

MECHANIZED HARVESTING OF SUGAR CANE
A technical, economic and social appraisal

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ABSTRACT

The study attempts a technical, economic and social evaluation of the effect of the introduction of mechanical harvesters into the Trinidad Sugar Industry.

Firstly a technical evaluation of the harvesting system, which incorporates 'Cary' harvesters and 4 wheel drive tractors, was undertaken. By analysing field tests and CARONI LTD. records, the following information was obtained and adjustments made in some cases to show expected future levels:-

	1968	FUTURE
Field Efficiency	65%	75%
Mechanical Efficiency	78%	78%
Reliability	46.5%	54-77%
Harvesting period	110 days	110, 120 days
Extraneous Matter Content	13%	13%
'Pick up' Cane	11.7%	10%
Infield transport	6 tons ev. 15 mins.	7.5 tons ev. 15 mins.

Reliability and harvesting period variations are due to different types of equipment.

Secondly these production characteristics were amalgamated to give a range of harvesting efficiencies which were then costed in two different ways. In method I it was shown that mechanical harvesting would reduce the cost of production by \$15-\$25 per ton of sugar depending on the efficiency achieved. In method II discount cash flow was used to compare various systems of harvesting and the effect of rate of introduction of harvesters. A low capital system was found marginally most profitable over 30,000 acres. The introduction of two harvesters each year instead of four would cause considerable monetary loss, depending on the efficiency of the system. A likely figure is \$1,200,000 over 5 years.

The social study involved estimation of the reduction of job opportunity from a fast turn over to mechanisation and investigation of the unemployment situation by questionnaire. The unemployment situation was very severe but would only be temporarily and fractionally alleviated by retarded mechanization, a course that threatens the viability of the Trinidad Sugar Industry.

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INTRODUCTION

1. INTRODUCTION

'Be it resolved that Government be requested to institute an enquiry into the economics of mechanization in the sugar industry'
This amendment was moved on a motion before the Trinidad and Tobago House of Representatives on February 23rd 1968 calling for a complete ban on sugarcane harvesters, the cause of mass unemployment in the sugar belt. Previous to moving this amendment the Minister of Agriculture suggested that the sugar industry was failing to honour the (1965) Industrial Court agreement which had ruled that mechanized harvesting could be introduced providing there was no retrenchment of labour.

What are the reasons for the Government's keen interest in a privately owned industry? To quote from REUBENS and REUBENS (1962):-
"Economic changes which tend to displace labour from existing employment are a matter of public concern in all nations. But such changes are particularly disturbing in the primary producing countries whose economies are not highly diversified, are not growing rapidly and are already plagued with widespread unemployment and under-employment. Public policy is therefore compelled to face , as a crucial problem, the issue of employment versus productivity."

This project attempts to balance the effect that mechanized harvesting will have on the productivity of the sugar industry, on the one hand; against the rise in unemployment which will result on the other. As far as possible, facts on both the potential of the harvester and the social problem were established by personal investigation.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1. The Advantages of Mechanized Harvesting.

Six principal advantages of mechanized harvesting are enumerated by BARNES, (1964). They are:-

- a. Higher productivity of man power.
- b. Easier maintenance of cane processing schedules.
- c. Flexibility and speed of working with avoidance of process losses caused by stale cane.
- d. Reduction of field wastage of cane.
- e. Labour economies in numbers employed and associated services including supervision.
- f. Lessening of fire risk to standing cane through the greatly reduced amount of labour in the fields at harvest.

HUMBERT (1963) states that mechanization is a 'must' but stresses the disadvantages rather than the advantages. These include soil compaction and puddling, trash in the mill and social problems. BOYCE (1963) discusses the labour imbalance resulting from mechanization of all techniques except harvesting. The maintenance of a large labour force in a rural area to ensure their availability for harvesting is sociologically and economically undesirable.

