An Evaluation of Alternatives in Swine Waste Management Systems*

猪排泄物處理系統替代方案之評估

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ABSTRACT

Systems analysis techniques were used in determining the least cost for swine waste management systems The various functions of manure collection, transport, storage and field distribution were divided into possible elements. An assessment was made of the cost of operating each of these elements in terms of variables such as live-stock numbers, cost of material and size of unit. A Shortest Path Network Analysis(SPNA)program was used to evaluate the alternatives arising from the use of different elements to perform the functions. Some least cost systems are presented with a discussion of possible alternative measures for the best arrangement for an individual.

中 文 摘 要

系統分析技術用於猪排泄物處理系統中以決定其最小費用，猪排泄物之搜集、運輸、儲藏及田間散播等各種處理階段被分成數個可能單元，每一單元間之操作費用導出以家畜頭數、材料費及規模大小爲變數之關係式，然後應用最短路徑網分析法之電子計算機程式評估由不同單元配合而成之不同選擇路徑，自電子計算機輸出結果中，提供處理系統中最小費用之替代方案，同時在某種情況下可能最佳安排亦一並提出討論。

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INTRODUCTION

Swine waste management systems contain a group of discrete functions cach of which can be performed by one or more elements. These functions may be called manure collection, transfer, storage or distribution. The elements might be called gutters, gutter cleaners, pumps, concrete storage tanks, tankers or irrigation pipe. Figure 1 shows how the parts fit into the whole manure use cycle.

