.7	72	5.7	1283	5.6
Manufacture of chemicals and chemical, petroleum, coal, rubber, and plastic products	294	2.5	597	5.9	152	11.9	1043	4.5
Manufacture of nonmetallic mineral products, except products of petroleum and coal	649	5.5	408	4.1	53	4.2	1110	4.8
Basic metal industries	44	0.4	72	0.7	27	2.1	143	0.6
Manufacture of fabricated metal products, machinery, and equipment	1580	13.5	1362	13.5	238	18.7	3180	13.8
Other manufacturing industries	394	3.4	197	2.0	12	0.9	603	2.6
Ceased operation	174	1.5	--	--	--	--	174	0.8
Manufacturing	11704	100.0	10057	100.0	1276	100.0	23037	100.0

[a]Detail is given in Table A2.

Table A2. Chile: Number of food-processing plants according to type and number of employees.

Type of industry	Cottage industries 1-4 employees		Small-scale industries 5-49 employees		Medium- and large-scale industries ≥ 50 employees		Total	
	No.	%	No.	%	No.	%	No.	%
Slaughtering, preparing, and preserving meat	344	9.7	232	7.4	41	12.7	617	8.8
Manufacture of dairy products	399	11.2	131	4.2	28	8.7	558	8.0
Canning and preserving of fruits and vegetables	56	1.6	99	3.1	24	7.4	179	2.6
Canning, preserving, and processing of fish, crustacea, and similar foods	6	0.2	47	1.5	38	11.8	91	1.3
Manufacture of vegetable and animal oils and fats	2	0.1	16	0.5	32	9.9	50	0.7
Grain mill products	391	11.0	151	4.8	22	6.8	564	8.0
Manufacture of bakery products	1796	50.6	1926	61.2	33	10.2	3755	53.5
Sugar factories and refineries	1	0.0	1	0.0	6	1.9	8	0.1
Manufacture of cocoa, chocolate, and sugar confectionery	41	1.2	57	1.8	10	3.1	108	1.5
Manufacture of food products not classified elsewhere	119	3.3	94	3.0	14	4.3	227	3.2
Manufacture of prepared animal feeds	67	1.9	39	1.2	4	1.2	110	1.6
Distilling, rectifying, and blending spirits	6	0.2	40	1.3	9	2.8	55	0.8
Wine industries	316	8.9	287	9.1	35	10.8	638	9.1
Malt liquors and malt	--	--	6	0.2	10	3.1	16	0.2
Soft drinks and carbonated waters industries	3	0.1	19	0.6	15	4.7	37	0.5
Tobacco manufacture	1	0.0	4	0.1	2	0.6	7	0.1
Manufacture of food, beverages, and tobacco	3548	100.0	3149	100.0	323	100.0	7020	100.0

Table A3. Chile: Number of people working in food industries according to job status.

Type of industry	Employees		Owners and family employees		Total	
	No.	%	No.	%	No.	%
Slaughtering, preparing, and preserving meat	7848	9.2	804	6.8	8652	8.9
Manufacture of dairy products	6235	7.3	850	7.1	7085	7.3
Canning and preserving of fruits and vegetables	4549	5.3	262	2.2	4811	4.9
Canning, preserving, and processing of fish, crustacea, and similar foods	9087	10.6	86	0.7	9173	9.4
Manufacture of vegetable and animal oils and fats	5989	7.0	19	0.2	6008	6.2
Grain mill products	4257	5.0	747	6.3	5004	5.1
Manufacture of bakery products	24681	28.9	7448	62.7	32129	33.0
Sugar factories and refineries	1288	1.5	1	0.0	1289	1.3
Manufacture of cocoa, chocolate, and sugar confectionery	2862	3.3	181	1.5	3043	3.1
Manufacture of food products not classified elsewhere	3440	4.0	322	2.7	3762	3.9
Manufacture of prepared animal feeds	981	1.1	75	0.6	1056	1.1
Distilling, rectifying, and blending spirits	1687	2.0	52	0.4	1739	1.8
Wine industries	6554	7.7	1008	8.5	7562	7.8
Malt liquors and malt	3017	3.5	7	0.1	3024	3.1
Soft drinks and carbonated waters industries	2061	2.4	11	0.1	2072	2.1
Tobacco manufactures	996	1.2	15	0.1	1011	1.0
Manufacture of food, beverages, and tobacco	85532	100.0	11888	100.0	97420	100.0

Table A4. Chile: Total incomes from sales or contracts or both for the small-scale food industry (5-49 employees) (U.S.$'000).

Type of industry	Incomes from in-plant manufacturing	Incomes from sales of purchased products	Incomes from production contracts	Incomes from repair and installation contracts	Total incomes
Slaughtering, preparing, and preserving meat	63703	3852	2720	201	70477
Manufacture of dairy products	20893	1071	--	67	22031
Canning and preserving of fruits and vegetables	21158	879	221	--	22258
Canning, preserving, and processing of fish, crustacea and similar foods	19666	608	25	214	20513
Manufacture of vegetable and animal oils and fats	20893	236	20	--	21150
Grain mill products	216439	2459	210	--	219109
Manufacture of bakery products	255855	20271	434	9	276570
Sugar factories and refineries	369	--	--	--	369
Manufacture of cocoa, chocolate, and sugar confectionery	5896	189	--	--	6085
Manufacture of food products not classified elsewhere	21314	2929	4	33	24280
Manufacture of prepared animal feeds	23673	1056	5	--	24733
Distilling, rectifying, and blending spirits	11542	242	23	--	11807
Wine industries	55861	1448	335	--	57644
Malt liquors and malt	2029	223	206	--	2458
Soft drinks and carbonated waters industries	8584	841	--	--	9425
Tobacco manufactures	98	--	--	--	98
Manufacture of food, beverages, and tobacco	747974	36305	4204	525	789008

Table A5. Egypt: Food industries production in 1978-79 (LE '000).[a]

Item (unit)	1978		1979	
	Quantity	Value	Quantity	Value
White sugar (t)	343835	38459	346522	39826
Refined sugar (t)	285748	38369	285643	34986
Molasses (t)	274041	3949	308549	6048
Alcohol (1000 L)	29628	7646	24204	6373
Yeast (dry and fresh) (t)	10932	2166	11864	2372
Vinegar (6.25 L) (1000 L)	9941	609	10630	758
Acetic acid (ice) (t)	731	268	1005	394
Perfumes and cosmetics (value)	--	27858	--	34537
Others in sugar industry (value)	--	14246	--	9697
Oil no. 15 (local and imported) (t)	160190	21728	167898	22379
Oil no. 3 (t)	10703	1154	8876	894
Margarine (t)	149915	33648	158368	36577
Laundry soap (t)	203991	24035	216741	25611
Toilet soap (t)	26386	10892	28036	12466
Animal feed (t)	803405	16000	981038	25919
Poultry feed (t)	47117	4498	31911	3397
Cottonseed cake (t)	429982	3256	441991	3348
Synthetic detergents (t)	22862	9519	27552	11714
Glycerine (t)	4018	1652	12591	1757
Soybean oil (t)	2604	781	5452	1636
Soybean cake (t)	16299	3063	26755	5859
Rice bran oil (t)	6308	200	6645	200
Linseed cake (t)	6053	443	8831	805
Rice chaff cake (t)	6308	200	6645	200
Rice chaff oil cake (t)	544	64	545	66
Castor oil (t)	80	32	85	34
Linseed (value)	--	161	--	152
Animal fats (value)	156	18	166	20
Others in oils and soaps industry (value)	--	8364	--	7146
Cigarettes (10^6)	27558	320007	29931	400822
Tobacco products (t)	3219	15686	3552	16894
Cigarette tobacco (t)	1466	16849	1464	16835
Molassed tobacco (t)	3460	13520	4017	15670
Chewing tobacco (t)	49	596	33	406
Snuff (t)	19	233	20	236
Others in cigarette industry (value)	--	11839	--	8424
Pasteurized milk (t)	72856	6625	69859	6346
Yoghurt (t)	7028	1419	7870	1790
Butter oil (t)	1517	1930	1539	1931
Soft cheese (t)	147407	81464	155343	86380
Hard cheese (t)	5003	5962	5019	5783
Rockford cheese (t)	153	202	154	200
Processed cheese (t)	9991	8287	9050	8102
Ice cream (t)	2761	2391	3445	2979
Fall cream (t)	844	143	10309	1752
Cream (t)	927	927	936	936
Other in dairy products (value)	--	370	--	745

Table A5. (Con't)

Juice, syrup, and preserved fruits (t)	26204	14885	26017	14775
Jam and marmalade (t)	10271	4942	12137	5891
Tomato products (t)	5838	2798	3911	1894
Vegetables, pickles, and meat products (t)	4173	3372	3126	3248
Preserved legumes (t)	7999	3297	4412	2135
Canned fish (t)	3927	3309	4683	4144
Frozen products (t)	1788	969	2447	1433
Dates and raisins (t)	1941	814	1511	656
Seaweeds and agar (t)	189	164	234	203
Others in canning industry (value)	--	6597	--	8429
Biscuit and toast (value)	21094	9145	21955	10058
Toast (value)	1267	386	1107	388
Chocolates and cocoa (value)	4169	9125	4577	11063
Toffee	1790	1001	1957	1211
Sesame pastry (Halwa Tehinia) (value)	37650	18799	31951	21450
Krammels (value)	2782	1666	2868	1843
Dried sweets (t)	21357	12814	22653	15885
Jelly (t)	421	336	421	336
Bakeries products (value)	--	6800	--	8500
Salt (glober) (t)	--	--	369	39
Others in confectionery and chocolates industry (value)	--	6202	--	7235
Aerated waters (1000 L capacity containers)	57916	33890	59352	58671
Others in aerated waters industry (value)	--	2760	--	2092
Bleached rice (t)	650000	32500	650000	32500
Beer (1000 hecto L)	423	16496	359	13353
Animal feed materials (t)	25528	866	23817	834
Others in beer industry (value)	--	223	--	--
Flavour concentrates (t)	341	4137	396	3821
Natural aromatic oils (t)	21	1336	14	1202
Others in aromatic oils industry (value)	--	7	--	38
Glucose (t)	36575	6497	34931	7136
Starch (t)	17579	3246	17811	4763
Macaroni (t)	96961	8726	99618	8966
Raw corn oil (t)	954	190	1156	231
Others in glucose and starch industry (value)	--	242	--	222
Ice (t)	142650	758	156188	900
Alcoholic beverages (1000 L)	621	745	636	851
Edible molasses (t)	74000	7400	74000	7520
Baking powder (t)	168	118	171	130

[a] PT82 = U.S.$1.00.

Table A6. Malaysia: Food processing establishments of Peninsular Malaysia, 1979.

Type of manufacturing activity	No. of establish-ments	Value of output (M$'000)[a]	Cost of raw material (M$'000)	No. of workers	Paid salary and wages (M$'000)	Fixed assets (M$'000)
Meat (processing/preserving)	7	23408	12743	454	1705	9500
Ice cream	12	26203	15059	707	3201	19687
Other dairy products	7	396969	325001	1534	12488	60817
Pineapple canning	4	67459	48581	2173	7387	17484
Other canning and preserving of fruits and vegetables	70	73935	52037	2384	6677	19177
Canning, preserving and processing of fish, crustacea, and similar foods	44	224356	173149	6377	12688	35762
Coconut oil manufacturing	69	169607	154878	946	2544	14732
Palm oil manufacturing	97	3287806	2646000	11260	51749	579894
Palm kernel oil manufacturing	33	419077	363425	1296	6489	25347
Other vegetable and animal oils and fats	11	272120	230226	1137	10185	38379
Large rice mills	117	361470	323749	3266	11140	70290
Flour mills	4	258170	217829	890	7085	46280
Sago and tapioca factories	25	37069	29344	811	2519	10004
Other grain milling	5	8033	4633	133	481	1951
Biscuit factories	40	91783	68714	3670	10490	24398
Bakeries	126	46150	34584	2215	5002	10037
Sugar factories and refineries	5	442683	348210	1801	12951	80846
Manufacture of cocoa, chocolate, and sugar confectioneries	27	134372	93200	2897	9009	46658
Coffee factories	50	33099	26742	863	1959	3517
Meehoon, noodles, and related products	49	68874	51922	2371	5545	17856
Spices and curry powder	20	12481	9354	428	1039	1377
Other food products	23	97740	57094	1512	9682	31773

[a]M$2.3 = U.S.$1.00.

Source: Industrial Surveys, Department of Statistics, Malaysia.

Table A7. Malaysia: Economic significance and relative efficiency of selected small-scale manufacturing industries, 1970.

Manufactured products	No. of establishments[a]	Value added (M$'000)	% of total: Employment SSI[b]	% of total: Employment MLI	% of total: Value added SSI	% of total: Value added MLI	Capital-labour ratio[c] SSI (M$'000)	Capital-labour ratio[c] SSI/MLI (%)
FOOD AND BEVERAGES								
Meat (preserved/processed)[h]	7	9.7	22.6	77.4	6.7	93.3	10.1	30
Ice cream[h]	12	10.8	28.8	71.2	10.2	89.8	9.2	30
Fish crustacea (preserved/processed)[h]	44	27.3	7.9	92.1	12.5	87.5	9.3	163
Coconut oil[i]	69	13.9	80.0	17.5	85.3	13.9	10.1	44
Palm kernel oil[i]	97	21.2	61.5	38.5	70.9	29.1	19.8	77
Rice (large mills)[i]	117	29.4	81.0	17.6	91.6	6.2	16.0	290
Sago and tapioca[h]	25	7.2	70.9	29.1	67.3	32.7	7.9	44
Biscuits[h]	40	20.1	18.4	81.6	13.5	86.5	3.1	50
Bakery products[j]	126	7.4	85.2	14.8	78.4	21.6	3.7	76
Cocoa, chocolate and confectionery[h]	27	24.1	11.3	88.7	3.9	96.1	3.2	18
Meehoon, noodles and related products[h]	49	14.0	42.2	57.8	19.4	80.6	4.0	50
Animal feeds (prepared)[h]	46	39.3	32.9	67.1	21.1	78.9	15.4	69
Distilled, rectified and blended spirits[i]	11	7.9	46.0	54.0	15.9	84.1	2.7	19
Soft drinks and carbonated beverages[h]	32	49.5	16.4	83.6	6.8	93.2	10.6	71

Source: Department of Statistics, World Bank Document No. 3851-MA.
Note: M$2.3 = U.S.$1.00.
[a]1979 data.
[b]SSI = small-scale industries, MLI = medium- and large-scale industries.
[c]Refers to value of fixed assets per person engaged.

Table A7. (Con't)

Manufactured products	Labour productivity[d]		Capital productivity[e]		Labour earnings[f]		Gross return to capital[g]	
	SSI (M$'000)	SSI/MLI (%)	SSI (no.)	SSI/MLI (%)	SSI (M$'000)	SSI/MLI (%)	SSI (%)	SSI/MLI (%)
FOOD AND BEVERAGES								
Meat (preserved/processed)[h]	9.3	25	0.9	82	3.2	76	60	61
Ice cream[h]	6.1	28	6.7	93	2.0	37	45	83
Fish crustacea (preserved/ processed)[h]	10.1	167	1.1	103	2.4	128	83	114
Coconut oil[i]	13.9	134	1.4	303	2.3	62	115	393
Palm kernel oil[i]	20.0	153	1.0	198	2.7	44	87	321
Rice (large mills)[i]	12.6	321	0.8	110	3.0	126	60	213
Sago and tapioca[h]	6.4	84	0.8	192	2.6	103	47	170
Biscuits[h]	4.0	69	1.3	138	1.7	64	75	146
Bakery products[j]	3.3	63	0.9	83	1.8	85	42	83
Cocoa, chocolate and confectionery[h]	4.3	32	1.3	177	1.9	61	75	128
Meehoon, noodles and related products[h]	3.6	33	0.9	67	1.9	75	41	41
Animal feeds (prepared)[h]	12.4	55	0.8	80	3.3	69	59	74
Distilled, rectified and blended spirits[i]	10.5	22	4.0	120	2.2	59	311	103
Soft drinks and carbonated beverages[h]	6.9	37	0.7	52	2.2	54	44	46

[d] Refers to annual value added per person engaged.
[e] Refers to annual value added divided by value of fixed assets.
[f] Refers to annual wages and salaries per person engaged.
[g] Refers to annual value added less salaries and wages divided by value of fixed assets as of December 1978.
[h] Establishment engaging 10-49 employees.
[i] Refers to all establishments.
[j] Includes establishments engaging 5-9 employees.

Table A8. Philippines: Total number of manufacturing and food manufacturing establishments by number of employees, fixed assets, and total production, 1977.

Manufacturing industry and no. of employees	No. of establishments		Total production		Fixed assets	
	No.	%	P'000	%	Amount	%
TYPE OF INDUSTRY AND NO. OF EMPLOYEES						
1-4 (Cottage level)	59435	75.5	490716	0.7	701080	3.0
5-19 (Small)	15729	20.0	529120	0.8	687806	3.0
20-99 (Small)	2356	3.0	6266333	9.3	1933193	8.4
100-199 (Medium)	466	0.6	5298600	7.9	1568640	6.8
≥ 200 (Large)	697	0.9	54671663	81.3	18165005	78.8
Total	78683	100.0	67256432	100.0	23055724	100.0
FOOD MANUFACTURING INDUSTRIES						
1-4 (Cottage level)	22132	28.1	170123	0.3	467277	2.0
5-19 (Small)	5271	6.7	110694	0.2	243777	1.1
20-99 (Small)	411	0.5	1706079	2.5	487078	2.1
100-199 (Medium)	63	0.1	2266638	3.4	327084	1.4
≥ 200 (Large)	121	0.2	13565122	20.1	4049412	17.6
Total	27998	35.6	17818656	26.6	5574628	24.2

Source: National Census and Statistics Office, EDP 1982.
Note : P$10 = U.S.$1.00

Table A9. Thailand: Number of food processing factories classified by types of food.

