THE MECHANIZATION AND CONTROL OF FARMSTEAD OPERATIONS

by

F. V. MacHardy

Member C.S.A.E.

Department of Agricultural Engineering, University of Alberta, Edmonton, Alberta

The trends in agricultural mechanization as Canada moves into the 1960's are quite clearly defined. There is the continuing trend to increase the output per man by increasing the size or capacity of his field machines. A second trend is the increasing emphasis that is being placed on the mechanization of farmstead operations or processes. This trend has been interpreted by many people as creating a "new" field of Agricultural Engineering interest. A name has been given to this area, the name being Materials Handling. A third definable trend is the appearance on the agricultural horizon of electronic or mechanical control. The control function can probably be illustrated by suggesting the tractor driver. A tractor operator normally adds nothing to the energy level available from the tractor. Instead he programmes the machine. That is, he starts, stops and turns it, and is responsible for detecting errors in the system operation and for correcting these errors.

Some aspects of these two latter trends in agricultural mechanization will be mentioned. There is not sufficient statistical information available to deal with farmstead mechanization from a statistical viewpoint. Development is taking place rapidly, and trends are probably not firmly enough established to offer adequate guidance to Agricultural Engineers at this time. In any case, it is hoped that Agricultural Engineers will not only follow trends, but will take a prominent role in *influencing* trends. If this is to take place, probably some analysis of the problem, rather than of the trend, is justified in order that a course of action may be developed.

Farmstead mechanization shows two distinct characteristics. First, there are usually a large number of alternative methods or processes of achieving some specific goal. Secondly, the amount of human effort, mechanical energy and plant varies greatly between alternatives. Problems arising from farmstead mechanization are also twofold. First, engineering science in a broad sense is necessary to develop the alternative courses of action, and second, methods of selecting from among available alternatives must be familiar to people working in this area of endeavour. These two functions must often be performed by the same person, even though the two aspects of the problem involve to some extent different basic disciplines.

THE ROLE OF DECISION-MAKING IN MECHANIZATION:

Consider first the task of selecting a level of mechanization, in other words, selecting one from among a number of alternatives. Farmstead problems invariably involve many factors. They are then, "complex" problems, and methods of arriving at solutions also stand a good chance of being complex. It might be of general interest here to outline a development taking place in Alberta designed to bring Agricultural Engineers into intimate contact with farmstead, and other complex problems and it is hoped, lead to worthwhile contribution in this field.

In attempting to get at this problem in Alberta, an industrial approach is being attempted. This approach, resulting from the re-grouping of the principles of scientific management, as developed at the turn of the century, numerical mathematical techniques as developed by classical scholars of the past two or three centuries, and the use of modern data processing equipment, has been called Operations Research.

Some mention of some of the basic mathematical tools of Operations Research may be of interest. The first technique or tool is mathematical programming, and particularly linear programming. Linear programming may be used in problems of selecting the best combinations of available machinery, for example, and for deciding the best "dial" settings on a feed grinder. Very briefly, linear programming is a method of representing business problems as a mathematical model in two parts, a "functional" which is to be minimized or maximized, and a set of constraints in the form of simultaneous equations, or inequations.

$$X_1 + X_2 = Z \qquad (1)$$

$$\begin{aligned} X_1 &< 0.9 \\ 0.5X_1 + X_2 &< 1.0 \qquad (2) \\ X_2 &< 0.8 \end{aligned}$$

Figure 1. Problem in linear programming.

Figure 1 represents a problem in linear programming where (1) is the functional and (2) is the set of constraints. For purposes of manipulation, the algebraic equations representing the constraints may be shown in matrix form as in figure 2.

$$\begin{bmatrix} 1 & 0 \\ 0.5 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} < \begin{bmatrix} 0.9 \\ 1.0 \\ 0.8 \end{bmatrix}$$

Figure 2. Set of constraints in matrix notation.

Matrices are always designated as m x n where m = number of rows and n = number of columns. The constraints in figure 2 form a 3 x 2 matrix. This is mentioned only so that some reference can be made of the amount of manual effort or the amount of computing equipment necessary to solve these problems.