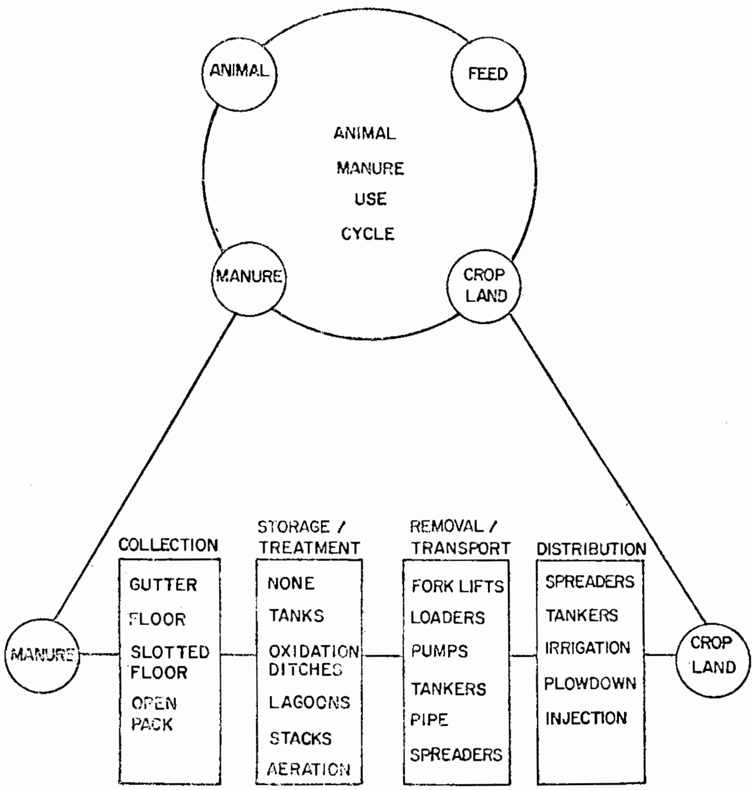
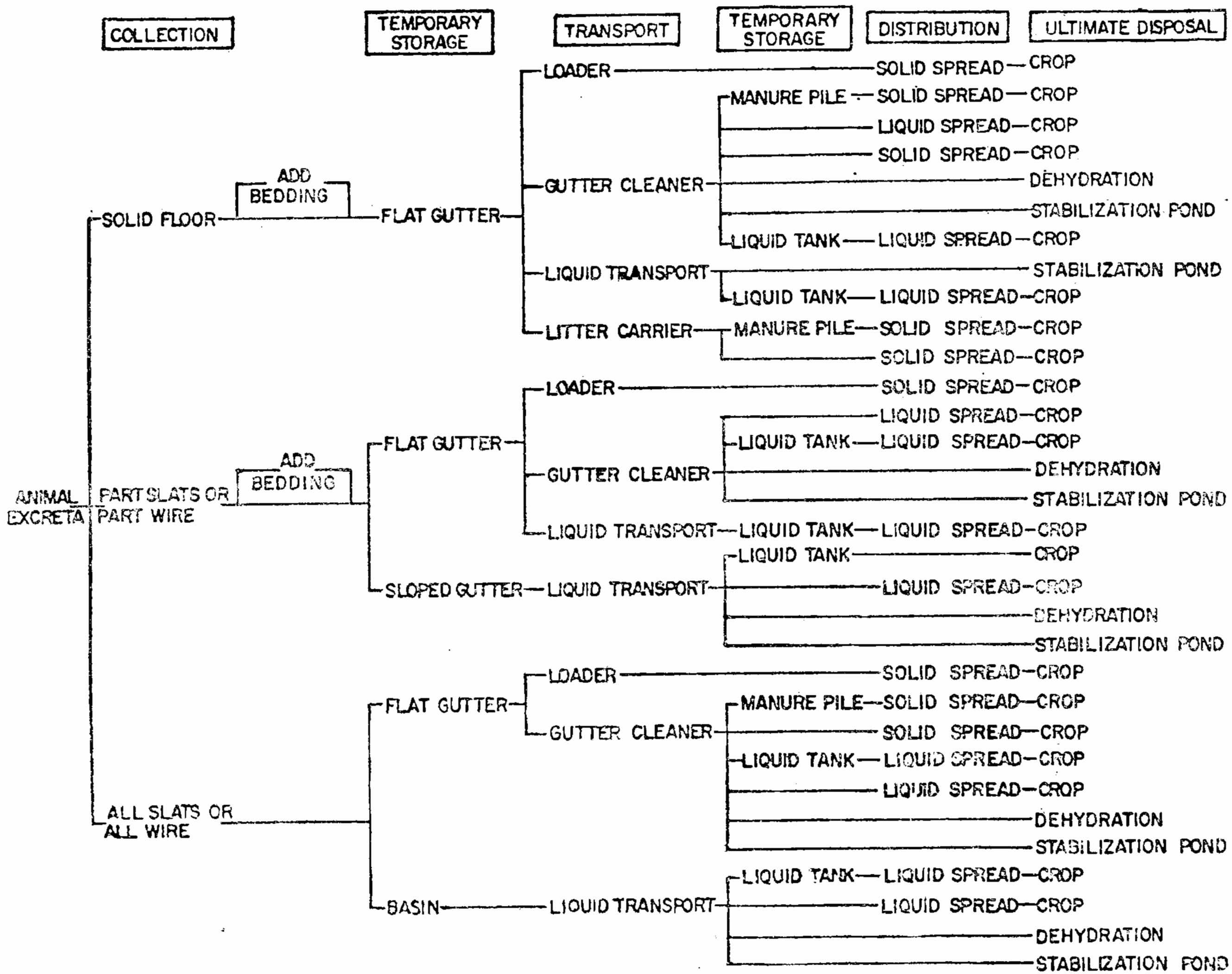


Figure 1 System components in the animal manure use cycle.

The systems described by the various functions and elements can be used for various species of livestock but this work refers to swine waste management only. It is possible to structure the elements of the system in such a way as to have a "branching tree" diagram as shown in Figure 2[a]. while each route may be followed to its conclusion, that conclusion is repeated many times, for example, crop. A more concise way of showing the elements is that of Figure 1 but it is not obvious which elements under one function could be used with an element under a following function. When the choice of pathways (the joining of elements together to get from manure collection to ultimate use) become large, calculations by hand become very tedious.

The idea of network analysis lies in the fact that many physical systems possess a feature that their elements can be represented by a network of nodes and connecting

a. Ogilvie, J. R. and F. R. Hore, 1963. Confined Livestock Manure Disposal. Paper presented at the CSAE Annual Meeting, Banff, Alta.