Type of product	No. of factories
FOOD[a]	
Bakery products	126
Biscuits	37
Roasted coffee	79
Pastilles and other sugar confectionery	5
Dairy (milk and milk products)	16
Butter	7
Ice cream	118
Canned meat products	44
Meat products	9
Grain mills	38
Tapioca pellets and chips	849
Tapioca mills	306
Canned fruits and vegetables	38
Preserved fruits and vegetables	33
Ground spices	78
Soft drinks	41
Vegetable and animal oil and fats	213
Vinegar	6
Rice mills	27231
Starches	155
Mung bean transparent noodles	23
Flour	81
Animal feed	19
Frozen seafood	24
Canned seafood	17
FISH AND RELATED PRODUCTS[b]	
Salted fish	141
Fish sauce	122
Fish meal	72
Dried shrimp	72
Shrimp paste	53
Steamed fish	46
Other fish sauce	38
Frozen seafood	25
Dried squid	8
Smoked fish	6
Canned seafood	17
Scale ice	3

Source: Information on the food processing factories was derived from the Department of Agricultural Economics, Faculty of Economic and Business Administration, Kasetsart University, Thailand, 1975, and from the "Industrial Directory (1979-80)", Department of Industrial Economics, Ministry of Industry, Thailand. Information on fish and related processing factories was obtained from the Department of Fisheries, 1974.

Table A10. Thailand: Typical statistics of transparent noodle factories.

Region	No. of factories	Production capacity (t/year)	No. of workers	Capital investment (Baht '000)[a]
CENTRAL				
Bangkok	2	86-195	22-350	100-2400
Saraburi	6	12-43	3-49	10-600
Nakorn Pathom	3	30-50	11-80	1100-1500
Karnchanaburi	1	n.a.[b]	10	50
Patum thani	2	12-300	10-80	1690-3500
Chachcengsao	1	105	25	3500
Samutsakorn	1	n.a.	n.a.	n.a.
NORTH				
Nakornsawan	2	36-218	up to 21	308-850
Kumpangpetch	1	n.a.	13	1360
Sawankalok	1	12	n.a.	186
Lampang	2	80-86	up to 50	250-2200
Chiengmai	1	50	n.a.	n.a.
Total	23	12-300	3-350	10-3500

[a] Baht 20 = U.S.$1.00.
[b] n.a. = not applicable.
Note: Total production capacity = 1100 t/year, export = 180 t/year, and local consumption = 920 t/year.

APPENDIX B

CHECKLIST OF QUESTIONS FOR USE DURING FACTORY VISITS

These 51 questions illustrate the wide range of information that needs to be collected to gain an understanding of a small-scale business. In any one situation it will not be necessary to ask all these questions; the most appropriate should be selected. Some of these questions will not be asked, but the answer will be obtained by observation (e.g., question 6).

General

1. Do you have any questions?
2. Do you need any assistance?
3. What are the overhead costs?
4. Is there a system for allocating overhead costs?
5. What plans does the company have for the future?

Production

6. Is the production area clean, hygienic, and safe?
7. Is there any system for regular provision of information on production costs?
8. What is the average utilization of production equipment?
9. What is the production process?

Equipment

10. Is there any requirement for new equipment or mechanization?
11. Is there a recognized system for maintenance of machinery?
12. Are there any problems with energy sources, or water sources?
13. Is there a convenient agent who is available to supply spare parts for imported equipment?
14. What is the typical annual maintenance cost?
15. How old is the existing equipment?
16. What is the depreciation period for major items of equipment?
17. Are there any stocks of spare parts?
18. Are stock checks of spare parts regularly carried out?

Production Planning and Control

19. Are the premises and production capacity suitable for planned requirements or any future expansion?
20. Is there any access to, or use made of, alternative services provided outside the firm?
21. How often, and why, is the plant idle?

22. Are raw materials and packaging provided in time to avoid production delays?
23. With what frequency are orders for raw materials placed?
24. What is the storage capacity for raw materials?
25. Is it possible to find out about raw material availability for planning purposes?
22. Are raw materials and packaging provided in time to avoid production delays?
23. With what frequency are orders for raw materials placed?
24. What is the storage capacity for raw materials?
25. Is it possible to find out about raw material availability for planning purposes?

Purchasing

26. What are the raw materials required for the production?
27. Are raw materials consistently available?
28. Do raw material prices vary significantly?
29. How many potential suppliers are there?
30. Are the prices of alternative suppliers regularly reviewed?
31. Do suppliers require cash or credit for orders?
32. Is there any collaboration between suppliers and the factory?
33. Are there alternative raw materials?

Quality Control

34. Is the quality of raw material checked?
35. Are there checks made during processing?
36. Is the quality of the finished product checked?

Marketing and Distribution

37. What outlets are there for the products?
38. If capacity were increased, would there be demand for the extra production?
39. What prices can be obtained for the products?
40. Are distribution costs paid by the company?
41. Are records of customer complaints kept?
42. Is any action taken about customer complaints?
43. Are some customers more important than others?
44. Is outside transport used?
45. What is the cost of transport?

Personnel

46. What are the different categories of skilled and semiskilled labour?
47. Is skilled and semiskilled labour easily available?
48. How many plant supervisors are present at any one time?
49. Is there any opportunity for upgrading skills?
50. What wages are paid to the different categories of workers?
51. Are there any other employee-related costs?

THAI DATA-COLLECTION FORMS

Date:		WORK STUDY RECORD SHEET				No:
Client:					By:	
Description	**Path symbol**	**Time**	**Capacity/ flow rate**	**Frequency**	**Sample**	**Remarks**
SO_2 fumigation	○ ⇨ □ D ▽	15 hrs		1		
Transport	○ ⇨ □ D ▽	-		1		
Mixing/kneading	○ ⇨ □ D ▽	19-23 min	100 kg/batch	1		1 bowl = 1 batch = 90 kg
Transport	○ ⇨ □ D ▽	-		1		
Manual mixing	○ ⇨ □ D ▽	38-44 min	100 kg/batch	1		
Transport	○ ⇨ □ D ▽	-		-		
Extrusion	○ ⇨ □ D ▽	32-36 min	100 kg/batch	1		1.5-2 min/pail 1 pail = 4-5 kg
Transport	○ ⇨ □ D ▽	-		-		
Freezing	○ ⇨ □ D ▽	17 hrs	360 kg/batch	1		
Transport	○ ⇨ □ D ▽	-		1		
Thawing at room temperature	○ ⇨ □ D ▽	2 hrs		1		
Washing noodles	○ ⇨ □ D ▽	-		-		
Dip in S solution	○ ⇨ □ D ▽	-		-		
Transport	○ ⇨ □ D ▽	-		-		
Sun dry	○ ⇨ □ D ▽	4 hrs		1		
Transport	○ ⇨ □ D ▽	-		-		
SO_2 fumigation	○ ⇨ □ D ▽	1 hr		1		
Transport	○ ⇨ □ D ▽	-		-		
Sun dry	○ ⇨ □ D ▽	3 hrs		1		
Transport	○ ⇨ □ D ▽	-		-		
Packing	○ ⇨ □ D ▽	-		1		

PROCESS SURVEY SHEET

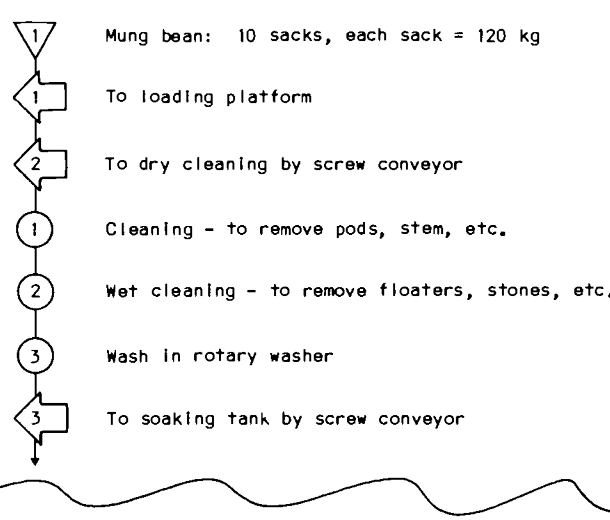
Client		Contact
Address		Tel.
Type	By	Date

PART I - GENERAL

1. Condition			
1.1 Plant production capacity			
Constraint			
1.2 Building area			Total area
L	W	H	Total volume
1.3 Management structure			
1.4 Personnel			Total
Male	Female	Staff	
1.5 Atmospheric condition			
Rainfall Avg.	Max. Min.	Ambient temp. Avg. °C	Max. °C Min. °C
% R.H. Avg.	Max. Min.	W.B. temp. Avg. °C	

2. Building	
Frame	Walls
Roof	Floor
Window	Door
Partition	
Walkway	
Drainage	
Location	
Exterior environment	

PART II - PLANT LAYOUT/FLOWCHART



PART III - RAW MATERIAL/PRODUCTS

1. Raw material 1.1 Source			
Purchased from			
Cost			
Grade			
Packaging			
Storage capacity			
% Impurities 1. 2.			
Delivered by:			

1.2 Chemical composition

% H_2O		
% Starch		
% Protein		
% Fiber		
Others		

1.3 Physical

Absorption ratio		
Size	Diameter	
	Length	
Variety		

2. Products

Type	Grade	Ratio of mixture	Quantity	Netweight	Package	Price
1.						
2.						
3.						
4.						
5.						
6.						

Time in storage Days	Capacity
Type of storage	Dispatch by:

2.1 By-products

Type	Quantity per day/batch	Price	Destination	Description
1.				
2.				
3.				
4.				

2.2 Waste disposal

Type	Quantity	Remarks
1.		
2.		
3.		
4.		

PART IV - UTILITIES

1. Electricity

Municipal source	V	Phase (Ph)	Type	Total consumption
	A	Hertz (Hz)	Unit cost	

Power	Duration	Cause
	Frequency (times per month or year)	

Wiring/hazard

Power generator	KVA	V	PH	Type
	No.	A	Hz	Energy consumption
Emergency lighting	Watt	V	Battery	Type
	No.	A		

2. Steam

2.1 Boiler	Capacity (lb/hr)	Condensate
Maximum pressure (PSIG)	Minutes pressure required for return (PSIG)	Disposal
Temperature °C	Dimension	Fuel consumption
Type and make		Electric consumption
2.2 Steam characteristics		Cost/unit

Pressure (PSIG)	Max.	Normal	Min.
Temperature (°C)			
Moisture (%)			
Value (Baht/million BTU)			
Leakage			
Cause			

3. Water

3.1 Boiler feed water	PSIG	°C	Value (Baht/cubic meter)
Treatment			Total consumption
Analysis			Remarks

3.2 Water source

Type	City	River	Underground
Where			
Flow rate			
Pressure PSIG			
Temperature °C			
Pump type spec.			
Operating cost (BHT)			

3.3 Water analysis

-Cations Ca Mg Na			
-Anions Bicarb. Carbonate Hydrox Cl SO_4			
-Total Hardness			
-Alkalinity			
-Fe -Silica -Org. matter			
-pH			
-Turbidity			

4. Fuel oil	Qty in storage	Cost/unit
Source		
Consumption	Flow rate (CFM)	Pressure (PSIG)
Heating value (BTU/hr)	BTU/unit volume	
Composition		

5. Fuel gas	Qty in storage	Cost/unit
Source		
Consumption	Flow rate (SCFM)	Pressure at boiling (PSIG)
Heating value (BTU/hr)	BTU/unit volume	
Composition		

6. Compressed air supply			
Supply from:			
Pressure of system (PSIG)	Line pressure	Oil/dirt filter	Moisture

7. Refrigeration

7.1 Refrigerating units — No.

Condensing unit	1.	2.	3.	4.
Motor type (HP)				
Rating (BTU/hr)				
Evaporator type				
Rating (BTU/hr)				
Heater (kW)				
Motors (HP)				

7.2 Cold rooms

Insulation	Wall	Ceiling	Floor	Construction structure
Material				
Thickness				

Product temperature in — No. of times (door open)

Final temperature out

Dimension		L	W	H	Loading capacity (kg)	Room temperature (°C)	Measured temperature (°C)
Room	1.						
	2.						
	3.						
	4.						

Heat load no. Light source			Total
Motors no.			Total
Equipment no.			Total

Layout of rooms (sketch)

PART V - PRODUCTION ANALYSIS

1. Process (material balance)

Date						Note
R.M.	Material in (kg)					
Soak	Water: bean					
	Time/temperature					
Grind	Material in (kg/hr)					
	Water: bean					
	Sieve size					
	Time					
Separation	Material in (kg/hr)					
	No. of centrifuge					
	Sieve size					
	Material out (kg/hr)					
	Time					
	Other means					

	Time					
	Fresh residue 1					
	Fresh residue 2					
	Dried residue					
	Residue recovery (%)					
Trough	Material in (flow rate)					
	Material out (whey)					
	Time					
	Starch 1					
	Starch 2					
Sediment	Material in					
	Water quantity					
	No. of tanks					
	No. of washing					
	Time					
Dewater	Material in					
	Material out					
	Time					
	Machine speed (RPM)					
	Other means					
	Sieve size					
	ST-1 recovery (%)					
	ST-2 recovery (%)					
Sulfur-fumigation	SO_2 quantity					
	Time					

Date						
Gel	Material starch quantity					
	Hot water					
	Time/temperature					
	No. of batches					
Mixing/kneading	Material starch:other starch					
	Water					
	Mixing time					
	Temperature					
Extrude	Material in/batch					
	No. of units					
	S.W. temperature					
	C.W. temperature					
	Time					
Refrigeration	Material in/room					
	Temperatures					
	Time					
	R.H. (%)					

Bleaching	SO_2 quantity					
	Material in/batch					
	Water					
	SO_2 (%)					
	pH					
Sun drying	Material in					
	Material out					
	Temperature range					
	Time					
High-grade starch products						
Drying.	Quantity of starch in					
	Drying time					
	Quantity of starch out					
	% Recovery					

2. Product output record

Products brand	Type									
	Regular	%	Short	%	Clump	%	Loose/broken	%	Crumbs	%

EQUIPMENT DATA SHEET

M/C and Acc. Description	Utilization	Capacity	Specification	Cost	Remarks

MASS BALANCE
ANALYSIS RECORD SHEET

Process step		Run no. 1	2	3	4	5	Remarks
A Beans	Protein (%)						
	Starch (%)						
	M.C. (%)						
	Impurity (%)						
B Soaked beans	Protein (%)						
	Starch (%)						
	M.C. (%)						
	Expansion ratio						
C Water	pH						
	Temperature (°C)						
	Appearance						
D Drained soaked water	pH						
	Starch (%)						
	M.C. (%)						
E Ground starch slurry	Density						
	Viscosity						
	pH						
F Coarse residue	Protein (%)						
	Starch (%)						
	M.C. (%)						
G Fine residue	Starch (%)						
	M.C. (%)						
H Starch slurry	Protein (%)						
	Starch (%)						
	M.C. (%)						
	pH						
	Viscosity						
	Density						
I Wet starch on upper part of trough	Starch (%)						
	M.C. (%)						
J Wet starch on lower part of trough	Starch (%)						
	M.C. (%)						
K Effluent (whey)	Protein (%)						
	Starch (%)						
	M.C. (%)						
	pH						
L(M) 35% moisture starch from upper part/lower part	Protein (%)						
	Starch (%)						
	M.C. (%)						
	pH						
	Viscosity						
	Granule size						

Process step			Run no. 1	2	3	4	5	Remarks
L(M)	35% moisture starch after SO_2 fumigation from upper/lower part	Protein (%)						
		Starch (%)						
		M.C. (%)						
		pH						
		Viscosity						
		Granule size						
		Fibre (%)						
		SO_2 content (ppm)						
	Dough consistency	Dough consistency						
	SO_2 solution	SO_2 content (ppm)						
		pH						
	Washed noodles	SO_2 content						
	Fumigated noodles	SO_2 content						
	Dried noodles	Protein (%)						
		Starch (%)						
		M.C. (%)						
		SO_2						
		Strength						
		Panel test after cooking						

HOW TO CONSTRUCT A FLOWCHART

Process Chart Symbols

A process chart is a pictorial representation of the activities of a process in which symbols are used to represent standard activities. These symbols are designed to be easily distinguishable and to represent an activity that would otherwise need many lines of writing. Five standard symbols are used in making process charts:

Symbol	Activity	Predominant result
○	Operation	Produces, accomplishes, changes, furthers the process, etc.
□	Inspection	Verifies quantity or quality or both
⇨	Transport	Moves or carries
D	Delay	Interferes or delays
▽	Storage	Holds, keeps, or retains

The two principal activities in any process are "Operations" and "Inspections." The other three symbols portray the type of nonproductive activities that can occur between operations or inspections or both.

- An "Operation" occurs whenever an object or material is changed in any of its properties or characteristics, physical or chemical, or when it is made ready for, or put away after, another activity. Typical activities that can be described by the use of the operation symbol include: altering the shape, size, or state of an object; a processing step; and arranging, assembling, or dismantling parts.
- An "Inspection" occurs when any of the properties or characteristics of an object are checked: quantity characteristics may be verified by measuring, counting, or weighing; and quality characteristics may be checked by testing to a standard or by grading.