Linear programs can be solved by means of numerical methods, one of which is known as the simplex method. This method establishes steps (based on fairly complex mathematics, but in themselves simple) that will lead in a definite number of steps to the solution. Anyone who can add, subtract, multiply and divide can follow this step by step procedure. The number of manipulations required is in the order of:

Iterations	n
Multiplications per Iteration	m (n+2)
Divisions per Iteration	m+n
Additions and Subtractions per Iteration	(m+n) (n+2)

Applying this to figure 1, the total number of operations is in the order of 74. This of course discourages hand calculations, and is one of the reasons that digital computers, which do simple manipulations very quickly are usually called upon to be used in the simplex method of solution to these problems.

It should be mentioned that analog computers may also be used to solve linear (and also non-linear) problems. This important fact seems to have been overlooked in the publicity that has surrounded digital computers. The number of analog computer elements (amplifiers) required to solve linear programmes is in the order of n+m. For the example in figure 1 this number is 8.

It is hoped that this short mention of programming will stimulate a number of Agricultural Engineers to investigate this field.

Another contemporary set of tools are the Monte Carlo techniques. These techniques combine the theory of probability with a random number device, such as a roulette wheel, to simulate and solve a variety of problems with queueing characteristics. One example might be the spacing of country elevators. Another problem that would probably yield to this technique is the problem of sizing combines to individual farms. The stochastic variable is of course the weather. There can be little doubt that recommendations could be made, with a much greater degree of confidence than is generally now the case, if the Monte Carlo was used to balance crop losses resulting from excessive weathering against the increased cost of owning a combine, or combines large enough to ensure timeliness.

A third type of problem that applies to farms, involves sequences of operations. For example, the same field may be tilled, drilled, harvested and weeded in sequence, and the same grain may be stored, ground, moved, stored again and moved, in a feeding operation. If these operations can be carried out in sequence rather than simultaneously and if a time limit is imposed, then there is a "one best size" (from an economic viewpoint) for each of the machines required in the sequence. Problems of this nature can be represented as mathematical models that yield to a mathematical solution developed by Count Louis La Grange in France over two hundred years ago. This problem and its solution represents an example of the nebulous but necessary association that exists between applied and theoretical fields.

These are but examples of the dozen or more techniques that make up the mathematical and statistical tools of Operations Research. There is little doubt that the number of applicable techniques will increase as the scope of the method broadens.

Activities such as Operations Research are concerned with establish ing the best level of mechanization as determined by the level of technological development, or the "present cost" of technology. The complementary problem mentioned earlier was the problem of engineering the alternative mechanized systems, from which one only would be recommended.

THE CONTROL FUNCTION IN MECHANIZATION

Engineers are beginning to think of mechanization in absolute rather than comparative terms, in order to establish definite goals for mechanization. For example, the Motorola Corporation (1) of Chicago has established a committee on advanced mechanization to establish absolute goals and to pinpoint each present operation of the plants on these absolute scales. The Motorola Corporation used the following basis for establishing a mechanization yardstick. They first define the automatable elements of an operation. Five classes of operations were established, depending on the degrees to which element had been automated. Each class was then assigned a percentage of automation, from zero for the lowest class to 100% for the highest class. A system of weights was devised to give more credit for those operations which are used the most number of times a year. On the basis of this system of measurement it was estalished that the company's operations were 15% automated in 1957.

It is not known if anyone has seriously attempted to develop a similar quantitative approach to agricultural mechanization (either for field or farmstead operation), however, it is bound to come, and Agricultural Engineers are the men who should perform this task. A word of caution should be inserted. "Automation" or advanced mechanization is much talked about but not too well understood, and even defining automatable elements is not a simple task.

Automation of an operation, regardless of how it may be defined, is made up of three functions in addition to the actual operation that is to be performed. The first function is that of programming. Programming implies that a timer, or a punched card, or a magnetic tape can start, guide and stop an operation. Second, transfer must be affected between steps without manual assistance. This requirement for transfer machines has been emphasized to the point that automation and the use of transfer machines have sometimes been considered to mean the same thing. (In farmstead operations, nature has generously taken care of the transfer function in most cases.) The third necessary function is error detection and correction. This essential function is the one that is generally absent in most "automated" system designs. The Agricultural Engineer who concerns himself with advanced mechanization whether for the purpose of assessment or for the purpose of development needs to familiarize himself with the technical areas that constitute a background to control engineering.