COLLECTION
TEMPORARY STORAGE
TRANSPORT
TEMPORARY STORAGE
DISTRIBUTION
ULTIMATE DISPOSAL
ANIMAL EXCRETA
SOLID FLOOR
ADD BEDDING
FLAT GUTTER
LOADER
SOLID SPREAD — CROP
GUTTER CLEANER
MANURE PILE — SOLID SPREAD — CROP
LIQUID SPREAD — CROP
SOLID SPREAD — CROP
DEHYDRATION
STABILIZATION POND
LIQUID TANK — LIQUID SPREAD — CROP
LIQUID TRANSPORT
STABILIZATION POND
LIQUID TANK — LIQUID SPREAD — CROP
LITTER CARRIER
MANURE PILE — SOLID SPREAD — CROP
SOLID SPREAD — CROP
PART SLATS OR PART WIRE
ADD BEDDING
FLAT GUTTER
LOADER
SOLID SPREAD — CROP
GUTTER CLEANER
LIQUID SPREAD — CROP
LIQUID TANK — LIQUID SPREAD — CROP
DEHYDRATION
STABILIZATION POND
LIQUID TRANSPORT — LIQUID TANK — LIQUID SPREAD — CROP
SLOPED GUTTER — LIQUID TRANSPORT
LIQUID TANK — CROP
LIQUID SPREAD — CROP
DEHYDRATION
STABILIZATION POND
ALL SLATS OR ALL WIRE
FLAT GUTTER
LOADER
SOLID SPREAD — CROP
GUTTER CLEANER
MANURE PILE — SOLID SPREAD — CROP
SOLID SPREAD — CROP
LIQUID TANK — LIQUID SPREAD — CROP
LIQUID SPREAD — CROP
DEHYDRATION
STABILIZATION POND
BASIN — LIQUID TRANSPORT
LIQUID TANK — LIQUID SPREAD — CROP
LIQUID SPREAD — CROP
DEHYDRATION
STABILIZATION POND

branches (Peart et al, 5). With this idea, a network diagram is constructed in which each node represents the function and each branch represents the element being employed.

The length of the pathways from one function to the next can be expressed in many terms. Examples are, time to do the work, cost per pig of operating each element, or the amount of energy per pig. Since the cost, time or energy can vary depending on the number of animals, the effects of scale must be determined.

Part of the field of Operations research deals with Network Analysis. Practical results of such analysis yields the critical path methods (CPM and PERT) whereby the longest pathway to get the work accomplished is determined. Efforts are made to shorten this critical path since it determines the completion date for the job. Another type of network analysis is that called Shortest Path (SPNA) whereby the minimum time required to complete an assignment by various routes is evaluated. This kind of analysis has use in waste wanagement since a cost in time, money or energy can be cattachedto each portion of a pathway. The minimum cost system in terms of money is the best if time restraints are satisfied. This system of analysis has been used in agriculture for some time (4, 5, 7, b).

The object of the work discussed here was to apply systems analysis techniques in order to determine what effect choiceof element or component had on the cost per animal.

BACKGROUND THEORY

Notwithstanding the fact there are several schemes to determine the shortest path from A to B given several alternatives, the most useful one is that which evaluates all paths. This means much calculation but for the purpose of this work, has certain advantages. The shortest path may not be the best in any given system since another pathway may be only slightly longer. The second path may contain elements with which the owner is more familiar or for which repair service is more readily available. An analysis which has calculated all routes can merely list them for later visual comparison.

The evaluation of the length of time (or cost) to complete a task depends on the resources available as well as on the methods. Some tasks may respond with a large reduction in time for a unit increase in labour, for example, while others may reach a point of diminishedor no returns. For this reason it is desirable to evaluate pathway length each time the number of hogs served varies.

The theory behind the SPNA is essentially based on the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT) which was developed in 1956-57 by E. I. dupont de Nemours Company and in 1958 by the U. S. Navy Special Project Office respectively (O'Brien, 3). The name Shortest Path Network Analysis was given because the shortest (least duration) rather than the longest route was so-

b. Coupland, G.A. and R.M. Halyk, 1969. Critical Path scheduting of Forage Harvesting Systems in Quebec. Paper presented at the Winter Meeting ASAE Chicago, Ill. No. 67, 678, December.

ught in this method. The aim of SPNA is to find which of the possible combinations of activities is superior to others from an array of alternatives displayed as a network. A forward and backward pass through the paths yields the earliest starting time (ES) and the latest starting time (LS) for each node. The DIFFERENCE is found as shown below.

$$DIFFERENCE = LS(J) - D(IJ) - ES(I) \quad [1]$$

where I=origin node

J=terminal node

D=duration of the activity or operation

The critical path (shortest path) is indicated as that set of nodes with activities or operations having zero DIFFERENCE.