It is important to recognize activities that on the surface bear some resemblance to inspection but, in reality, are operations. When an inspection occurs, the condition of the material is checked against a standard and this check will be followed, in the case of failure, by rejection or some form of reprocessing.

- A "Transport" occurs whenever there is movement from the immediate area of the preceding activity. Transports may be performed by various agencies, human or mechanical. Typical examples include:

material being carried by lift, truck, lorry or hand; material flowing through a pipeline; and a person walking.

- A "Delay" occurs when conditions do not permit the immediate performance of the next activity. This symbol is used to depict the various delays and interrruptions that arise in the normal course of work. Typical examples include: material held up during the process, a letter on a desk awaiting signature, and someone waiting.
- A "Storage" occurs when there is an authorized retention in a specified area. Typical examples include: holding stage in process, buffer stocks within a process, and goods in warehouse awaiting despatch.

All five symbols can be used to represent a very wide range of activities. In some cases, a change in emphasis will show certain activities in a different light altogether, as, for example, when the recording of transport work as such involves considering the transfer of goods from one point to another, not as a transport but as an operation.

Process Chart Conventions

Process chart symbols are placed vertically, one below the other in sequence and joined to each other by a vertical line. To the right of each symbol, the activity is described concisely. Symbols are numbered to facilitate reference and comparison. Like symbols are numbered serially from the beginning of the chart (Fig. B1, A).

Process charts are a means to an end -- a visual aid to comprehension and analysis. They can, therefore, be adapted by the individual to suit his or her purpose. A certain recognizable uniformity is, however, desirable and the following conventions are generally observed:

- Combined symbols -- The simultaneous occurrence of two different activities is shown by the use of combined symbols. One symbol is superimposed upon the other. Where it is possible to distinguish the relative importance of the two, the outer symbol will represent the major activity.

This combination indicates that a minor operation is taking place simultaneously with a more important inspection. The number of the outer (more important) symbol is placed first, separated by a hyphen from the number of the other symbol.

- Introduction of materials -- Where a number of materials or subassemblies is involved, a chart may contain more than one vertical line of symbols. In all cases, the main line of the process is placed to the right of any other line, while materials and parts are introduced from the left. The introduction is made by a horizontal line with a brief description of the material. Numbering also proceeds first down the right-hand side and then in sequence toward the left (Fig. B1, B).
- Rejects and reprocessing -- Materials and components may be discarded during the process, either for destruction or reprocessing as rejects, or to enter another process not being charted. The exit of materials is indicated to the right of the line from which they are discarded (Fig. B1, C). If the material is returned to an earlier stage in the process for further treatment, the transfer can be

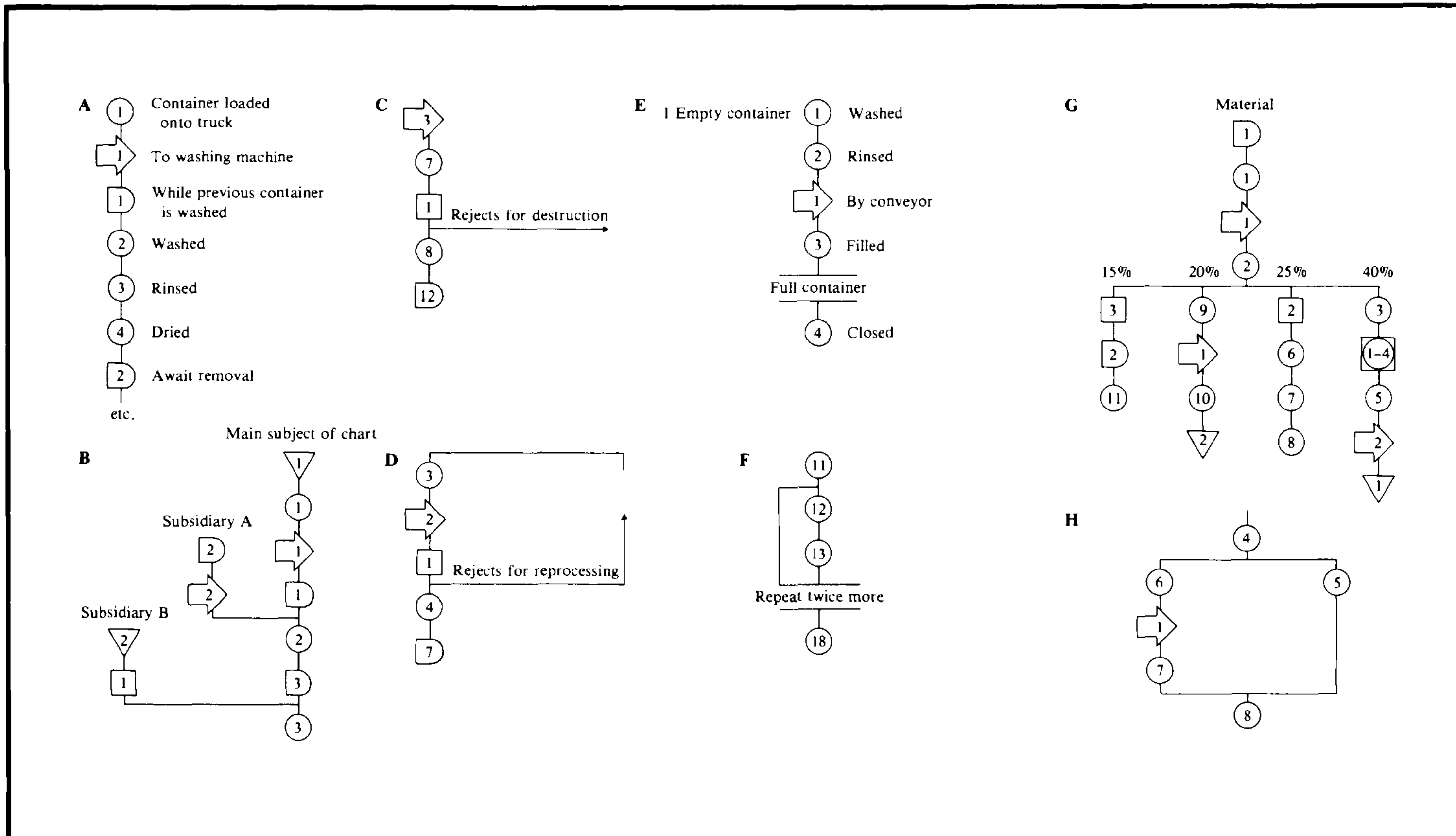


Fig. 81. Process chart conventions.

indicated by a line joining it to the earlier stage (Fig. B1, D).

- Change of state -- When the material charted undergoes a significant alteration as a result of some operation, so that its handling properties from that stage on are changed, this is indicated on the chart by identifying the initial condition, e.g., empty container, and the stage at which there is a change e.g., full container, by breaking the chart line and inserting the change within two parallel lines. Because a change of state is likely to occur after nearly every main operation, this convention is only used when it is thought desirable to draw attention to the change (Fig. B1, E).
- Repetition -- One or more activities may be repeated a number of times before the process continues. Here again, the chart line is broken at the appropriate point by two parallel lines. The upper line is joined to a bracket that encloses the activities repeated (Fig. B1, F).

This convention must only be applied to a sequence that is truly repetitive. Sometimes the first and last repetitions differ slightly from the others. In this case, these will be charted in the normal way and the convention will be applied only to the intervening identical repetitions. Special care must be taken to note the correct number of recurrences, so that the proper continuity of numbering is preserved.

- Alternative routes -- At certain stages, a process may diverge along alternative routes. For example, as a result of an operation, material may be divided into several portions each of which receives separate treatment. In such a case, the main trunk of the chart is divided into the appropriate number of branches, with the major flow on the right-hand side. Other flow lines are drawn successively to the left in order of importance (Fig. B1, G).

When materials may proceed along alternative routes for a while before resuming the same path, the chart can be split into two or more paths. This convention can also be used to record activities of different parts of the same material, where they are subdivided (Fig. B1, H).

- Adding further data -- Any quantitative data can be added to the chart. When process, waiting, and other times or costs are known, for example, they are sometimes entered alongside the chart, to the left of the appropriate symbol. Distances also can be entered to the left of the appropriate transport symbol.

Bar Charts

To translate the flowchart shown in Fig. B2 into a bar chart, the times shown against each operation must be transferred onto a time scale and recorded in sequence as shown in Fig. B2. It is assumed, for this example, that once a batch is started it must continue through the four operations without waiting (Fig. B3).

Clearly, the bottleneck operation is packaging and shipping. It is this operation that determines that the production cycle time is 8 hours. If a process improvement is suggested that will reduce the time for this operation to 6 hours the chart will now look like Fig. B4. This chart shows that all the benefit from reducing the time for operation four by 2 hours has not been achieved. The bottleneck operation is now processing and cooking, and the packaging machine now is idle for 1 hour in each cycle of 7 hours. It is important to realize that each operation cannot be looked at in isolation, particularly when assessing the cost-benefit of any proposed improvement.

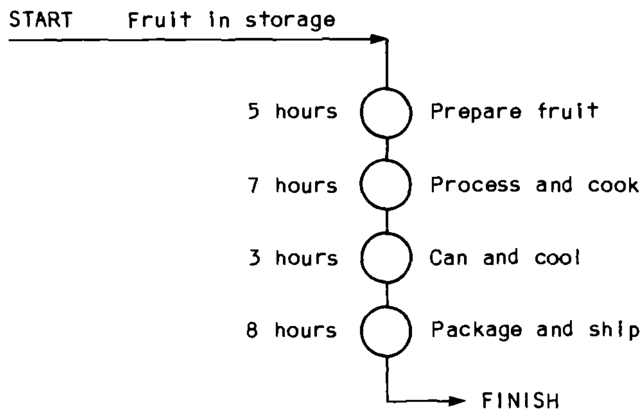


Fig. B2. A sample OPC chart before translation into a bar chart.

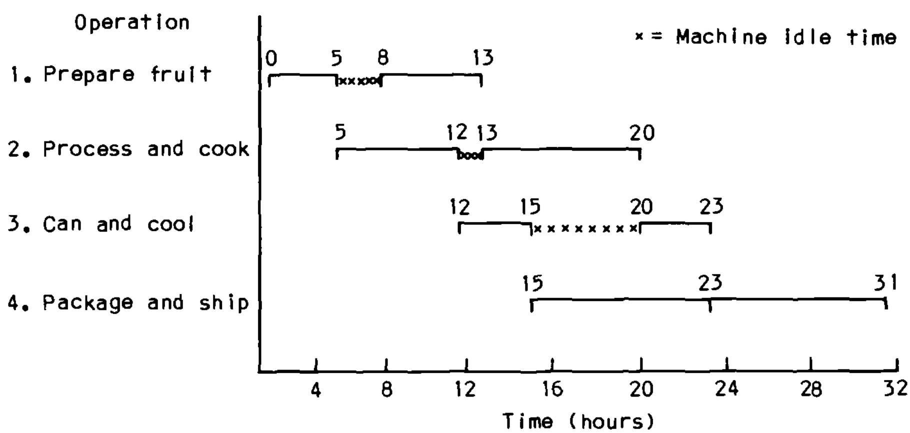


Fig. B3. Bar chart showing the bottleneck as "package and ship."

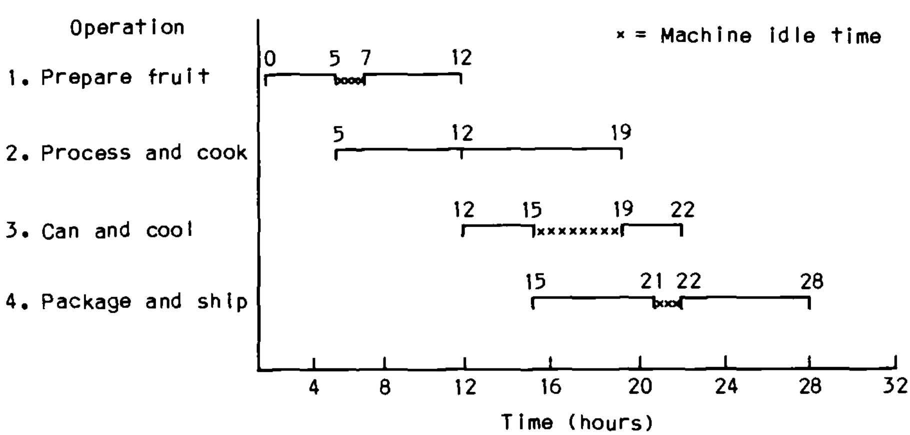


Fig. B4. Process improvement made at the "package and ship" stage.

WORK SAMPLING STUDY

Work sampling is a simple, easily learned and applied technique, based on sound mathematical principles, that shows how working time is utilized as an aid to identifying opportunities for improvement. Any technique used to study work should be carefully planned to obtain maximum effectiveness. It is most essential to plan carefully all preliminary and follow-up stages as well as the main study itself. The following ground rules will assist in establishing the sequence to be followed:

- The first step is to select the job to be studied. If this is the first study there will be no difficulty deciding which are the major cost areas of the whole operation (production, warehousing, clerical, etc.).
- When this has been done and an area for study selected, set down the "purpose" of the study (i.e., the reason for carrying out study). Next the "scope" or "terms of reference" of the study should be clearly defined (i.e., where does it start and stop). Make sure management agrees with the objectives laid down in the purpose and the range of work to be covered as defined in the scope. This study definition must be settled initially to ensure no misunderstandings develop as to the nature and range of work contemplated.
- Determine the elements of work that make up the daily activity in the area where the work sampling study is to be carried out. The study requirements may be such that only the percentage of time spent "working" and "not working" provides sufficient information upon which action may be taken. This is, obviously, the simplest form of work sampling study. However, to determine what is occurring when "not working" is observed, this heading may be broken down into smaller categories (e.g. "waiting for work," "absent from workplace," "answering telephone," etc.). The observer carrying out the study should be able to recognize these categories easily so they must be specific and clearly defined. A simple method that can be used to accomplish this breakdown is illustrated in Fig. B5. In the figure, work classifications, or activities, A-J can be used as headings and under which all observations in a work sampling study, in a bakery in this example, can be recorded. Similar headings as used in Fig. B5 would probably be used for other types of food processing plants. A preliminary survey will also be necessary during this stage.
- Decide the number of trips by the observer that can be most economically carried out during a normal working day and that will produce the desired number of observations for the accuracy required within the period of time allocated for the study. The decision concerning the number of trips to be made will be a direct function of the following major points of consideration: the area being covered in each trip, the number of personnel available to make observations, the number of observations to be made each trip, the range of accuracy to be produced by the study, the time during which the subject of the study will be available, and the economic limitations imposed by the purpose of the study.
- All observations made during the course of a work sampling study must be made at random intervals. Any observations that are carried out in a fixed cycle or time pattern (e.g., observations spaced 30 min apart throughout the day) will defeat the whole principle of the study that, as stated earlier, is based on statistical concepts. The observer will always be expected by the operators if a fixed pattern of time is followed and they will react accordingly.

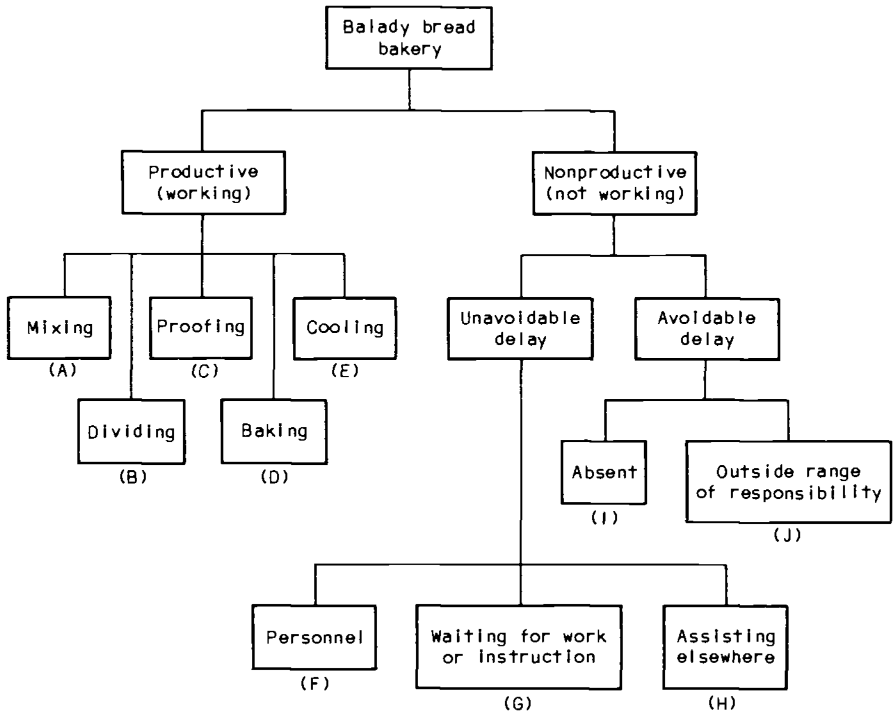


Fig. B5. Example of a "tree" breakdown in a work sampling study of a small-scale "balady" bread bakery in Egypt.

Machines are also likely to be in a specific stage of their cycle of operation. The best method of determining the time intervals between observations can be effected using a random numbers table by converting random numbers into random times for a work sampling study. When using this method, the random numbers series should always be one more than the number of trips intended (i.e., if 10 work sampling trips are desired there should be 11 sets of random numbers chosen to determine the times for the trips). If the quantity of random numbers chosen is identical with the number of trips to be made then the final trip will always occur on the last minute of the working day. This is undesirable for both statistical and obvious practical reasons.