By way of illustration, figure 3 shows an error detection and correction system added to a belt type feed blender.

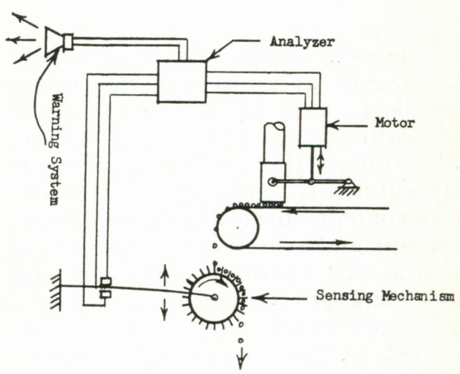

Figure 3. Error detection and correction system.

The characteristics of this feed back system are analagous to those of a spring-mass-damper system such as that illustrated in Figure 4.

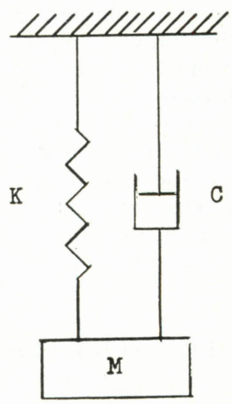

Figure 4. Spring-mass-damper system.

This is familiar in mechanical vibration studies and the behaviour of the system is explained quantitatively by solving second order differential

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Different operating conditions place different demands on combines and thus a machine that is flexible to meet varying conditions and operate as efficiently as possible is desired. Labor and fuel costs, the value of the grain being harvested and weather conditions influence the selection of the rate of work on a combine. A combination of low labor costs, high crop price and lack of risk of unfavourable weather will usually result in operation at a capacity giving highest efficiency. A low price for a crop or the risk of unfavourable weather will usually result in operation at a higher capacity with a slight reduction in efficiency.

The above remarks illustrate some of the factors which affect the very complex question of combine capacity and efficiency and why it is necessary to consider all these factors when rating a machine for comparative purposes. In the final analysis however, it is the responsibility of the user to obtain maximum output at minimum cost under the conditions encountered.

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equations. Solutions to problems of system stability and critical damping appear in the values for system coefficients.

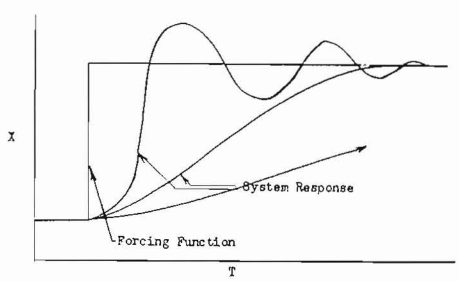

Figure 5.

It should be mentioned that as the same general diferential equations appear in many other engineering areas, including electrical circuits containing inductance, capacity and resistance, that a great deal of useful simulation of control circuitry can be carried out by means of an analog computer. This important tool with its natural ability to directly simulate physical phenomena is often overlooked in favor of digital computers. Digital machines have caught the public fancy, but are only capable of handling differential problems that lend themselves to numerical approximations. Analog machines on the other hand can even include human elements in system simulation.

A second characteristic of such a system as that illustrated in figure 3, is the decision to be made by the system as to whether or not an error signal is a true indication of an error or whether it is a random impulse or "noise". This aspect of control involves the theory of statistical quality control and communications theory, both of which generally fall outside of standard undergraduate curricula.

These are briefly, the technical areas in which solutions to problems of farmstead mechanization and control circuitry wherever found, are to be located. Much of this is unfamiliar ground to Agricultural Engineers. Nevertheless if Agricultural Engineers are to make a high level contribution to advanced mechanization then some understanding of these fields is necessary. It is hoped that educators will keep these needs in mind, particularly in developing graduate programs of study and research, and that all keep in mind that technical libraries contain all of the technical material that has been referred to. The responsibility to make use of this information rests with individual Agricultural Engineers.

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field as the test is conducted. Multi-channel tape recorders and digital computors can be used for an automatic data processing system. Through proper analysis of data collected in this manner engineers can design and develop new machines of proper durability and performance in a much shorter period of time.

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