In describing the network in technical terms, the pathway from element to element is called an arrow or arc and includes one element. It has some finite length in terms of hours, dollars per pig, kilowatt hours per pig or other unit.

The durations for each activity in the model may or may not be fixed. If not, they are calculated from respective length equations (T-equations) containing variable (V's). The T-equation is a simple mathematical function describing a particular activity in terms of time, cost or other unit. The great strength of the SPNA technique is the use of T-equations in which the variable can be changed. This allows for a sensitivity analysis of certain parameters to be done.

In evaluating the alternatives in swine waste management, the criterion has been set as the initial cost per hog. Thus, the T-equation is to describe the cost of that operation carried from one phase to another per unit hog. Therefore the shortest path determined by SPNA would represent the lowest initial cost among the possible alternatives in the system.

METHODS AND RESULTS

This project was conducted in conjunction with Agriculture Canada and used a modification of the Shortest Path Network Analysis Program developed by Preston (6) and modied by Lievers

The functions in swine waste management were considered to be:

Housing or type of manure
Collection
Transfer
Storage-short or long term
Distribution

Under each function were placed the elements that comprised a part of the system and could perform the function. A qutter, for example, is an element which performs the collection function. The elements were joined by arrows so as to create a path from the start to the finish.

C. Livers, K. W. 1973. Shortest path network analysis program documentation Engineering Research Service, Research Branch, Agriculture Canada Ottawa, Canada.

Having so constructed the network for the given elements, the most difficult work began. This consisted, firstly, of evaluating the length or duration of each activity, in this case, capital cost per pig. This, of course, had a variable value depending on the number of animals. The second task was to get the computer program to accept the data and to turn out meaningful results.

A diagram of a portion of a system for swine waste management is shown in Figure 3 (1, 2, 8, 9). The arrows linking each of the nodes illustrates the complexity that has been removed from Figure 1. Significantly, one does not have to use a node under each function, if the function can be bypassed. It is possible to have a gutter cleaner move manure to long term storage or into a transfer device for field distribution without intermediate storage and second handling.