• Design the necessary forms that will be used during the study. These should be simple, clear, easy to read and use. There should be ample space available for special comments, remarks, etc., as well as for recording observations. The three basic forms used in a work sampling study are: the observation sheet, which is used for recording observations made during the trips, i.e., which activities are being carried out at the time of the trip, and can be varied for specific purposes (Fig. B6); the summary sheet, which summarizes all daily results and should also be capable of enabling weekly results to be entered; and each category or work element observed during the

Sample no. 1 By: Time: 8:45 a.m.	Operator										Department Date: 3 July
Activity	1	2	3	4	5	6	7	8	9	10	Total
A		✓	✓								2
B	✓									✓	2
C							✓	✓			2
D				✓							1
E											0
F											0
G											0
H					✓						1
I						✓			✓		2
J											0
Total	1	1	1	1	1	1	1	1	1	1	10

Fig. B6. A sample style of observation sheet. A check is made in the appropriate square to indicate the activity observed for each operation. A separate sheet is needed for each trip.

course of the study, after being summarized daily, should have the results plotted on a "cumulative graph" (Fig. B7). This method of illustrating results can be of great value in determining the consistency of the data collected and deciding when sufficient samples have been taken.

- Select the person or persons who are going to carry out the work sampling study. Brief them thoroughly on the nature of the work being observed, the purpose of the study, and the limitations within which they are to operate. Make sure that they understand the importance of the randomness of their observations. The following few simple rules will assist the individual when making observations: (a) Select a spot from which the observations will be made before setting out on the trip. (b) Vary the location of this selected point of observation often, preferably each day and always before the trips are made. (c) Do not anticipate machine or operator activities when making observations. Record exactly what is happening at the instant of observation only, and nothing else. Do not slow down or hasten the approach to the selected point of observation to "catch" a particular activity or the randomness of the observation will be lost. (d) Vary

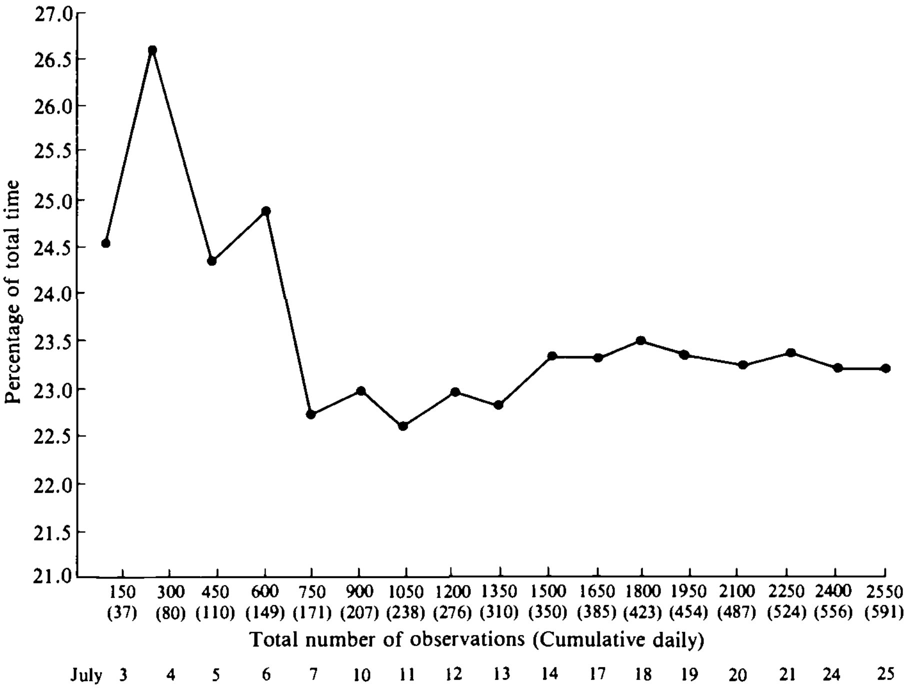


Fig. B7. Graphical summary (cumulative graph) for one activity (A). (Total observations for all activities = 150/day.)

the approach to the observation point to prevent a quickening or change of activity by the individual being observed. This will prevent bias in results. (e) Enter the area where observations are to be made using a different route each day or, if possible, each trip.

- Before the observations begin all personnel who are to be involved in the work sampling study should be informed of what is about to occur, introduced to the person who will be making the study, and told how it will be carried out. Most important, let everyone know why it is being done and how it will affect them. Too many people are prone to view any type of study as a "head hunting" technique. Employees who have been fully informed by an enlightened management will always cooperate in any work study that will aid the company's growth and hence ensure the security of their jobs.
- Make the observations following the principles outlined in the previous sections. The observation sheet should be securely mounted on a clipboard and the observer should endeavour to keep these sheets in good condition.
- At the end of each day summarize all the daily observations and enter results on the summary sheet and cumulative graph. This should not take more than 15-30 min/day. Discuss the results obtained to date and make any alteration in procedure or method as indicated. This daily "summing up" of activites is most important.
- At the completion of the work sampling study prepare and

present a report of the work done to management. This report should outline the purpose and scope of the work sampling study, a summary of conclusions, recommendations, and estimated savings arising from the recommendations. The body of the report should contain details of the method of implementation of the recommendations and all the necessary back-up data needed to verify the conclusions made.

• When management authorizes implementation of the recommendations arising from the study, close supervision of the changes involved should be maintained, preferably by the personnel who conducted the original study. After implementation, a regular check-up should be carried out every 3 months to ensure that changes installed are producing the savings anticipated. (An example of a work sampling study is provided in IDRC-MR56e.)

APPENDIX C

EXAMPLE OF A SCREENING EXPERIMENT

Problem Definition

A dried food manufacturer has been investigating a new formulation for a dried drink mix. The company now wishes to define the optimum processing conditions for the product that is to be dried on a double-roller drum dryer. The objective is to define the optimum processing conditions for roller drying the new drink mix.

Experimental Variables

The following response variables were considered important to the product: (a) moisture content of dried product, (b) viscosity of prepared drink, (c) sediment in prepared drink after a prespecified time, and (d) acceptability of the drink to consumers. Seven input variables were defined as being important to the process. Upper and lower limits for these variables are show in Table C1.

Table C1. Variables and limits for roller drying.

	Variable	Upper limit	Lower limit
A	Water/solids	2.0	1.5
B	Soak time[a]	75 min	30 min
C	Soak temperature	65°C	15°C
D	Steam pressure	350 kPa	230 kPa
E	Nip height[b]	4 cm	2 cm
F	Nip gap[c]	35 mm	20 mm
G	Drum speed	2.8 rpm	1.4 rpm

[a] Soak time = time of soaking dry mix prior to drying.
[b] Nip height = depth of slurry between rollers.
[c] Nip gap = distance between rollers at closest point.

Experimental Design

Plackett and Burman provide the following experimental plans for screening N-1 variables in N experiments. The first line of the matrix is provided and each row is generated by moving this first row one space to the left N-2 times and adding a final row of minus. The + indicates variables are set at the high and - at the low level.

N = 8 + + + - + - -
N = 12 + + - + + + - - - + -
N = 16 + + + + - + - + + - - + - - -
N = 20 + + - - + + + + - + - + - - - - + + -
N = 24 + + + + + - + - + + - - + + - - + - + - - - -

The experimental plan is selected for N higher than the number of variables in the problem. The leftover variables, termed dummy variables, are used to calculate the experimental error in determining significance of effects.

Seven variables were too many to consider in process experiments. A Plackett and Burman screening experiment was, therefore, planned to define the most important process variables. A 12-run experiment was planned with the seven process variables and four dummy variables to estimate experimental error (Table C2).

Table C2. Plackett and Burman design for roller drying.

Run no.	A	B	C	D	E	F	G	H	I	J	K
1	+	+	-	+	+	+	-	-	-	+	-
2	+	-	+	+	+	-	-	-	+	-	+
3	-	+	+	+	-	-	-	+	-	+	+
4	+	+	+	-	-	-	+	-	+	+	-
5	+	+	-	-	-	+	-	+	+	-	+
6	+	-	-	-	+	-	+	+	-	+	+
7	-	-	-	+	-	+	+	-	+	+	+
8	-	-	+	-	+	+	-	+	+	+	-
9	-	+	-	+	+	-	+	+	+	-	-
10	+	-	+	+	-	+	+	+	-	-	-
11	-	+	+	-	+	+	+	-	-	-	+
12	-	-	-	-	-	-	-	-	-	-	-

Note: Variables A-G are defined in Table C1. Variables H, I, J, and K represent dummy variables.

An attempt was made, as far as possible, to randomize the runs. It was, however, considered important to run all common nip gap runs consecutively to avoid error due to resetting of the rolls. The results of the experiment are shown in Table C3.

Calculation of Effects and Error

Effects of the variables A-G and the four dummies H-K were calculated as follows:

$$E_A = (\text{Total of all R at high level } (+))/6 - (\text{Total of all R at low level } (-))/6$$

where E_A = effect of A and R = response or result. Effects for the four response variables moisture, viscosity, sedimentation, and sensory score are shown in Tables C4 and C5. The dummy effects were combined to estimate the variance of an effect:

Table C3. Results of Plackett and Burman experiment.

Run no.	Moisture %	Viscosity cps	Sedimentation (%)[a]	Sensory score[b]
1	2.32	15.0	64	5.8
2	1.65	29.0	88	5.0
3	2.02	10.5	54	7.0
4	3.30	20.0	59	7.0
5	3.57	16.5	78	5.3
6	3.25	31.0	83	5.0
7	2.94	26.0	58	6.5
8	4.27	12.5	38	6.8
9	2.22	32.5	74	6.4
10	5.93	27.5	69	5.5
11	5.69	16.0	41	5.5
12	2.18	37.5	66	6.2

[a] Sedimentation % is defined as completeness of particle distribution (i.e., 100% = complete distribution).
[b] Sensory score is the average acceptable score on a 10-point scale (five people).

$$V_{eff} = \text{Total of all } (E_d)^2/n$$

where V_{eff} = variance of an effect, E_d = effect of dummy, and n = number of dummy variables. The standard error of an effect was calculated as: $S.E._{eff} = \sqrt{V_{eff}}$. The significance of each effect was determined by using the t-test: $t = \text{effect}/S.E._{eff}$. Tests of significance are shown in Tables C4 and C5.

A summary of the significant effects (>80%) shows that of the response variables, moisture is significantly affected by soak temperature, steam pressure, nip gap, and drum speed; viscosity by soak time, soak temperature, and nip gap; sediment by water/solids, soak temperature, and nip gap; and the sensory score by water/solids. The results indicate that specific variables are important in determining the level of different responses. With more than one response variable, the experimenter has to make choices between the important input variables for further study. Priorities were set on the four response variables in the following order: moisture, viscosity, sediment, and sensory score. The sensory score was ranked last because most of the drinks were acceptable and there were only minor differences in overall acceptability between samples. It was then decided to run a three-variable full factorial experiment to further optimize the process conditions. The important variables chosen were nip gap, soak time, and drum speed.

Soak temperature was set at ambient because it was considered too difficult to maintain high temperature soak conditions within the factory. There may also be problems with microbial spoilage. This step is contrary to that suggested by the experimental results that indicated an inverse relationship between the response variables viscosity and sediment and the soak temperature. If a satsifactory product

Table C4. Variables and effects -- moisture and viscosity.

Code	Moisture		Viscosity	
	Effect	t-test	Effect	t-test
A	0.117	0.24	0.667	0.17
B	-0.183	-0.38	-8.883	-2.18 (90)
C	1.063	2.22 (90)	-7.167	-1.77 (85)
D	-0.863	-1.80 (85)	1.167	0.29
E	-0.090	-0.19	-0.333	-0.08
F	1.687	3.52 (95)	-7.833	-1.93 (85)
G	1.220	2.55 (90)	5.333	1.32 (75)
H	0.530	1.11 (70)	-2.167	0.54
I	-0.573	1.19 (70)	-0.167	0.04
J	0.523	1.09	-7.333	-1.81 (85)
K	0.183	0.33	-2.667	-0.66

Note: Values within parentheses are percentages $\geq 70\%$.

Table C5. Variables and effects -- sediment and sensory score.

Code	Sediment		Sensory score	
	Effect	t-test	Effect	t-test
A	18.33	3.01 (95)	-0.800	-1.67 (80)
B	-5.33	0.88	0.333	0.69
C	-12.33	-2.03 (85)	0.267	0.56
D	7.00	1.15 (70)	0.067	0.14
E	0.67	0.11	-0.500	-1.04
F	-12.67	-2.08 (85)	-0.200	-0.42
G	-0.67	-0.11	-0.033	-0.07
H	3.33	0.55	0	0
I	3.00	0.49	0.333	0.69
J	-10.00	-1.65 (80)	0.700	1.46 (75)
K	-5.33	-0.88	-0.567	-1.18 (70)

Note: Values within parentheses are percentages $\geq 70\%$.

cannot be obtained at ambient temperature soaking then consideration of higher temperature soaking will be made at a later stage.

Water/solids ratio was set at the high level as suggested by the high positive relationship between the water/solids ratio and sedimentation, i.e., a better dispersion was obtained as a result of a high water/solids ratio feed to the roller dryer.

Steam pressure was the fourth variable in order of importance to affect moisture. Because this was the only response variable that it affected, it was decided to set steam pressure at the low level, consistent with giving a high moisture content, which is desirable for the product.

In conclusion, the Plackett and Burman screening experiment indicated that six out of the seven original process variables had some effect on one or more of the response variables. The results of the experiment were used to select three out of these six process variables for further experimental evaluation and to set the levels of the remaining three variables for that experiment.

EXAMPLE OF A FACTORIAL EXPERIMENT

A laboratory dehulling machine fitted with eight abrasive discs, each 25 cm in diameter, driven by a variable speed electric motor was to be evaluated for performance in dehulling cowpeas in Thailand. Dehulling takes place through the abrasive action of the rotating discs on the seed coat. It should be noted that the discs are not selective for the seed coat only and there is considerable cotyledon loss during prolonged processing. Flour was produced from the dehulled cowpeas using a small pin mill with a screen containing holes of 0.035 inches in diameter.

Experimental Design

Evaluation of the characteristics of the dehuller was carried out using a full factorial experimental design with three variables at two levels:

Variable	Lower level	Upper level
Time (min)	2	10
Batch size (kg)	1.5	2.5
Speed (rpm)	600	1400

When the dehuller was loaded with cowpeas there was some reduction in rotational speed. This reduction was dependent on the weight of the load. The rotational speeds used in the experiment were those under load, not free run.

The complete experimental design was derived from the standard format in Table C6 as shown in Table C7. After each run the response variables were obtained as follows:

- The percentage yield was measured as the weight of cowpeas retained on a 1/8 inch screen expressed as a percentage of the initial weight before dehulling.
- Flour was prepared from batches of dehulled beans from each of the eight experimental runs and the absorbance (on a spectrophotometer) of the flour pastes was measured. The percentage hull remaining in each sample was read from a standard curve derived earlier that

Table C6. Factorial design for a three-factor, two-level experiment.[a]

Experiment	Treatment code	Variable A	Variable B	Variable C
1	1	Low (-)	Low (-)	Low (-)
2	a	High (+)	Low (-)	Low (-)
3	b	Low (-)	High (+)	Low (-)
4	ab	High (+)	High (+)	Low (-)
5	c	Low (-)	Low (-)	High (+)
6	ac	High (+)	Low (-)	High (+)
7	bc	Low (-)	High (+)	High (+)
8	abc	High (+)	High (+)	High (+)

[a] The treatment codes shown are commonly used in experimental design. The presence of a lower case letter in the treatment code indicates that the corresponding variable is at the high level for that run while all others are at the low level. For example, in run 2 the treatment code is a indicating that variable A is at the high level and the other two variables are at the low level.

Table C7. The factorial experimental design.

Run	Time (min)	Batch (kg)	Speed (rpm)
1	2	1.5	600
a	10	1.5	600
b	2	2.5	600
ab	10	2.5	600
c	2	1.5	1400
ac	10	1.5	1400
bc	2	2.5	1400
abc	10	2.5	1400

related absorbance to percentage hull in flour.

• Previous studies showed that the seed coat of the particular cowpea variety under study is about 14% of the total seed weight. The expected yield, given no cotyledon loss, was calculated as: expected yield (Ey) = 100 - 14 x H where H is the fraction of hull removed. The percentage loss of cotyledon was then calculated as: (Ey - Ay)/Ey, where Ay is the actual recorded yield.

The results from the experiment are shown in Table C8. The results for percentage yield, percentage hull remaining, and percentage cotyledon lost were analyzed by Yates' analysis. Yates' method applied to a two-factor experiment is as follows: Write down the treatments (1) a, b, ab in column form as shown in Table C9. Alongside these put the actual responses obtained for each treatment. Then proceed to carry out a simple mathematical exercise by adding the first two figures in the second column and placing them at the top of the third column. Then add the next two figures and place them beneath the first figure in the third column. Then subtract the top result in the second column from the second result in the second column and place the answer in the third place in the third column, and finally, subtract the third result in the second column from the last result and put the answer at the end of the third column. This process is repeated for a further column. The effects of each treatment code are calculated by dividing the fourth column by four. This gives the β_i values that can be used in predictive equations as coefficients of the input variables.

Table C8. Results of the full factorial experiment.

Run	Percentage yield	Percentage hull remaining	Percentage cotyledon lost
1	95.8	82	2
a	81.9	41	11
b	97.9	81	0
ab	85.1	48	8
c	83.5	35	8
ac	62.7	14	29
bc	89.1	52	5
abc	61.9	7	29

Table C9. An example of Yates' analysis.