The main theme of most authors, when discussing the benefits of mechanization, is productivity (BARNES, 1964; BOYCE, 1963; HUMBERT, 1963). They discuss man hours per ton of sugar, comparing in particular Puerto Rico and Hawaii. The U.S.D.A. Sugar Report (1961) states that in Puerto Rico 89 man hours are required to produce a ton of sugar, comparable figures for Louisiana and Hawaii being 48.5 and 17 respectively. PETERSEN, (1964) points out that labour costs and number of man hours per ton of sugar reflect changes in cost of production only if related to the quantity of cane required to produce one ton of raw sugar. For example the cost of labour in Puerto Rico is one third that of Hawaii and yet Hawaii has a lower labour cost per ton of sugar due both to lower labour input and to a better cane : sugar ratio.

With respect to manual productivity the Australian cane worker will cut up to 13 tons of cane per day in comparison with the West Indian who will not do more than 3 tons (HUMBERT, 1963). It is interesting to note that in Puerto Rico labour efficiency has declined. (BREWER, 1964).

1958	5.4 tons/day	
1959	4.09	"
1963	3.64	"

To quote from the opening address at the Massey Ferguson Conference by Mr. J.W. BEITH (1964):- 'Costs of production are rising. As they increase a number of acres, at present productive but marginal or unsuitable for mechanization, will go out of operation. At the same time labour in a number of areas is unsettled and highly sensitive in its relationship with management ---. The incentive to mechanize is therefore obvious since production costs alone can be reduced by as much as 50% through cheaper harvesting and handling costs. Moreover the employee under a mechanized system eventually achieves a superior status by specialization.'

2.2. Mechanized Harvesting Experience throughout the World.

2.2.1. Hawaii

DUNCAN (1960) reviews the history of harvesting in Hawaii. The first harvester was demonstrated by Henry G. Ginaca in 1906 but there was little or no progress for the next 30 years. In 1937, grab harvesting was started at Ewa Plantation Company. In 1940 the tractor mounted push-rake for uncut cane was introduced and became the standard tool for piling and windrowing cane. These very crude methods compensated for the considerable labour shortage brought on by the war. They could not be regarded as a final solution because of field damage, sucrose loss and cleaning plant costs. Since 1936, 29 different self propelled cane cutters and harvesters have been tried in Hawaii. CARRAS (1966) reviews the six lines of approach that have been tried:-

- a. Push-rake - grab load.
- b. Vee cut - then push rake.
- c. Vee cut - pick up transport - roadside dump.
- d. Cutter transport - into windrows.
- e. Grab
- f. Cut load.

Most authors (BOYCE, 1963; HARKNESS 1967; HUMBERT, 1963) point out the abnormality of the Hawaiian crop in that it is a two year crop with yields reaching a maximum of 120 tons. Consequently its problems are somewhat different from other parts of the world. BOYCE (1963) lists the following factors as intimately concerned with mechanical harvesting in Hawaii:-

- (1) methods of loading and transport
- (2) juice losses during harvesting
- (3) handling losses of cane left in the field
- (4) losses due to trash soil and water being mixed with the cane
- (5) field damage affecting the productivity of the next crop

Of the machines developed in Hawaii two are of most general interest. The first, as described by Burton (1960), is a radical departure from the general trend of harvesters; being a forage type harvester for recumbent cane. Initial tests were encouraging. Maximum tonnage rate was 27.3 tons per hour, load density was 25 lbs. cu. ft. and loss over hand cutting was 1-2%. The important factor of this machine is its low capital and running cost. The second machine of interest is Machine No. 29 the Hawaiian Sugar Producers Association experimental cut load harvester, as described by DUNCAN, (1960). This has a forward speed of 3-4 m.p.h., a capacity of 1 ton/minute and a load density of 16.2 lbs/ft³. DUNCAN, (1964) gives further production figures for this type of machine after more experience had been gained as follows:-

Yield: 114 tons/acre
Burn: very good
Cane cut: 445 tons
Cutting time: 4 hours 12 minutes
Cut load rate: 1.76 tons/minute
Cut load range: 1.3-2.2 tons/minute
Speed: 2.5 m.p.h.
Average load density: 12.8 lbs/cu. ft.
Tare: 4.8%
Cane on ground: 1.5%

If these figures could be normally attained, the problems of mechanized harvesting would be near solution.