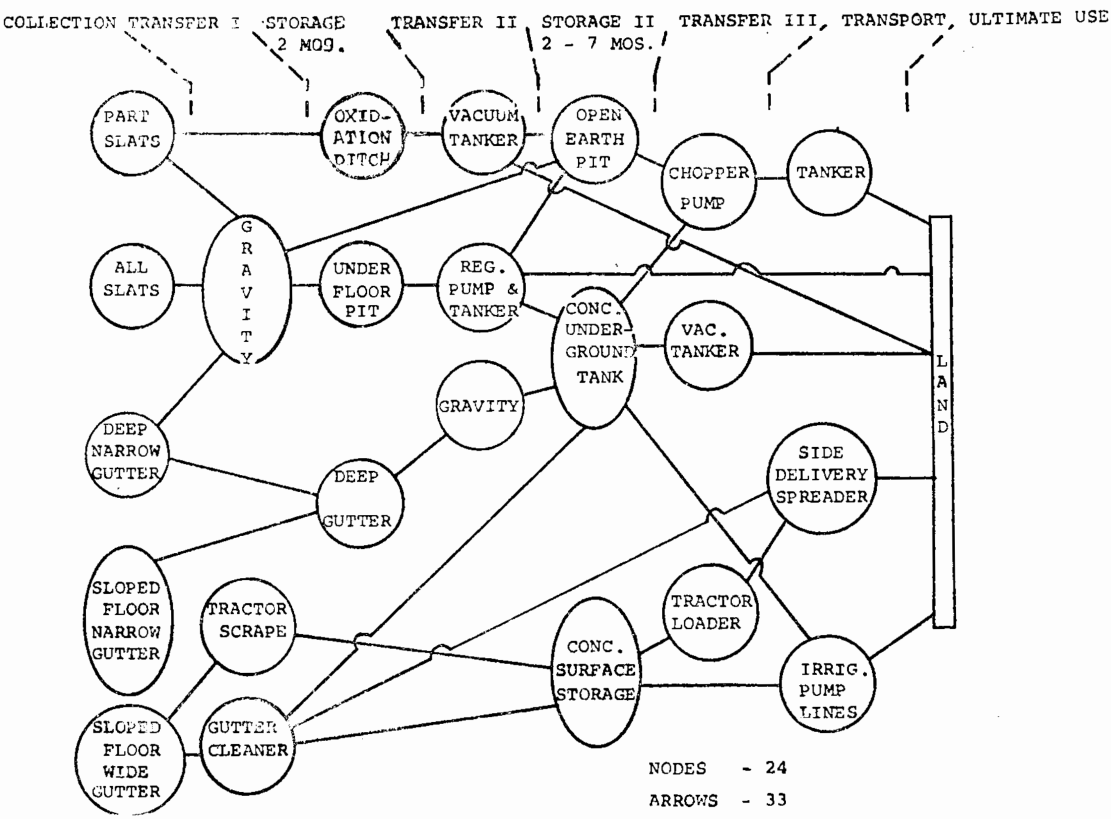


Figure 3 Swine waste and management alternatives.

The capital cost for each activity is influenced by:

- number of animals sharing the use eg a vacuum tanker
- change in cost with size eg storage tanks
- time available to perform function eg large or small tanker

The logic flow chart for the SPNA program is shown in Figure 4. This program includes a facility for having random node numbers ie number 250 may preceed number 210 although the normal rule requires larger numbers to follow smaller. There is also a provision whereby different sets of variables may be used eg a 500 head herd and a 200 head herd. This can illustrate the effect of scale.

If the duration of the activity is affected by the number of animals or other variable, a subroutine may calculate the duration of each arrow during program execution using the different variable mentioned above.