Treatment code	Result	Column 3	Column 4	Effect (β_i)
(1)	1	1+4 = 5	5+7 = 12	3.0
a	4	2+5 = 7	3+3 = 6	1.5
b	2	4-1 = 3	7-5 = 2	0.5
ab	5	5-2 = 3	3-3 = 0	0.0

The significance of these effects should be tested by relating their levels to the experimental error. The experimental error will normally be calculated from repeat runs of the same treatment. The standard error can then be calculated from the variance in results.

Discussion of Results

Results indicate that all three variables -- percentage hull remaining, percentage cotyledon lost, and percentage yield are all affected adversely by increases in process time and disc speed. Batch size had no effect within the range tested (Tables C10-12).

Table C10. Yates' analysis for percentage hull remaining.

Percentage hull		Column 1	Column 2	Column 3	Mean effect	t = effect/ 0.69
1	82	123	252	360	45.0	65.2
a	41	129	108	-140	-17.5	-25.4[a]
b	81	49	-74	16	2.0	2.9
ab	48	59	-66	-16	-2.0	-2.9
c	35	-41	6	-144	-18.0	-26.1[a]
ac	14	-33	10	8	1.0	1.5
bc	52	-21	8	4	0.5	0.72
abc	7	-45	-24	-32	-4.0	-5.8

[a] Significant at 99.9% level.

Note: Standard error of repeat runs = 0.69, α 0.01 = 4.54. Only the two main effects time and speed are significant at the 99.9% level. The predictive equation is: $Y = 45.0 - 17.5X_1 - 18.0X_3$, where X_1 = time and X_3 = speed (coded units). The uncoded predictive equation is: Percentage hull = $116.3 - 4.4X_1 - 0.045X_3$.

Table C11. Yates' analysis for percentage yield.

Percentage yield		Column 1	Column 2	Column 3	Mean effect	t = effect/ 0.55
1	95.8	177.7	360.7	657.9	82.2	149.5
a	81.9	183.0	297.2	-74.7	-9.3	-17.0[a]
b	97.9	146.2	-26.7	10.1	1.3	2.3
ab	85.1	151.0	-48.0	-5.3	-0.66	-1.2
c	83.5	-13.9	5.3	-63.5	-7.9	-14.4[a]
ac	62.7	-12.8	4.8	-21.3	-2.7	-4.9[a]
bc	89.1	-20.8	1.1	-0.5	-0.06	-0.11
abc	61.9	-27.2	-6.4	-7.5	-0.47	-0.85

[a] Significant at 99.9% level.

Note: Standard error of repeat runs = 0.55. The predictive equation is: $Y = 82.2 - 9.3X_1 - 7.9X_3 - 2.7X_1X_3$, where X_1 = time and X_3 = speed (coded units). The uncoded equation is: Percentage yield = $107.1 - 0.83X_1 - 0.0108X_3 - 0.0015X_1X_3$.

Table C12. Yates' analysis for percentage endosperm in waste fraction.

Percentage endosperm		Column 1	Column 2	Column 3	Mean effect	t = effect/ 0.55
1	2	13	21	92	11.5	20.9
a	11	8	71	62	7.8	14.1[a]
b	0	37	17	-8	-1.0	-1.8
ab	8	34	45	2	0.25	0.45
c	8	9	-5	50	6.3	11.4[a]
ac	29	8	-3	28	3.5	6.4[a]
bc	5	21	-1	2	0.25	0.45
abc	9	24	3	4	0.5	0.91

[a] Significant at 99.9% level.

Note: Standard error of repeat runs = 0.55. The predictive equation is: $Y = 11.5 + 7.8X_1 + 6.3X_3 + 3.5X_1X_3$, where X_1 = time and X_3 = speed (coded units). The uncoded equation is: percentage endosperm lost = $-2.63 - 0.25X_1 + 0.0019X_3 + 0.0022X_1X_3$.

It is expected, however, that at very high batch sizes, for example, 5 kg, there will be a reduction in processing efficiency due to the limiting of movement of the seeds and, therefore, the reduction in time that each seed is in contact with the abrasive discs.

Cooking trials indicated that flour with a hull content of 30% remaining was acceptable. The processing trials indicated that there is no real advantage in using slower speeds to improve the quality of the dehulled seed. There is, however, an advantage in reducing the time required for processing by using higher speeds. Also at higher speeds there is a reduction in the cotyledon loss. Table C13 shows the predicted time required using the predictive equations (derived from the analysis of results) to achieve a 70% removal of hull (i.e., 30% hull remaining) at speeds used in the experiment.

Table C13. Predicted cotyledon loss at various speeds.

Speed (rpm)	Time (min)	Batch size (kg)	Percentage hull remaining	Percentage cotyledon loss
1400	5	2.5	30	14.2
1500	4	2.5	30	12.4
1600	3	2.5	30	10.2
1700	2	2.5	30	7.6

Although there are definite advantages in reducing the processing time, it is suggested that this should not be too low. At very low processing times the recording of this time will become extremely critical and any small extension over the required time will result in a significant increase in cotyledon loss.

It is, therefore, recommended that for the cowpea variety tested a speed of 1600 rpm be used for 3 min for 2.5 kg batches. Under these conditions 70% of the hull should be removed with a loss of about 10% of the cotyledon.

EXAMPLE OF AN EVOP STUDY

A small company manufactures a canned fish product that requires bleaching as one processing stage. The company has had a number of complaints on the colour of its product, which tends toward a light brown. The marketplace requires a cream-coloured product. Although management realizes a need to improve the colour of the product it does not wish to stop production while laboratory trials are carried out. EVOP was chosen as an in-process experimentation procedure to evaluate the effect of process conditions on product colour.

EVOP Procedure

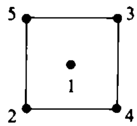
Colour of the product is graded on a 10-point scale ranging from 1 (dark brown) to 10 (light cream). Two variables that were considered to have greatest effect on product colour were sulphite concentration in the bleaching liquor and time for bleaching. Previous experience of the management led to the definition of the conditions for the first cycle of an EVOP as noted in Table C14.

Each of the five conditions was carried out during normal production runs at the factory. The average product colour was determined for each operating condition by taking a sample of 10 kg of

Table C14. Definition of the conditions for the first cycle of an EVOP trial.

Operating condition	Sulphite (ppm)	Time (min)
1	200	60[a]
2	150	50
3	250	70
4	150	70
5	250	50

[a] Existing conditions.



Cycle n = 1

Response — Colour

Calculation of averages						Calculation of "S"
Operating conditions	(1)	(2)	(3)	(4)	(5)	
(a) Previous cycle sum						Previous sum S =
(b) Previous cycle average						Previous average S =
(c) New observations	***6***	***7***	***3***	***8***	***9***	New S = R x $f_{k,n}$*
						=
						=
(d) Differences (b) — (c)						Range =
(e) New sums	***6***	***7***	***3***	***8***	***9***	New sum S =
(f) New averages	***6***	***7***	***3***	***8***	***9***	New average S =

Calculation of effects

Time effect = $\frac{1}{2}(\bar{y}_3 + \bar{y}_4 - \bar{y}_2 - \bar{y}_5)$ =
= ½ (***3*** + ***8*** - ***7*** - ***9***) = ***-2.5***

Sulphite effect = $\frac{1}{2}(\bar{y}_3 + \bar{y}_5 - \bar{y}_2 - \bar{y}_4)$ =
½ (***3*** + ***9*** - ***7*** - ***8***) = ***-1.5***

t x s effect = $\frac{1}{2}(\bar{y}_1 + \bar{y}_3 - \bar{y}_4 - \bar{y}_5)$ =
½ (***6*** + ***3*** - ***8*** - ***9***) = ***-4.0***

Change of mean = $\frac{1}{5}(\bar{y}_2 + \bar{y}_3 + \bar{y}_4 + \bar{y}_5 - 4\bar{y}_1)$ =
⅕ (***7*** + ***3*** + ***8*** + ***9*** - (***4 x 6***)) = ***0.6***

Calculation of error limit

New average = $2\sigma/\sqrt{n}$ =
= ***2 x 1.5/√1*** = ***±3.0***

New effects = $2\sigma/\sqrt{n}$ = ***±3.0***

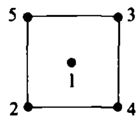
Change in mean = $1.78\sigma/\sqrt{n}$ =
1.78 x 1.5/√1 = ***2.7***

Prior estimate of σ (from previous colour grading experience) = ***1.5***

Remarks: None of effects exceed effects limits, change of mean does not exceed mean limits, and not enough data in the first run. Repeat.

*$f_{k,n}$, found in standard tables for each value of range and number of values in range.

Fig. C1. Sample of the EVOP worksheet for cycle n = 1, 2, and 3 colour response (values in bold face italics are those measured or calculated during the trials).



Cycle n = 2

Response — Colour

Calculation of averages						Calculation of "S"
Operating conditions	(1)	(2)	(3)	(4)	(5)	
(a) Previous cycle sum	6	7	3	8	9	Previous sum S =
(b) Previous cycle average	6	7	3	8	9	Previous average S =
(c) New observations	4	7	5	7	8	New S = R x $f_{k,n}$ = 4 x 0.3 = 1.2
(d) Differences (b) — (c)	2	0	-2	1	1	Range = 2 - (-2) = 4
(e) New sums (a) + (c)	10	14	8	15	17	New sum S = 1.2
(f) New averages -(9) $\bar{y}$ = (e)/n	5	7	4	7.5	8.5	New average S = 1.2

Calculation of effects

Time effect = $\frac{1}{2}(\bar{y}_3 + \bar{y}_4 - \bar{y}_2 - \bar{y}_5)$ =
= $\frac{1}{2}(4 + 7.5 - 7 - 8.5) = -2.0$

Sulphite effect = $\frac{1}{2}(\bar{y}_3 + \bar{y}_5 - \bar{y}_2 - \bar{y}_4)$ =
= $\frac{1}{2}(4 + 8.5 - 7 - 7.5) = -1.0$

t x s effect = $\frac{1}{2}(\bar{y}_1 + \bar{y}_3 - \bar{y}_4 - \bar{y}_5)$ =
= $\frac{1}{2}(5 + 4 - 7.5 - 8.5) = -3.5$

Change of mean = $\frac{1}{5}(\bar{y}_2 + \bar{y}_3 + \bar{y}_4 + \bar{y}_5 - 4\bar{y}_1)$ =
$\frac{1}{5}(7 + 4 + 7.5 + 8.5 - (4 \times 5)) = 1.4$

Calculation of error limit

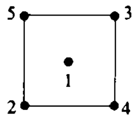
New average = $2\sigma/\sqrt{n}$ =
= $2 \times 1.2/\sqrt{2} = \pm 1.7$

New effects = $2\sigma/\sqrt{n} = \pm 1.7$

Change in mean = $1.78\sigma/\sqrt{n} = \pm 1.5$

Remarks: Time effect exceeds effects limits; change of mean does not exceed mean limits, therefore, time having effect, but need another run; and conditions (4) and (5), are higher than (1) by greater than 2 x S = 2.4. Repeat to check.

Fig. C1. Cont'd



Cycle n = 3

Response — Colour

Calculation of averages						Calculation of "S"
Operating conditions	(1)	(2)	(3)	(4)	(5)	
(a) Previous cycle sum	**10**	**14**	**8**	**15**	**17**	Previous sum S = **1.2**
(b) Previous cycle average	**5**	**7**	**4**	**7.5**	**8.5**	Previous average S = **1.2**
(c) New observations	**7**	**7**	**3**	**6**	**8**	New S = R x $f_{k,n}$ = **1.23**
(d) Differences (b) — (c)	**-2**	**0**	**1**	**1.5**	**0.5**	Range = **3.5**
(e) New sums (a) + (c)	**17**	**21**	**11**	**21**	**25**	New sum S = **1.2** + **1.23** = **2.43**
(f) New averages $\bar{y}$ = **(e)/n**	**5.7**	**7.0**	**3.7**	**7.0**	**8.3**	New average S = **1.22**

Calculation of effects

Time effect = $\frac{1}{2}(\bar{y}_3 + \bar{y}_4 - \bar{y}_2 - \bar{y}_5)$ = $\frac{1}{2}$ **(3.7 + 7 - 7 - 8.3) = -2.3**

Sulphite effect = $\frac{1}{2}(\bar{y}_3 + \bar{y}_5 - \bar{y}_2 - \bar{y}_4)$ = $\frac{1}{2}$ **(3.7 + 8.3 - 7.0 - 7.0) = -1.0**

t x s effect = $\frac{1}{2}(\bar{y}_1 + \bar{y}_3 - \bar{y}_4 - \bar{y}_5)$ = $\frac{1}{2}$ **(5.7 + 3.7 - 7 - 8.3) = -2.9**

Change of mean = $\frac{1}{5}(\bar{y}_2 + \bar{y}_3 + \bar{y}_4 + \bar{y}_5 - 4\bar{y}_1)$ = $\frac{1}{5}$ **(7 + 3.7 + 7 + 8.3 - (4 x 5.7)) = 0.64**

Calculation of error limit

New average = $2\sigma/\sqrt{n}$ = **2 x 1.22/√3 = ± 1.41**

New effects = $2\sigma/\sqrt{n}$ = **± 1.41**

Change in mean = $1.78\sigma/\sqrt{n}$ = **± 1.25**

Remarks: Time effect exceeds error limits and treatment (5) has a higher score than (1) by more than 2 x S = 2.44, therefore, we have an improved condition, so processing conditions at number (5) give improved colour of product.

Fig. C1. Cont'd

product and colour grading on the 10-point scale. The weight of the product in each colour grade category was reported and a weighted average colour calculated as follows: Average colour = weight of sample in colour category X1 + weight of sample in colour category X2 +.../number of samples

or in mathematical expression: $$\text{Average colour} = \sum_{i=1}^{10} w_i x_i / 10$$

where x_i = colour score (1, dark to 10, light), and w_i= weight graded in category i; i.e., $w_i x_i$ = weight of sample in each category x colour grade category score.

The average colour gradings were recorded on the EVOP worksheet (Fig. C1) and the appropriate calculations made as shown for cycle n - 1. This cycle of five operating conditions was repeated three times. The resultant colour gradings and calculations are shown on the worksheets (Fig. C1).

After three cycles enough information is available from the top part of the figures to select an improved set of operating conditions; at 250 ppm of sulphite for 50 min the average colour after three cycles had an 8.3 grading, but at the existing condition of 200 ppm for 60 min the grading was only 5.7. The difference between the two operating conditions is 2.6 colour units. The average standard deviation after three cycles is 1.22. The colour score difference divided by the average standard deviation is 2.13, which shows a significant improvement. The bottom part of the worksheets is to isolate significant effects. This information may be omitted if not essential. It is clear that reduction in time should result in improved colour over the existing process.

It was suggested as a result of the first three-cycle EVOP experiment that a further EVOP round be carried out with 250 ppm sulphite for 50 min being the new centre point. The conditions decided in consultation with management for the five trials are shown in Table C15.

The second round of EVOP did not result in a significant improvement in colour and 250 ppm of sulphite for 50 min was maintained as

Table C15. Final conditions for the EVOP trials.

Operating condition	Sulphite (ppm)	Time (min)
1	250	50
2	200	40
3	300	60
4	200	60
5	300	40

the ongoing process conditions. The company continued to carry out similar on-line process experiments because of the direct product improvements that resulted and because of the interest created both at the factory operator and at the management level.

EXAMPLE OF A MIXTURE EXPERIMENT

Problem definition -- A new puffed snack food similar to the traditional fish cracker keropok but using a high percentage of tapioca is to be designed for the Malaysian market. Preliminary formulation trials indicate that the snack food should contain soy flour, tapioca flour, fish, water, monosodium glutamate (MSG), salt, and phosphate. A high-protein snack food with a high level of consumer acceptance is required.

Aim of experimental formulation -- To select a combination of ingredients and define their respective levels to produce an acceptable, high-protein snack food.

Mixture design -- This experiment was planned to optimize the protein level without lowering the acceptability of the puff. Salt content, phosphate, MSG, and water were held constant, whereas the tapioca, fish, and soy content were the components subjected to the study. The requirements were: tapioca (T), 50-80%; fish (F), 5-10%; and soy (S) 20-45% (expressed in the percentage of mix T + F + S). Figure C2 shows the complete space available for the mixture design. The limits on the three ingredients, T, F, and S, restrict the area of experimentation to the feasible region.

Batches of the puffed snack were prepared from mixtures of T + S + F = 200 g as follows: 150 T + 40 S + 10 F, 140 T + 40 S + 20 F, 100 T + 80 S + 20 F, 100 T + 90 S + 10 F, and 124 T + 62 S + 14 F with each batch including 143 mL water, 3.2 g MSG, 6.3 g salt, and 1.5 g phosphate. A panel of 12 Malaysians were asked to rank the five snack foods in order of preference giving a rank of one to the best and five to the worst. Total ranks from the 12 respondents were: A = 29, coded as high T, low S, and low F; B = 31, high T, low S, high F; C = 30, low T, high S, high F; D = 45, low T, high S, low F; and E = 45 as the median.

Study of effects -- The effects of each of the three ingredients were evaluated by comparing the total ranks at the high and low levels of each ingredient: the high tapioca score was 29 + 31 = 60 and the low score was 30 + 45 = 75; therefore, a high amount of tapioca was preferred (positive effect); the high soy score was 30 + 45 = 75 and the low score was 29 + 31 = 60; therefore, a lower amount of soy was preferred (negative effect); and the high fish score was 30 + 31 = 61 and the low score was 29 + 45 = 74; therefore, a high amount of fish was preferred (positive effect).