2.2.2. Australia

In Australia development of mechanized harvesting has taken place over much the same length of time as Hawaii without the massive burst of development that occurred in the latter country due to labour shortage in the 1940's. According to PEARCE, (1962) 1889 saw the first ideas on mechanized harvesting and the first machines were developed in 1909. In 1950, after 40 years inactivity, the tempo increased and in 1960 2½% of the crop was harvested by machine. By 1966 50% of the crop was mechanically harvested and nearly 100% was mechanically loaded. These figures represent a 42% increase in harvester cut cane over 1965 (HARKNESS 1967). The slower initial development of mechanized harvesting is due to (a) the farm rather than the plantation basis of the crop (b) the less acute labour shortage and (c) the factories demand for high quality cane (HARKNESS, 1967; HUMBERT, 1963; PEARCE, 1962). This initial slow rate of development was made possible, cost wise, by the intermediate step of introducing mechanical loading (PEARCE, 1962).

ATKINSON et al, (1965) categorise three main determinants which are:-

- a. the physical nature of the crop
- b. the environment
- c. the demands of the mills

VALLANCE (1966) reports on investigations into harvesting operations in Queensland. He stands out strongly in favour of whole stalk harvesters, the disadvantages of chopper harvesters being rapid deterioration of chopped cane, increased cost of transport through the necessity to provide bins and the inferior capacity of a chopper harvester in relation to outlay. Extraneous matter determinations showed a figure of 97% sound cane. Rate of deterioration of sugar depend on weather conditions. A delay of 2-3 days may result in 10% loss of sugar. WHITAKER (1962) makes three points. Mechanized harvesting can reduce time lag between cutting and milling at the week end. Contractors should be discouraged because they are likely to have low work standards and to absorb a considerable cost saving whose benefit should go to the farmer. Finally it may be necessary to sacrifice yield per acre for easy harvesting. QUAID (1962) stipulates his criteria for choosing the type of in field transport. These are mill transport and reception, harvesting methods, weather conditions, size of farm and cane field terrain.

The Queensland Cane Growers council traced the development of mechanized harvesting as follows:-

1956	2% of total crop	-	182,000 tons
1960	2.7%		
1961	5.4%		
1962	8.7%		
1963	13.4%		
1964	20.0% (estimate)		2,800,000 tons

Several authors, (A.S.P.A., 1962; BAXTER, 1964; WHITAKER, 1962) discuss the part that the Massey Ferguson harvester has played in this development. In 1963, 143 M.F. harvesters cut a total of 1,100,000 tons of cane. HARKNESS (1967) points out that Australia leads the world in number and variety of harvesters; all, with the exception of the Massey Ferguson, stemming from the invention of individual farmers. In 1967 between 50-60% of the Australian crop was harvested mechanically and some factories received up to 90% of such cane. Popular harvesters were the Toft and the Chrifton of the whole stalk type and the Don Mizzi of the chopper type. (ANON 1968).

2.2.3. Louisiana

HARKNESS (1967) reports that Louisiana has achieved 100% mechanical harvesting. Unfortunately the region, which produces 70% of the sugar obtained from cane in the U.S.A. has peculiar conditions so that the system evolved is not applicable elsewhere. According to BOYCE (1964) the operation is one of cut - burn - load, the trash

having to be dessicated before it can be successfully burnt. A mechanical stalk harvester cuts and tops 3-6 rows and places them in a continuous windrow. After burning, tractor mounted loaders load the cane into 3-5 ton carts which transport it either to a transload station or direct to the mill.

MAYEUX (1967) reports on a study of transport costs, taking into account various methods of slinging the cane. Generally he concludes that it is cheaper to transport cane in infield transport up to a distance of 5 miles. Above that distance it is best to transload into a 20 ton road trailer.

RAMP (1956) states that due to the high percent of trash in the form of leaves and soil, there is a loss to the producer and processor of 8-22 lbs sucrose per ton of cane or US \$9.6-\$24 per acre. The same author (1962) reviews the development of a cutter - cleaner - loader sugar cane harvester for use in Louisiana and discusses the advantages of the machine.