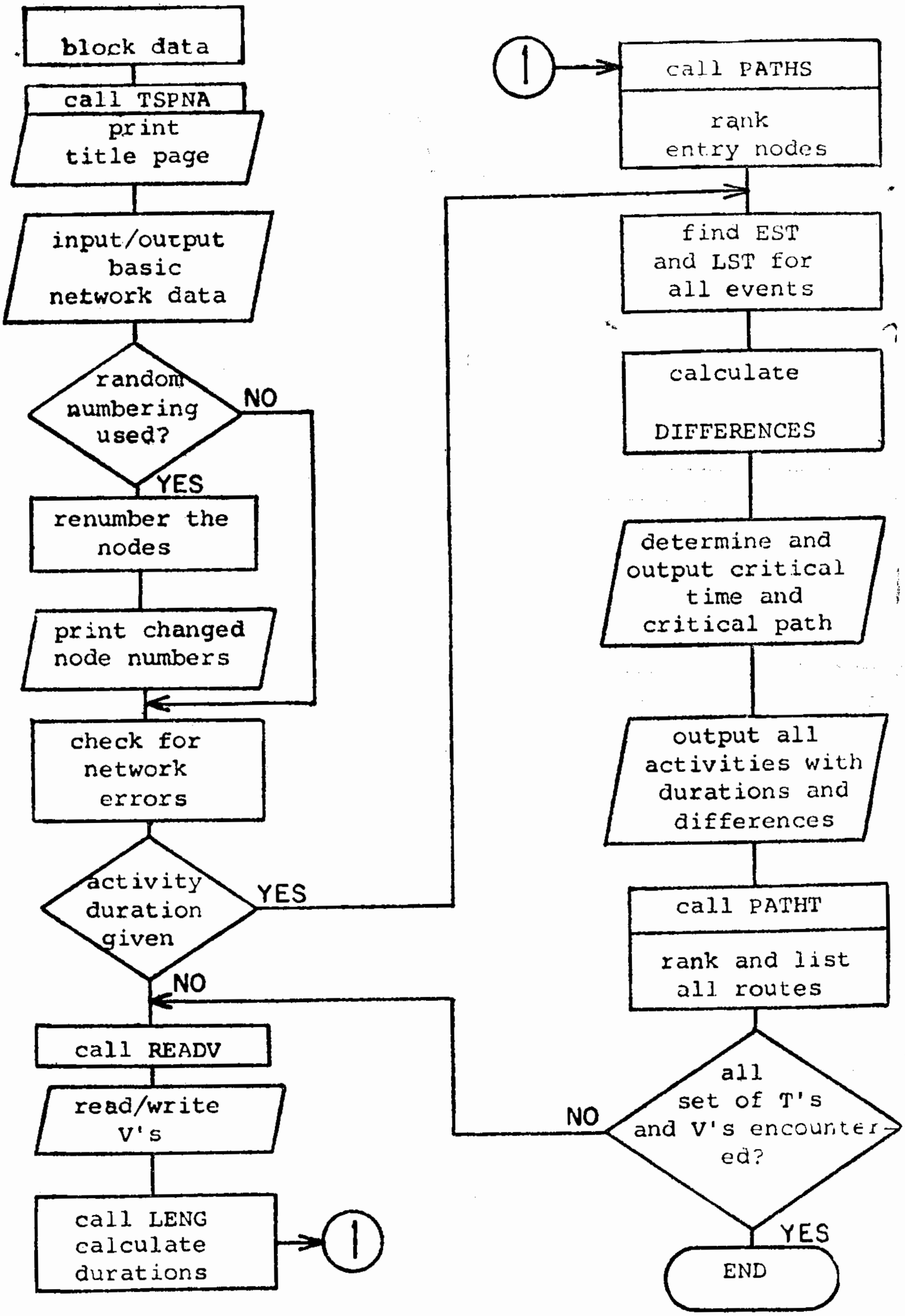


Figure 4 Logic flow chart for SPNA program.

A typical length equation would be for a chopper pump:

$$T = 1500/V(j) \text{ where } V(j) \text{ is the number of hogs and } T \text{ is in dollars per pig.} \quad [2]$$

Finally the critical path is shown and other paths listed in their order based on the length of the path. The latter provides the opportunity to examine systems that are very much alike in cost but unlike in components.

The printout from the computer is in terms of node numbers and one must refer back to layouts like Figure 3 where each node has a number to determine the actual components on the path. A portion of the printout is copied in Table I dealing with some of the same components shown in Figure 3. The results show the system components that are the least costly to purchase. Whether this system is applicable to the farm unit depends on factors such as climate, labour available and personal desire.

TABLE I DATA PRESENTION ON VARIABLES & CRITICAL PATH

THE V'S OF SET 1 ARE:

V1	200.0000	NO. OF HOGS
V2	50.0000	COST OF RC IN PLACE/CU. YD.
V3	0.2700	CONST. COST OF UDGD CIRC TANK PER CU. FT.
V4	0.5000	EXCA. COST/CU. YD.
V5	1000.0000	TANK SPREADER CAPACITY (GAL.)

CRITICAL TIME IS, 0.19049988E+02

ACTIVITIES ON CRITICAL PATH

INITIAL NODE	FINAL NODE	ACTIVITY IDENTIFICATION	DURATION	DIFFERENCE LS(J)-D(IJ)-ES(I)	DIFFERENCE WITH EXPONENT
1	100	Deep Narrow Gutter	4.75	-0.00	-0.13351440E-04
100	260	Gravity	0.0	-0.00	-0.13351440E-04
260	500	Earth Storage	1.80	-0.00	-0.13351440E-04
500	710	Chopper Pump	7.50	-0.00	-0.13351440E-04
710	810	Small Tanker	5.00	-0.00	-0.13351440E-04
810	900	Broadcast	0.0	0.0	0.0
900	999	Land disposal	0.0	0.0	0.0
The *Difference* with the smallest absolute value greater than zero is from:					
500	750	Small vacuum tanker	9.0	-1.50	-0.15000134E+01

DISCUSSION

As with many activities that are linked to computers, the rule garbage in, garbage out is true in this case. Any error in evaluation of the cost of a component can show up in the final results. The simplest model is often the best to obtain practical results because one can better keep track of inputs.

An examination of individual components may determine an element sensitive to the size of operation. The ranking of paths under different sizes of enterprise is the alternative provided by this analysis technique.

Further work remains to be done to verify more alternatives open to the hog farmer.

CONCLUSIONS

The shortest Path Network Analysis program is a powerful way of evaluating alternatives open to farmers in waste management.

ACKNOWLEDGEMENTS

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planting operation, the other two holes can be covered with wax. Hence, this planter can be used for any kind of varietal type.

3. The transportation wheel of this planter was drived by wheel axis of the power tiller. At the same time, the planter was equiped with clutch for controlling the planter to stop dropping of seed during driving on the road of turning in the field.

4. Although this planter have several advantages but for practical use, there are several things to be done on this machine:

① Better ways of sowing operation.

② The design of adjusting row spacing.

③ The mechanism of applying fertilijer at the time of sowing.

④ The design of 4 or 6-row machine.

If such modification could be completed, the efficiency of this machine would be improved.