This simple analysis shows that an excess of the beany or nutty flavour resulting from high soy levels was not well accepted. A high proportion of soy is required, however, to give a high protein content in the snack food. Formulas A, B, and C gave similar acceptability ranks, indicating an interaction between the fish and soy tastes. Increasing the proportion of fish tends to offset the soy flavour.

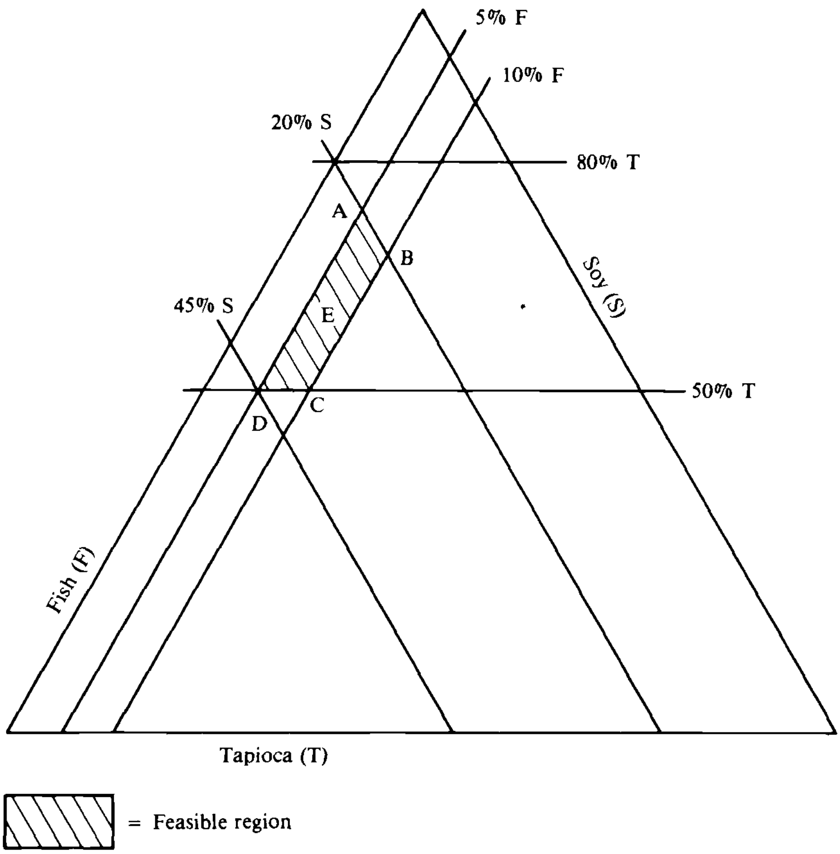


Fig. C2. Complete mixture space showing feasible area for experimentation (where A = 75T, 20S, 5F; B = 70T, 20S, 10F; C = 50T, 40S, 10F; D = 50T, 45S, 5F; and E = 62T, 31S, 7F, at the centre point).

New area for experimentation -- The new area in the mixture space (Fig. C3) was selected to preserve a high level of soy and to increase the level of fish. The full recipes of T + S + F = 200 g were as follows: 100 T + 30 F + 70 S, 110 T + 30 F + 60 S, 100 T + 40 F + 60 S, and 120 T + 20 F + 60 S with each recipe, including 143 mL water, 3.2 g MSG, 6.3 g salt, and 1.5 g phosphate.

A panel of 17 Malaysians ranked the four products in order of preference. The total ranks were: F = 48, G = 27, H = 32, and I = 33. Mixture G gave the most preferred product. This mixture was chosen for further pilot plant and process development. The recalculated formulation was: 32.0% tapioca flour, 8.4% fish, 16.9% soy flour, 40.3% water, 1.0% MSG, 1.8% salt, and 0.6% phosphate. This mixture fulfilled the aim of the experimental formulation. It used a

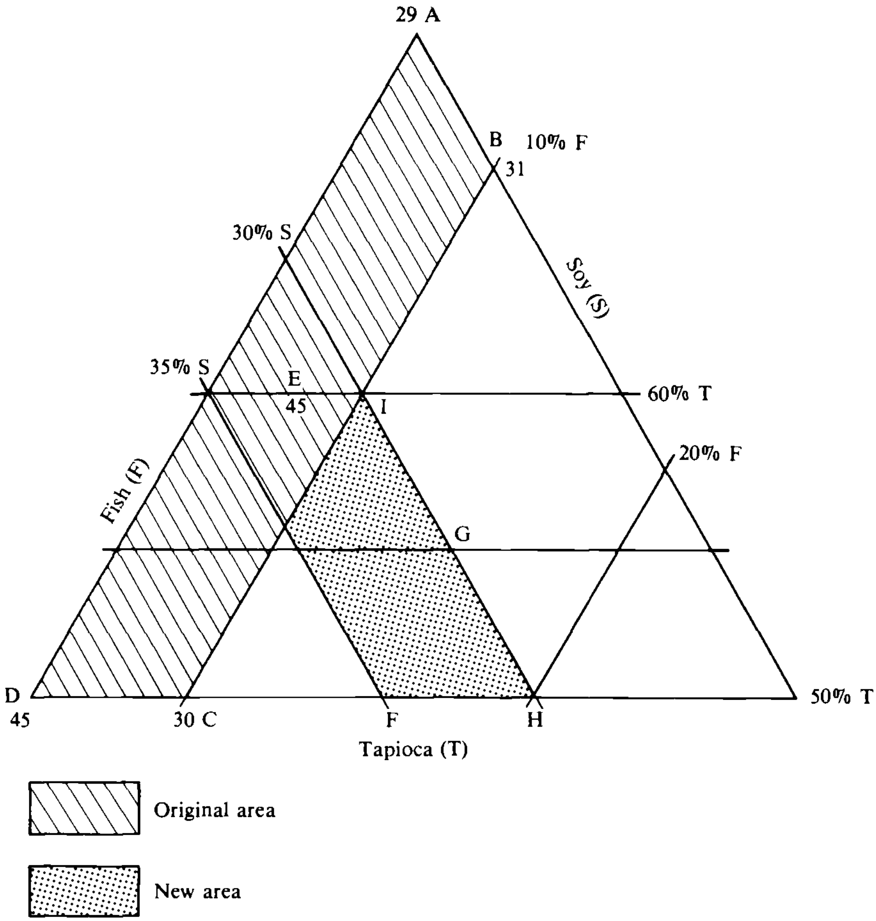


Fig. C3. Mixture space showing original (ABCDE) and new areas of experiment (FGHI) where F = 50T + 15F + 35S, G = 55T + 15F + 30S, H = 50T + 20F + 30S, and I = 60T + 10F + 30S (extracted from Fig. C2).

large amount of tapioca, was high in protein, and was acceptable to the consumer.

EXAMPLE OF A LINEAR PROGRAMMING INVESTIGATION

A small company has to decide upon a mixture of ingredients for a dry mix. The ingredients have the composition and costs that are set out in Table C16. The goal is the cheapest blend of those ingredients that complies with certain nutritional standards. The standards are set out in the footnote to the table.

Table C16. Composition and costs of the ingredients in a dry mix.

Ingredients (%)	Bean flour	Cereal flour	Root flour
Protein	50	50	0
Fat	25	10	0
Carbohydrate	15	0	90
Indigestible fibre and ash	10	40	10
Cost ($/t)	60	50	40

Note: In the blend, protein must be not less than 25%, fat must be not less than 10%, and indigestible matter must not exceed 20%.

Let b, c, and d represent the proportions in which the bean, cereal, and root flours are present in the blend. If we settle the values of two of these (b and c) the third one is fixed automatically because the three ingredients together make up the whole mixture, so $b + c + d = 1$ or $d = 1 - b - c$.

The cost of 1 t of the blend is itself a blend of the costs of the ingredients in the proportions b, c, and d. If we call the cost Q, then $Q = 60b + 50c + 40d$ or $Q = 20b + 10c + 40$ by substituting for d. What is required is to choose b and c, each of them a positive fraction, so as to make the cost per tonne Q, as low as possible. However, the choice is not an entirely free one: it is constrained, first by the standards imposed (Table C16) and second because d cannot be less than zero, so we can express this as: $b + c \leq 1$.

The next condition arises from the specification of protein content. The amount of protein in 1 t of the blend will be 50% of b tonnes from the bean flour, 50% of c tonnes from the cereal, and none from the root flour. This total amount of protein must be not less than 25% of 1 t, so $50b + 50c \geq 25$, or $b + c \geq 1/2$. Similarly, the specification of fat content implies $25b + 10c \geq 10$, or $5/2\ b + c \geq 1$. The requirement with regard to indigestible fibre and ash is a little more awkward to express in terms of b and c. In terms of b, c, and d it is straightforward: $10b + 40c + 10d \leq 20$. Substituting for d we obtain $30c \leq 10$ or $c \leq 1/3$.

The axes of the chart in Fig. C4 are scales for b and c. Any point on the chart thus corresponds to a pair of values (b, c). For some points the constraints will be satisfied while for others they will not. The lines corresponding to each constraint ($b + c = 1$, $b + c = 1/2$, $5/2\ b + c = 1$, $c = 1/3$) have been drawn on the graph.

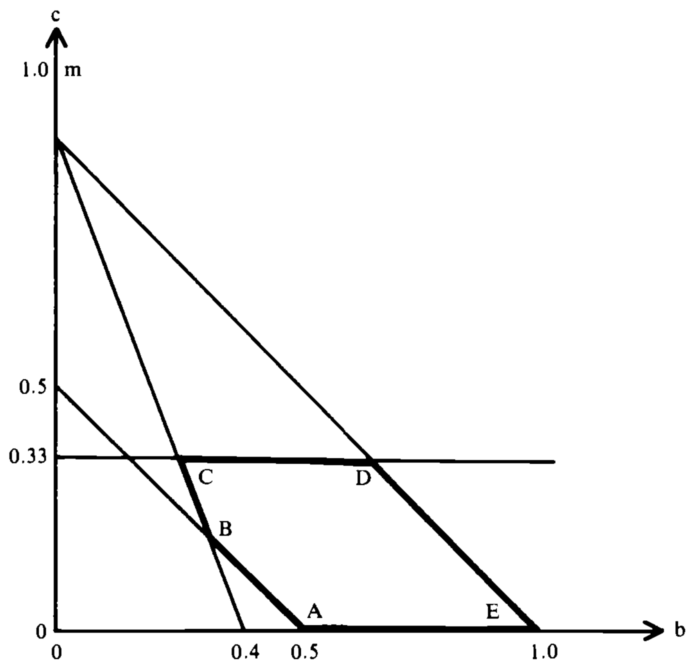


Fig. C4. The region of feasible solutions for the blending problem.

Each of the conditions states that acceptable values of b and c must correspond to a point that lies on, or to one side of, the appropriate line. An easy way to check the consistency of the conditions is, therefore, to draw the line for each condition in turn and shade that area of the chart that the condition rejects. Any unshaded area left after this has been done for all the conditions contains points whose coordinates, b and c, satisfy all the conditions.

The area ABCDE contains all the points whose coordinates, b and c, comply with all the conditions of the problem. This area is called the region of feasible solutions. Had the conditions been incompatible no such unshaded region would have existed. The problem would then have been insoluble. The result for the food manufacturer would have meant his seeking further ingredients. However, the problem does have feasible solutions and in the area ABCDE there is a wide range of choice. It is the extent of this choice that leaves room for the seeking of the optimal or best solution, which in this case means the cheapest.

The chart of Fig. C4 provides a very simple process for finding the cheapest mixture. The cost per tonne of blended ingredients we found to be $Q = 20b + 10c + 40$, which we can rearrange as $c = -2b + Q/10 - 4$. If a particular cost is chosen, say \$50/t, we can put $Q = 50$ in the equation and find $c = -2b + 1$. This is the equation of a straight line. All the mixtures for which b and c satisfy this equation are represented by the points on this line, and all these mixtures are ones that would cost \$50/t. The line is shown as AP in Fig. C5. Repeating the process for a cost of \$45/t gives another line, also shown in the figure with the equation $c = -2b + 0.5$. Any choice of Q will give such a line, and every line of this kind will have the same slope, that is, -2. These lines are contours of cost in Fig. C5. The cost increases steadily as these contours get further and further from the origin. The cheapest possible blend is given by the values of b and c for the point B in the feasible region because this is the first acceptable point that a line of slope -2 will strike as it slides away from the origin.

In the example, then, the optimal mixture is one-third bean flour, one-sixth cereal, and one-half root flour. Its cost is \$48.3/t.

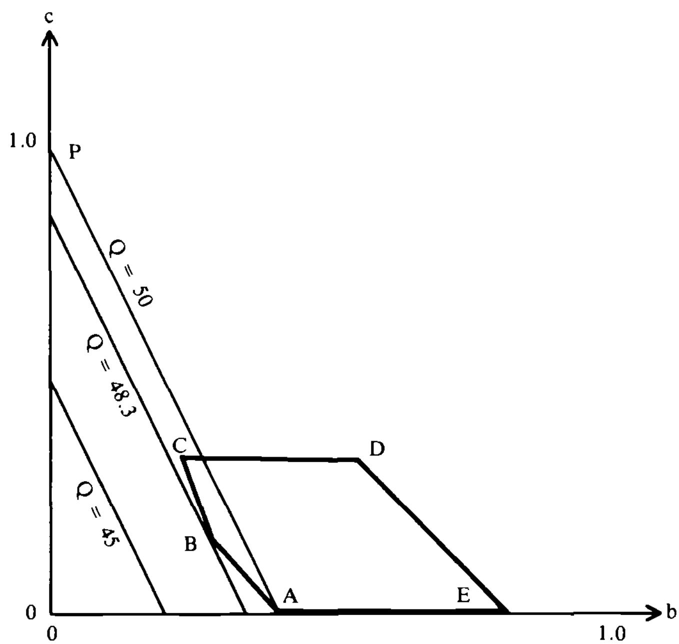


Fig. C5. Cost contours and the feasible region for the blending problem.

This form of algebraic problem turns out to be a symbolic model of a remarkably large variety of planning problems. The optimum sought may be a minimum, as it was in our example, or a maximum, as it might have been had the example been based on the manufacturer's profits rather than his costs. The quantity to be optimized is called the objective function. When the objective function and the constraints take the form that they took in the example, they are called linear (all our drawing involved only straight lines) and the problem is called a problem in linear programming (LP).

We were able to get the solution by a graphical method because there were only two variables, b and c, to be found. Had there been four ingredients to be mixed, three of the proportions would have had to be determined to fix the fourth. It would then not be possible to solve the problem graphically. Instead, a computer solution is necessary. Computer packages are readily available, simple, and efficient. The notion of the feasible region crossed by contours of the objective function still applies.

Another typical application is in production planning. A factory manufacturing 10 different food products by nine different processes from two highly perishable and seasonal raw materials, required two LP models for planning, one for six successive periods of a month, the other adding two further periods of 3 months each. The constraints included those on production, maximum and minimum stock levels, availability of raw material and some contractual obligations. The objective, to maximize profit, had to be modified in various ways. Products that had forecast sales, therefore, had a constant expected revenue from sales, and because the raw material cost was the principal variable element in their manufacture, the minimization of this cost was adequate. Other products were essentially users of residual raw materials, and their contributions were taken as expected gross profit margins. Stock holding costs were included, including the hiring of warehouse space if necessary (for example, Jones, W.G. and Rope, R.M. (1964). Linear programming applied to production planning - a case study. ORQ 15, 293-302).

PRODUCTION PLANNING OF SEASONAL PRODUCTS USING THE TRANSPORTATION METHOD OF LINEAR PROGRAMMING

The transportation algorithm is a special case of linear programming that can be used, for example, to minimize the total cost of distributing goods from a dispatch point to receiving points, provided the following conditions are satisfied: (a) the number of items to be dispatched from, and the number to be received at, each point is known, and (b) the cost of transportation between each pair of points is known.

This method can also be adapted for use in seasonal production planning problems. Each production time period may be considered a separate destination, and each harvesting period for each product may be considered a source of supply. The cost of "transportation" is found by combining the relevant production cost with the storage cost for the appropriate number of time periods.

The following example, based on fruit processing in Jamaica, has been simplified for explanatory purposes. A company processes mangoes and oranges into candied peel. The capacity of the plant is 600 t/month. Mangoes are picked in May and June: expected quantities are 1000 and 1700 t, respectively. Oranges are picked in September and October: expected quantities are 1000 and 500 t, respectively. It is estimated that the processing cost of mangoes is $5/t if processed less than 3 months after picking and $6/t in the 4th month, $7 in the 5th month, and $9 if processed 6 months or more after picking. Storage is expensive because the fruit must be kept in cool conditions; it is estimated that it costs $2/t/month to store mangoes. For oranges, the production costs are $3/t if processed within 2 months of picking, and $5/t if processed after 2 months of picking. Storage costs for oranges are $5/t/month (Table C17).

Table C17. Costs of processing and storage for fruits.

Picking month	Processing month							Supply available ('00 t)
	May	June	July	August	September	October	November	
Mangoes								
May	5	7	9	11	14	17	21	10
June	x[a]	5	7	9	11	14	17	17
Oranges								
September	x	x	x	x	3	8	15	10
October	x	x	x	x	x	3	8	5
Processing capacity available ('00 t)	6	6	6	6	6	6	6	42

[a] An 'x' indicates that it is not possible to process fruit until it is picked.

The first step toward finding the best cost production plan is to obtain a feasible solution. There are many ways of doing this and it does not matter which one is used. Assume that the manager makes an initial guess that the plan in Table C18 is the best, perhaps in recognition of the higher cost of storing oranges compared to mangoes.