2.2.4. Florida

The best review of mechanical harvesting in Florida is by CLAYTON and WHITTEMORE (1966). There are some 200,000 acres of sugar cane in the state, dependant for its manual labour largely on the Jamaican sugar cane workers. In recent years even this imported labour has been short, due to United States labour policy, and there has been an acceleration of interest in mechanical harvesting. It is important to note that all steps except actual cutting of the cane were mechanized before this period. Mechanization of cutting was delayed due to environment problems. These include a large percentage of loose soil types which, coupled with shallow rooting, due to impeded drainage, and periodic winds of high velocity, lead to badly recumbent and tangled cane at time of harvest.

The history of mechanized harvesting is roughly as follows:-

- 1930 Falkiner Machines, belonging to the U.S. sugar corporation were tried extensively but without enough success to warrant further development.
- 1964 $\frac{1}{2}\%$ of total acreage was cut mechanically.
- 1965 1.2% was cut mechanically. This year saw the intensification of interest in mechanical harvesting and the U.S. sugar corporation produced 4 prototype machines. Only the track mounted version was able to operate in all conditions.
- 1966 26 machines were in operation, a number of them on trial only.

HARKNESS (1967) points out that Florida is not among the most important producers of harvesters for export. This can be ascribed to their late entry into the field due to a sufficiency of cheap field

labour. Nevertheless their methods are of considerable interest especially as their overriding concern is with recumbent cane.

2.2.5. Puerto Rico

Puerto Rico must be considered because its economic situation is of particular interest to other Caribbean producers. Little machine development has occurred on the island.

The sugar industry in Puerto Rico has been declining. For a number of years now, it has been unable to fulfil its U.S. quota (EFFERSON, 1965). There are two reasons for this, increased cost of labour and management inertia. In the period 1950 to 1965 wages were doubled but productivity per man only increased 31%. In fact productivity of cane cutters has been dropping (BREWER, 1964). Just recently there has been an upsurge of interest in mechanized harvesting. In 1967 4% of the total crop was mechanically harvested. SMITH (1967) describes how the original resistance to mechanization from the workers gave way to cooperation as the labour shortage intensified.

SMITH (1967) reviews the three types of machine that have been most successful on the island. The Duncan ranks in No. 1 position and harvested 90,000 tons in 1967. The newer Duncana will overcome many of the problems associated with the older version. 45,000 tons were harvested by the Chuck Hart machine which cuts a row and then transfers it to the next uncut row. Thirdly the Cary was also run on a near production basis, the new double scroll improving its performance in lodged cane.

WILLETT (1967) maintains that a saving of \$1.14/ton cane would result from mechanization so that a machine would pay for itself in 2 years, cutting 12,000 tons/year. The Department of Agriculture has allocated US \$400,000 for harvester development.

2.2.6. Summary

Of the 5 countries reviewed, Puerto Rico is most closely comparable with Trinidad but has been just as backward in the development of mechanical harvesters. Hawaii, Florida and Louisiana all have different habits of crop and have tackled their problems in a variety of ways. None of them have been conspicuously successful except in as far as the crude methods employed in Hawaii saved the industry when the critical labour shortage occurred in 1940. Australia is most closely comparable in crop habit and conditions to Trinidad but the form of the industry is different, being based on the farm rather than Trinidad's plantation and small holder production. Correlated with this, the industry is supplied with a greater amount of both managerial and technical expertise. Even the Puerto Rican situation is moving away from the Trinidad one because of the advent of labour shortage, the latter island having severe unemployment in the sugar cane areas.

Hawaii and Australia are the first countries to have achieved successful mechanical harvesting. Trinidad should try to avoid the

crude 'push pile' techniques of Hawaii because the problems that come in its wake, trash at the mill, severe field damage, are nearly as legion as those that it solves. Conventional harvesting has not achieved any major breakthrough. In Australia the principles applied to harvesting are more generally acceptable and many types of harvester have been developed. Unfortunately they are generally of lighter construction and lower capacity than the 'round the clock' machine that is required in the plantation based Trinidad industry. Apart from machinery development each country offers experience in the various associated problems of mechanical harvesting. The main lesson is that there is no single right way of harvesting cane. It appears that Trinidad must remain open to a number of possible developments.