The total cost of the original plan, $30 100, is found by adding the costs of the chosen activities (i.e., May picking/May processing, May picking/June processing, etc.). This solution is unlikely to be optimal, so the manager tries to improve upon it by using the concept of marginal costs for supply and production. The supply cost plus the production cost is equal to the actual cost for each used cell of the cost matrix. By starting with the used cells having the highest production cost in a processing month, the other cells can be related to them using marginal supply costs. Setting the supply cost in May at zero means that other supply costs will be negative numbers. For example, the production cost in June is seven (established in May) but the actual cost is five; therefore, the supply cost is -2.

From the used cells only, supply costs and production costs can be determined for supply and processing months, respectively. These are, for supply: May, 0; June, -2; September, -8; and October, -13; and for production: May, 5; June, 7; July, 9; August, 11; September,

Table C18. Initial production plan for fruit processing.

Picking month	Processing month: May	June	July	August	September	October	November	Quantity available ('00 t)	Total cost ($'00)
Mangoes									
May	6	1					3	10	100
June		5	6	6				17	121
Oranges									
September					6	4		10	50
October						2	3	5	30
Total cost									301

11; October, 16; and November, 21. These costs are then imposed on the unused cells and are seen as the costs that are derived from a particular pattern of the processing activities. Should the pattern change so too would some if not all of the cost relationships.

To optimize a given plan, an unused cell could be included if the derived cost exceeded the actual cost. In other words, it would be an improvement to convert such an unused cell into a used cell. For the present example, the comparison of derived and actual costs found in Table C19 indicates a saving if June-picked mangoes were processed in November.

The manager, therefore, wishes to process as much as possible of the June supply in November, as this gives the maximum saving of $2/t. If the manager does this he or she will need to make some changes to the previous solution, as noted in Table C20. The cost of the revised plan is $29 500 (because the cost has been reduced by moving 300 t at a $2/t saving).

The manager is not certain that this is the optimal solution, so again he or she makes an attempt to improve it, by calculating supply and production costs to determine if any of the other cells represent a cost saving (Table C21). As all potential savings are negative, the manager has obtained an optimal solution.

There are three complications that can arise when using the transportation algorithm:

- It is possible to determine the supply and distribution costs accurately only when at least m+n+1 cells are used (m and n refer to the size of the matrix, e.g., m sources of supply, and n destinations). Where fewer cells are used the optimal solution may not

Table C19. Potential savings by each unused cell.

Supply month	Processing month	Derived cost	Actual cost	Saving
May	July	0 + 9 = 9	9	0
	August	0 + 11 = 11	11	0
	September	0 + 11 = 11	14	-3
	October	0 + 16 = 16	17	-1
June	September	-2 + 11 = 9	11	-2
	October	-2 + 16 = 14	14	0
	November	-2 + 21 = 19	17	+2
September	November	-8 + 21 = 13	15	-2

Table C20. Second possible production plan.

	Processing month							Quantity available ('00 t)	Total cost ($'00)
	May	June	July	August	September	October	November		
Mangoes									
May	6	4						10	58
June		2	6	6			3	17	157
Oranges									
September					6	4		10	50
October						2	3	5	30
Total cost									295

be obtained (i.e., the situation is "degenerate") but the computational difficulties are not insurmountable and means of overcoming this situation are available, e.g., allocating a small amount of production to an unused cell.

Table C21. Supply and production costs calculated to determine if any other cells represent a cost saving.

Used cells		Unused cells		
Supply costs	Production costs	Supply month	Process month	Saving
May = 0	May = 5	May	July	0 + 9 - 9 = 0
June = -2	June = 7		August	0 + 11 - 11 = 0
September = -6	July = 9		September	0 + 9 - 14 = -5
October = -11	August = 11		October	0 + 14 - 17 = -3
	September = 9		November	0 + 19 - 21 = -2
	October = 14	June	September	-2 + 9 - 11 = -4
	November = 19		October	-2 + 14 - 14 = -2
		September	November	-6 + 19 - 13 = 0

- Supply needs to balance exactly with the capacity. If the total supply exceeds the capacity an additional "dummy" capacity column must be added to the matrix to accommodate this excess supply. If total capacity exceeds total supply a dummy row must be introduced to satisfy this extra capacity. In both cases all dummy costs are zero.
- If it is desired to maximize the costs (for instance, if the "costs" were profits) rather than minimize, improvements are sought from cells not in use by selecting the cells with the largest negative saving.

EXAMPLE OF AN INVENTORY PROBLEM

For a mung bean noodle factory, the owner needs to have 1 t of beans every day for each batch of the process. The owner attempts to process 360 days/year. On average it is estimated that beans cost 10 000 Baht/t. For each order of beans, the owner must leave the factory, drive to the city, and deliver the purchased quantity of beans to the plant. It is estimated that costs associated with each order are 1280 Baht. There is a large area for storage of beans at the plant, but the owner must borrow some money to purchase the beans, with a current interest rate of 16%. Even if he did not need to borrow money, for each order he will have invested his own money in stocks of raw material, so he will be foregoing a potential interest-making opportunity assumed to be at the same interest rate. The owner currently has a very erratic stocking procedure sometimes buying 5 t, then 20 t, so he is seeking a plan for his purchase of beans, so that he does not have to leave his factory so often for beans, which would reduce his costs and at the same time assure him that he would always have sufficient stock on hand.

There are many possibilities and these can be assessed simply as follows (Table C22): total stock requirement or demand (D) = 360 t, cost of each order (A) = 1280 Baht, cost of beans (C) = 10 000 Baht/t, and interest rate (I) = 16%. It is assumed that the amount of beans in the factory stock will average around one-half of the order quantity, the stock quantity will decline to zero between each ordering period as in Fig. C6.

Table C22. Assessment of stock possibilities.

No. of orders per year (n)	Quantity ordered -- delivered each time (Q)	Cost of each order (nA)	Stock holding cost (Q/2IC)[a]	Total cost (X)
1	360	1280	288000	289280
2	180	2560	144000	146560
3	120	3840	96000	99840
4	90	5120	72000	77120
5	72	6400	57600	64000
6	60	7680	48000	55680
10	36	12800	28800	41600
12	30	15360	24000	39360
15	24	19200	19200	38400
20	18	25600	14400	40000
30	12	38400	9600	48000
36	10	46080	8000	54080

[a] See Fig. C6.

Table C22 clearly illustrates large, infrequent orders will have low ordering and delivery costs but will have excessive interest costs, whereas many small orders will have much lower interest costs but higher costs. It is apparent that there is a compromise stage where a minimum total cost is incurred. This lies between 15 and 20 trips. The optimum then is 15 trips at 24 t/trip.

This could be shown graphically also. Because it is nonlinear, calculus could also be used to find the optimum. This is a much more rapid method of solution. The total cost X has to be minimized $X = nA + QIC/2$ or $DA/Q + QIC/2$. Differentiating, $dx/dQ = -DA/Q^2 + IC/2$. At an optimal point $dx/dQ = 0$. So $DA/Q^2 = IC/2$, i.e., $Q^2 = 2DA/IC$ or $Q = \sqrt{(2DA/IC)}$, or here $= \sqrt{(2 \times 360 \times 1280 \times 100/16 \times 10\,000)} = 24$. In this case Q, the order of quantity on each trip, is 24 t, i.e., 15 trips are necessary.

This may be the minimum, but there may be some factory constraint that makes this impractical, e.g., the factory truck may only hold 20 t. This needs to be taken into account. There would be little

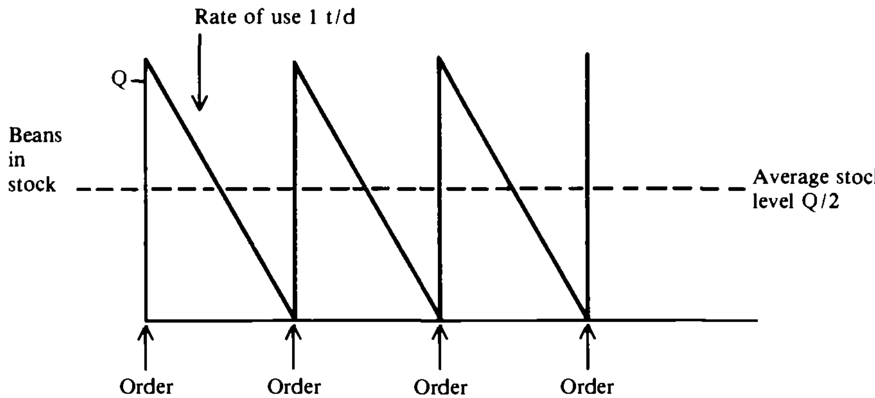


Fig. C6. Assumed stock level over time.

increase in costs around the minimum, so that 18 trips for 20 t would in fact be the optimum for the factory in this case. (Another example is shown in IDRC-MR56e, pp. 107-109.)

TWO-ACTIVITY PROCESS GRINDING -- ECONOMICS

In this example, material A is finely ground by the grinding activity after which it is transferred to the mixing activity where materials B and C are added and thoroughly mixed. The mixing process results in the final finished product, which is then transferred to the finished-goods section for storage until sale. This example assumes that: (a) all material A placed in process for grinding is placed at the time grinding is first begun; (b) all materials B and C placed in process in mixing are placed evenly throughout the process, i.e., it is assumed that when the product is one-third processed, it has received one-third its materials B and C, and that when the product is three-fourths processed, it has received three-fourths of its materials; and (c) labour and overhead applied in each process are applied evenly throughout the process.

At the end of the April cost period, after entries recording materials, labour, and overhead were posted, the two "goods in process accounts" appeared as noted in Table C23.

On 30 April, the production reports prepared by the economist gave the information listed in Table C24 in regard to inventories and goods started and finished in each activity during the month.

After receiving the production reports, the economist prepares a process cost summary, Table C25, for the grinding. A process cost summary is a report peculiar to a processing factory; a separate one is prepared for each processing activity and shows: (a) the costs charged to the activity, (b) the activity's equivalent unit processing

Table C23. Goods in process accounts at the end of the April cost period.

Date	Explanation	Debit	Credit	Balance
GOODS IN PROCESS (GRINDING ACTIVITY)				
April 1	Beginning inventory			4250
30	Materials	9900		14150
30	Labour	5700		19850
30	Overhead	4275		24125
GOODS IN PROCESS (MIXING ACTIVITY)				
April 1	Beginning inventory			3785
30	Materials	2040		5825
30	Labour	3570		9395
30	Overhead	1020		10415

Table C24. Inventories and goods started and finished in each activity during the month.

	Grinding	Mixing
Units in the beginning inventories of goods in process	30000	16000
April 1 stage of completion of the beginning inventories of goods in process	1/3	1/4
Units started in process and finished during period	70000	85000
Total units finished and transferred to next department or to finished goods	100000	101000
Units in the ending inventories of goods in process	20000	15000
Stage of completion of ending inventories of goods in process	1/4	1/3

costs, and (c) the costs applicable to the activity's goods in process inventories and its goods started and finished.

As shown in Table C25 a process cost summary has three sections.

In the first, the costs charged to the activity are summarized. Information for this section comes from the activity's goods in process account. Compare the first section of Table C25 with the goods in process account of the grinding activity as shown in Table C24.

The second section of a process cost summary shows the calculation of equivalent unit costs. The information for this section as to units involved and fractional units applicable to the inventories comes from the production report. Information as to material, labour, and overhead costs comes from the first section of the summary.

In the second section of Table C25, two separate equivalent unit calculations are made. Two calculations are required because material added to the product and labour and overhead added are not added in the same proportions and at the same stages in the processing procedure of this particular activity. As previously stated, all material is added at the beginning of this activity, and labour and overhead are added evenly throughout the process. Consequently, the number of equivalent units of material added is not the same as the number of equivalent units of labour and overhead added.

In the second section of Table C25, in the calculation of equivalent finished units for materials, the beginning inventory is assigned no material. In the grinding activity all material placed in process is placed there at the beginning of the process. The 30 000 beginning inventory units were one-third completed at the beginning of April. Consequently, these units received all their material during March when their processing was first begun and should bear none of the $9 900 cost of material issued to the activity during April.

In the calculation of equivalent finished units of labour and overhead the beginning inventory units that were one-third completed at the beginning are each assigned two-thirds of a unit of labour and overhead. If these units were one-third completed on 1 April, then they were two-thirds completed during the April cost period.

A process cost summary's third section shows how the material, labour, and overhead costs charged to an activity are assigned to its inventories and goods started and finished. In Table C25, for example, it should be noted how costs are assigned to the beginning work in process inventory. The first amount charged is the $4250 beginning inventory costs. This amount represents the material, labour, and overhead costs used to one-third complete the inventory during March, the previous cost period. Normally, the second charge to a beginning inventory is for additional material assigned to it. However, the second charge to a beginning inventory is for additional material assigned to it. Yet, in the grinding activity, no additional material costs are assigned during April to the beginning inventory because these units received all of their material when their processing was first begun during the previous month. The second charge to the beginning inventory is for labour. The $1200 portion of applicable labour costs is calculated by multiplying the number of equivalent finished units of labour used in completing the beginning inventory by the cost of an equivalent finished unit of labour (20 000 equivalent finished units of labour at $0.06 each). The third charge to the beginning inventory is for overhead. The applicable $900 portion is determined by multiplying the equivalent finished units of overhead used in completing the beginning inventory by the cost of an equivalent finished unit of overhead (20 000 x $0.045). After costs are

Table C25. Process cost summary (grinding activity) for month ended 30 April.

COSTS CHARGED TO THE ACTIVITY

Material requisitioned	$ 9900
Labour charged	5700
Overhead costs incurred	4275
	19875
Goods in process at the beginning of the month	4250
Total costs to be accounted for	24125

EQUIVALENT UNIT PROCESSING COSTS

	Units involved	Fraction of a unit added	Equivalent units added
Material			
Beginning inventory	30000	0	0
Units started and finished	70000	one	70000
Ending inventory	20000	one	20000
			90000

Equivalent unit processing cost for material: $9900 ÷ 90000 = $0.11

	Units involved	Fraction of a unit added	Equivalent units added
Labour and overhead			
Beginning inventory	30000	2/3	20000
Units started and finished	70000	one	70000
Ending inventory	20000	1/4	5000
			95000

Equivalent unit processing cost for labour: $5700 ÷ 95000 = $0.06
Equivalent unit processing cost for overhead: $4275 ÷ 95000 = $0.045

COSTS APPLICABLE TO THE WORK OF THE ACTIVITY

Goods in process, one-third processed at the beginning of April	
Costs charged to the beginning inventory of goods in process during previous month	4250
Material added (all added during March)	0
Labour applied (20000 x $0.06)	1200
Overhead applied (20000 x $0.045)	900
Cost to process	6350
Goods started and finished in the activity during April	
Material added (70000 x $0.11)	7700

Table C25 Cont'd

Labour applied (70000 x $0.06)	4200
Overhead applied (70000 x $0.045)	3150
Cost to process	15050
Total cost of the goods processed in the activity and transferred to the mixing activity (100000 units at $0.214 each)	21400
Goods in process, one-fourth processed at the end of April	
Material added (20000 x $0.11)	2200
Labour applied (5000 x $0.06)	300
Overhead applied (5000 x $0.045)	225
Cost to one-fourth process	2725
TOTAL COSTS ACCOUNTED FOR	24125

assigned to the beginning inventory, the procedures used in assigning these costs are repeated in assigning costs to the work started and finished and to the ending inventory.

In the second section of the grinding activity's process cost summary the equivalent finished unit cost for material is $0.11, $0.06 for labour, and $0.215 for overhead. However, in the third section of the summary the unit cost of the 100 000 units finished and transferred is $0.214. The cost of the units finished and transferred is $0.214, which is less than $0.215, because unit costs were less in the activity during the previous month and the 30 000 beginning units were one-third processed at these lower costs during the previous month.

After completing the grinding activity's cost summary, the economist prepares the following entry to transfer from the goods in process account of the grinding activity to the goods in process account of the mixing activity the cost of the 100 000 units processed in the activity and transferred to the mixing activity during April. Information for the entry as to the cost of the units' transfer was taken from the third section of the process cost summary in Table C25.

Posting the entry 30 April, goods in process (mixing activity) of $21 400 and goods in process (grinding activity) of $21 400 to transfer the cost of the 100 000 units of product transferred to the mixing activity had the effect on the accounts as shown in Table C26. The effect is one of transferring and advancing costs from one activity to the next just as the product is transferred and advanced in the manufacturing procedure.

After posting the entry transferring to the mixing activity the grinding activity costs of processing the 100 000 units transferred, the economist prepares a process cost summary for the mixing activity. Information required in its preparation was taken from the mixing activity's goods in process account and production report. The summary appeared as in Table C27.

Two points in Table C27 require special attention. The first is the calculation of equivalent finished units. Because the materials, labour, and overhead of the mixing activity are all added to the product evenly throughout the process of this activity, only a single equivalent unit calculation is required. This differs from the grinding activity where two equivalent unit calculations were required. Two were required because material and the labour and overhead were not placed in process at the same stages in the processing procedure.

Table C26. Effect of transferring the cost of 100 000 units of product transferred to the mixing activity.

Date	Explanation	Debit	Credit	Balance
GOODS IN PROCESS (GRINDING ACTIVITY)				
April 1	Beginning inventory			4250
30	Materials	9900		14150
30	Labour	5700		19850
30	Overhead	4275		24125
30	Units to mixing activity		21400	2725
GOODS IN PROCESS (MIXING ACTIVITY)				
April 1	Beginning inventory			3785
30	Materials	2040		5825
30	Labour	3570		9395
30	Overhead	1020		10415
30	Units from grinding activity	21400		31815

Table C27. Process cost summary (mixing activity) for month ended 30 April.

COSTS CHARGED TO THE ACTIVITY	
Materials requisitioned	$ 2040
Labour charged	3570
Overhead costs incurred	1020
Total processing costs	6630
Goods in process at the beginning of the month	3785
Costs transferred from the grinding activity (100000 units at $0.214 each)	21400
Total costs to be accounted for	31815

Table C27. Cont'd

EQUIVALENT UNIT PROCESSING COSTS

	Units involved	Fraction of a unit added	Equivalent units added
Materials, labour, and overhead			
Beginning inventory	16000	3/4	12000
Units started and finished	85000	one	85000
Ending inventory	15000	1/3	5000
			102000

Equivalent unit processing cost for materials: $2040 ÷ 102000 = $0.02
Equivalent unit processing cost for labour: $3570 ÷ 102000 = $0.035
Equivalent unit processing cost for overhead: $1020 ÷ 102000 = $0.01

COSTS APPLICABLE TO THE WORK OF THE ACTIVITY

Goods in process, one-fourth completed at the beginning of April	
Costs charged to the beginning inventory of goods in process during previous month	3785
Materials added (12000 x $0.02)	240
Labour applied (12000 x $0.035)	420
Overhead applied (12000 x $0.01)	120
Cost to process	4565
Goods started and finished in the activity during April	
Costs in the grinding activity (85000 x $0.214)	18190
Materials added (85000 x $0.02)	1700
Labour applied (85000 x $0.035)	2975
Overhead applied (85000 x $0.01)	850
Cost to process	23715
Total accumulated cost of goods transferred to finished goods (101000 units at $0.28)	28280
Goods in process, one-third processed at the end of April	
Costs in the grinding activity (15000 x $0.214)	3210
Materials added (5000 x $0.02)	100
Labour applied (5000 x $0.035)	175
Overhead applied (5000 x $0.01)	50
Cost to one-third process	3535
TOTAL COSTS ACCOUNTED FOR	31815

The second point needing special attention in the mixing activity cost summary is the method of handling the grinding activity's costs transferred to this activity. During April, 100 000 units of product with accumulated grinding activity costs of $21 400 were transferred to the mixing activity. Of these 100 000 units, 85 000 were started in process in the department and finished. The remaining 15 000 were still in process in the activity at the end of the cost period.

In the first section of Table C27 the $21 400 of grinding activity costs transferred to the mixing activity are added to the other costs charged to the activity. Compare the information in this first section with the mixing activity's goods in process account as it is shown in Table C25.

In the third section of the mixing process cost summary the $21 400 of grinding costs are apportioned between the 85 000 units started and finished and the 15 000 units still in process. The 16 000 beginning goods in process units received none of this $21 400 charge because they were transferred from grinding during the previous month. Their grinding costs are included in the $3785 beginning inventory costs.

The third section of the mixing activity's process cost summary shows that 101 000 units of product with accumulated costs of $28 280 were completed in the activity during April and transferred to finished goods. The economist used the following entry to transfer the accumulated cost of these 101 000 units from the mixing activity's goods in process account to the finished goods account: 30 April, finished goods $28 280, goods in process (mixing activity) $28 280. Posting this entry has the effect shown in Table C28.

Table C28. Effect of transferring the accumulated cost of 101 000 units of product from the mixing activity's goods in process account to the finished goods account.

Date	Explanation	Debit	Credit	Balance
GOODS IN PROCESS (MIXING ACTIVITY)				
April 1	Beginning inventory			3785
30	Materials	2040		5825
30	Labour	3570		9395
30	Overhead	1020		10415
30	Units from grinding activity	21400		31815
30	Units to finished goods		28280	3535
FINISHED GOODS				
April 30	Units from mixing activity	28280		28280

COST VARIANCE FOR STANDARD COSTING

When variances occur, they are isolated and studied for possible remedial action and to place responsibilities. For example, assume that company X has established the following standard costs per unit for its product Z: material (1 lb/unit at $1/lb) $1, direct labour (1 hour/unit at $3/hour) $3, and overhead ($2/standard direct labour hour) $2, for a total standard cost/unit of $6.

For "material variances" assume that during May, company X completed 3500 units of product Z, using 3600 lb of material costing $1.05/lb, or $3780. Under these assumptions the actual and standard material costs for the 3500 units are actual cost: 3600 lb at $1.05/lb = $3780 and standard cost: 3500 lb at $1/lb = $3500 for an excess of actual over standard cost of $280. The actual material cost for these units is $280 above their standard cost. This excess cost may be isolated as to causes in the following manner: quantity variance -- actual units at the standard price: 3600 lb at $1/lb = $3600 and standard units at the standard price: 3500 lb at $1/lb = $3500 for a variance (unfavourable) of 100 lb at $1/lb = $100, and price variance -- actual units at the actual price: 3600 lb at $1.05/lb = $3780 and actual units at the standard price: 3600 lb at $1/lb = $3600 for a variance (unfavourable) 3600 lb at $0.05/lb = $180 resulting in an excess material cost of quantity variance ($100) + price variance ($180) = $280.

The foregoing analysis shows that $100 of the excess material cost resulted from using 100 lb more than standard, and $180 resulted from a unit price $0.05 above standard. With this information the manager can go to the responsible individuals for explanations.

For "labour variances" labour cost in processing depends on a composite of the number of hours worked (quantity) and the wage rate paid (price). Therefore, when the labour cost for a task varies from standard, it too may be analyzed into a quantity variance and a price variance. For example, the direct labour standard for the foregoing 3500 units of product Z is 1 hour/unit, or 3500 hours at $3/hour. If 3400 hours costing $3.10/hour were used in completing the units, the actual and standard labour costs for these units are: actual cost: 3400 hours at $3.10/hour = $10 540 and standard cost: 3500 hours at $3.00/hour = $10 500 for an excess of actual over standard cost of $40.

In this case actual cost is only $40 over standard, but isolating the variances involved reveals this: quantity variance -- standard hours at standard price: 3500 hours at $3/hour = $10 500 and actual hours at standard price: 3400 hours at $3/hour = $10 200 for a variance (favourable) of 100 hours at $3/hour = $300 and price variance -- actual hours at actual price: 3400 hours at $3/hour = $10 540 and actual hours at standard price: 3400 hours at $3/hour = $10 200 for a variance (unfavourable) of 3400 hours at $0.10/hour = $340 and an excess labour cost of price variance ($340) - quantity variance ($300) = $40.

The foregoing analysis shows a favourable quantity variance of $300, which resulted from using 100 fewer direct labour hours than standard for the units produced. However, this favourable variance was more than offset by a wage rate $0.10 above standard.

When a factory has workers of various skill levels, it is the responsibility of the foreman or other supervisor to assign to each task a worker or workers of no higher skill level than is required to accomplish the task. In this case, an investigation could reveal that workers of a higher skill level were used in producing the 3500 units of product Z; therefore, fewer labour hours were required for the work. However, because the workers were of higher grade, the wage rate paid them was higher than standard.

When standard costs are used, factory overhead is charged to production by means of a predetermined standard overhead rate. The rate may be based on the relation of overhead to standard labour cost, standard labour hours, standard machine hours, or some other measure of production. For example, company X charges its product Z with $2 of overhead per standard direct labour hour; and because the direct labour standard for product Z is 1 hour/unit, the 3500 units manufactured in May were charged with $7000 of overhead.

Only 3400 actual direct labour hours were used in producing these units and overhead is charged to the units not on the basis of actual labour hours but on the basis of standard labour hours. Standard labour hours are used because the amount of overhead charged to these units should not be less than standard simply because less than the standard (normal) amount of labour was used in their production. In other words, overhead should not vary from normal simply because labour varied from normal.

A flexible factory overhead budget is the starting point in establishing reasonable standards for overhead costs. A flexible budget is necessary because the actual production level may vary from the expected level; and when this happens, certain costs vary with production, but others remain fixed. This may be seen by examining company X's flexible budget as shown in Table C29.

In Table C29 company X has established standard costs for five production levels, ranging from 60% to 100% of capacity. Such a range is established because when actual costs are known, they should be compared with the standards for the level actually achieved and not with the standards at some other "hoped for" level. For example, if the plant actually operated at 80% of capacity during May, actual costs incurred at this 80% level should be compared with standard costs at this level, and not with costs established for the 90% or 100% levels.

In setting overhead standards, after the flexible overhead budget is prepared, management must determine the standard (normal) operating level for the plant. This can be 100% of capacity; but it seldom is because errors in scheduling work, breakdowns, and, perhaps, the inability to sell all the product produced commonly reduce the operating level to some point below full capacity.

After the flexible budget is set up and the standard (normal) operating level is determined, overhead costs at the standard operating level are related to, for example, labour hours at this level to establish the standard overhead rate. The rate thus established is then used to charge overhead to production. For example, assume company X decided that 80% of capacity is the standard (normal) operating level for its plant. The company then arrived at its $2/direct labour hour overhead rate by dividing the budgeted $8000 of overhead costs at

Table C29. Company X: flexible overhead costs budget for month ended 31 May.

	Production levels (%)			
	70	80	90	100
Production in units	3500	4400	4500	5000
Standard direct labour hours	3500	4000	4000	5000
Budgeted factory overhead				
Fixed costs				
Building rent	$ 1000	1000	1000	1000
Depreciation, machinery	1200	1200	1200	1200
Supervisory salaries	1800	1800	1800	1800
Totals	$ 4000	4000	4000	4000
Variable costs				
Indirect labour	$ 1400	1600	1800	2000
Indirect materials	1050	1200	1350	1500
Power and lights	700	800	900	1000
Maintenance	350	400	450	500
Totals	$ 3500	4000	4500	5000
TOTAL FACTORY OVERHEAD	$ 7500	8000	8500	9000

the 80% level by the 4000 standard direct labour hours required to produce the product manufactured at this level.

As previously stated, when standard costs are used, overhead is applied to production on the basis of a predetermined overhead rate. Then, at the end of a cost period, the difference between overhead applied and overhead actually incurred is analyzed and variances are calculated to set out responsibilities for the difference.

Overhead variances are computed in several ways. A common way divides the difference between overhead applied and overhead incurred into (a) the volume variance and (b) the controllable variance.

The "volume variance" is the difference between (a) the amount of overhead budgeted at the actual operating level achieved during the period and (b) the standard amount of overhead charged to production during the period. For example, assume that during May company X actually operated at 70% of capacity, producing 3500 units of product Z, which were charged with overhead at the standard rate. Under this assumption the company's volume variance for May is: volume variance -- budgeted overhead at 70% of capacity: $7500 and standard overhead charged to production (3500 standard labour hours at $2/hour): $7000 for a variance (unfavourable) of $500.

To understand why this volume variance occurred, reexamine the flexible budget of Table C29 and observe that at the 80% level the $2/hour overhead rate may be subdivided into $1/hour for fixed overhead and $1/hour for variable overhead. Furthermore, at the 80% (normal) level, the $1 for fixed overhead exactly covers the fixed overhead. However, when this $2 rate is used for the 70% level, and again subdivided, the $1 for fixed overhead will not cover all the fixed overhead because $4000 is required for fixed overhead and 3500 hours at $1/hour equals only $3500. In other words, at this 70% level, the $2/hour standard overhead rate did not absorb all the overhead incurred; it lacked $500, the amount of the volume variance. Or again, the volume variance resulted simply because the plant did not reach the standard (normal) operating level.

An unfavourable volume variance tells management that the plant did not reach its normal operating level, and when such a variance is large, management should investigate the cause or causes. Machine breakdowns, failure to schedule an even flow of work, and a lack of sales orders are common causes. The first two may be corrected in the factory, but the third requires either more orders for sales or a downward adjustment of the operating level considered to be normal.

The "controllable variance" is the difference between (a) overhead actually incurred and (b) the overhead budgeted at the operating level achieved. For example, assume that company X incurred $7650 of overhead during May, and because its plant operated at 70% of capacity during the month, the company's controllable overhead variance for May is: controllable variance -- actual overhead incurred: $7650 and overhead budgeted at operating level achieved: $7500 for a variance (unfavourable) of $150.

The controllable overhead variance measures management's efficiency in adjusting controllable overhead costs (normally variable overhead) to the operating level achieved. In this case management failed by $150 to get overhead down to the amount budgeted for the 70% level.

Although the controllable overhead variance measures management's efficiency in adjusting overhead costs to the operating level achieved, an overhead variance report is a more effective means for showing just where management achieved or failed to achieve the budgeted expectations. Such a report for company X appears in Table C30.

The volume and controllable variances may be combined to account for the difference between overhead actually incurred and overhead charged to production. For example, company X incurred $7650 of overhead during May and charged $7000 to production, and its overhead variances may be combined as follows to account for the difference: volume variance -- budgeted overhead at production level achieved: $7500 and standard overhead charged to production (3500 standard hours at $2/hour): $7000 for a variance (unfavourable) of $500 and controllable variance -- actual overhead incurred: $7650 and overhead budgeted at operating level achieved: $7500 for a variance (unfavourable) of $150 and an excess of overhead incurred over overhead charged to production of $650.

The use of standard costs makes possible the application of a control technique known as "management by exception." Under this technique management gives its attention only to the variances in which actual costs are significantly different from standard and it

Table C30. Company X: factory overhead variance report for month ended 31 May.

VOLUME VARIANCE

Normal production level	80% of capacity
Production level achieved	70% of capacity
Volume variance	$500 (unfavourable)

CONTROLLABLE VARIANCE

	Budget	Actual	Favourable	Unfavourable
Fixed overhead costs				
Building rent	1000	1000		
Depreciation, machinery	1200	1200		
Supervisory salaries	1800	1800		
Total fixed	4000	4000		
Variable overhead costs				
Indirect labour	1400	1525		$125
Indirect materials	1050	1025	$25	
Power and lights	700	750		50
Maintenance	350	350		
Total variable	3500	3650		
Total controllable variances			25	175
Net controllable variance (unfavourable)			150	
TOTAL			175	175

ignores the cost situations in which performance is satisfactory. In other words, management concentrates its attention on the exceptional or irregular situations and pays little or no attention to the normal. This can be used also by the research team to get the maximum benefit from their subsequent research efforts to develop and test improved processing technology.

MARGINAL AND COST-BENEFIT ANALYSIS

In "marginal analysis" the following example illustrates use of a partial budget for a change in a food process operation where it is proposed to switch the process from one that produces only one grade of rice flour noodles to a process that will produce two grades of rice flour noodles and wheat flour noodles. Without any addition of capital equipment or plant space, the additional costs and returns are as listed below and it can be concluded that it is worthwhile to introduce the new grade of product:

ADDITIONAL COSTS		ADDITIONAL RETURNS	
Labour	$ 500	10 t of premium quality rice flour noodles	$ 70000
Electricity	350		
Fuel	700		
Water	100	25 t of wheat flour noodles	42000
Wheat flour	17000		
REDUCED RETURNS		REDUCED COSTS	
Decreased production of 35 t medium-quality rice flour noodles	52500	Reduced purchase of rice flour	16000
A. Total annual additional costs and reduced returns	71150	B. Total annual additional returns and reduced costs	128000
		Minus A	71150
		Net change in income (B minus A)	56850

In "cost-benefit analysis" the following is a simple hypothetical example of calculating net present value (NPV), cost-benefit ratio, and internal rate of return on an investment in a food processing business. Assume the investment represents the addition of an additional line of mixing, extruding, drying, and packaging for a small noodle manufacturer. The following estimates of costs and benefits are made: capital equipment = $35 000, operating costs (per year) are labour = $5000, ingredients = $10 000, fuel and power = $7000, water = $1000, interest = $3500, equipment maintenance = $1750 and revenue (per year) in increased production = $42 000.

Also assume equipment lasts 10 years (no salvage value) and that the initial discount rate chosen equals 10% equal to market interest rate. The following table shows the result of the calculated NPV at 10% for this investment:

	Costs			Revenue		
Year	Actual costs	Discount factor	Present value	Actual revenue	Discount factor	Present value
0	35000	1.00	35000	-	-	-
1	28250	0.909	25679	42000	0.909	38178
2	28250	0.826	23335	42000	0.826	34692
3	28250	0.751	21216	42000	0.751	31542
4	28250	0.683	19295	42000	0.683	28686
5	28250	0.621	17543	42000	0.621	26082
6	28250	0.564	15933	42000	0.564	23688
7	28250	0.513	14492	42000	0.513	21546
8	28250	0.467	13193	42000	0.467	19614
9	28250	0.424	11978	42000	0.424	17808
10	28250	0.386	10905	42000	0.386	16212
			208569			258048

NPV = 258048 - 208569 = 49479

$$\text{Benefit/cost ratio} = \frac{258048}{208569} = 1.24$$

[a] The discount factor is used to convert future values into present values and equals $1/(1+i)^n$, where i is an appropriate annual interest rate (the discount rate) and n is the number of years.

Note: With a discount rate of 10%, the NPV is +\$49479. At a rate of 50%, the NPV is -\$7969. By definition, the internal rate of return is the discount rate that brings NPV to 0; therefore, in this case, it would be somewhere between 10 and 50%. The simplest procedure to find the IRR is to interpolate between two discount rates, ignoring signs of the NPVs. In this case, 10% + (49 479/(49 479 + 7969))40% = 44.5%. Interpolating over an interval as large as the one in this example is subject to a serious loss of accuracy; therefore, experimentation with alternative pairs of discount rates with smaller intervals is advisable.