2.3. Development of a Sugar Cane Harvester

Few authors seem to have touched at all deeply on the basic problems of harvesting sugar cane although they are more forth coming about the requirements of a harvester. Articles by PETERSON (1966); RAMP (1956) and GAUNT (1964) are of interest.

PETERSEN'S article is entitled 'Mechanized harvesting - a materials handling problem' which implies some kind of technical analysis. The author disappoints in this respect although he makes some useful points. His major contention is that it is time that sugar producers stopped demanding a special machine for their special conditions and realized that they must meet the designers half way. He asserts, without qualification, that the industry cannot afford custom built machines. Rationalization of production is necessary to suit the machine - for example by converting from banks to ridges, by sacrificing yield for good harvestability and by concentrating production on flat land. The author points out that sugar belongs to the lowest priced group of agricultural commodities in the world. It is particularly susceptible to transport costs because of its bulk.

RAMP (1956) discusses Louisiana conditions with respect to yield, habit, green leaf character, normal elapsed time between cutting and milling, loss resulting from such delay and finally distribution of trash and sucrose in the plant. From these studies requirements for a mechanical harvester were drawn up as follows:-

- i. The harvester should be capable of cutting cleaning and loading sugar cane as one continuous operation.
- ii. The harvester should have a capacity of 10 acres per 9 hour day or 200 tons.
- iii. The average trash content of the cane should be 3% or less.
- iv. The harvester should be capable of opening a field without prior operations.
- v. The harvester should be capable of acting independantly of the hauling or transport tractor.

- vi. The harvester should be capable of cutting all the rows in a field.
- vii. The harvester should be capable of harvesting erect cane up to 50 tons per acre.
- viii. The harvester should be capable of harvesting partially lodged cane.
- ix. The harvester should be economically practical.

GUANT (1964) discusses development of the Massey Ferguson machine. He reviews development of other machines up to the time of its inception and explains how the idea of a chopper machine was arrived at and how problems were overcome by trial and error. The theoretical requirements were:-

- i. The machine should be capable of harvesting any condition of crop.
- ii. The machine should be a true harvester not a cutter. Cane should be delivered loaded for the mill.
- iii. The machine should be within the means of the average farmer.
- iv. The working parts should be independently powered so that functional efficiency did not depend on maintaining a steady forward speed.

Most of Trinidad's requirements are covered by these two sets of criteria except that neither stipulate how much lost cane is acceptable and neither consider 'round the clock' operations.

2.4. Problems Associated with Mechanized Cane Harvesting.

2.4.1. Land Forming

The most extensive review of land forming of sugar lands is by ALLISON (1967) who considers in turn the benefits, approach, cost, choice of machines and after care of newly formed lands. Land forming should

- i. control the flow of surface irrigation
- ii. provide surface drainage for excess rainfall
- iii. enlarge field boundaries
- iv. more fully utilize rainfall

Adaptation for mechanized operation is not mentioned. SMITH (1966) lays down the requirements for mechanization. These include long and regular fields, cross alleys to assist drainage and entry, level fields and uniform ridges. PETERSEN (1966) points out that ridge cultivation, as well as facilitating harvesting, provides better drainage and is easier for manual cutting. HUMBERT (1963) contrasts the well prepared fields of Louisiana with the chaotic conditions of Hawaii and states that,

though land preparation is expensive, it must pay off in the long run. CAMPBELL (1964) studied the cane lands of Grenada and maintains that land forming would improve root room, aid conservation and facilitate mechanized operations. Interestingly BARTLET (1964), a South African sugar lands engineer, emphasizes the importance of land forming for mechanized harvesting although it is very much in its infancy in the country. His requirements are long parallel rows, good tilth, even ground surface, uniformity of stool height and width. He insists on runs of not less than 250 Yards.

In Trinidad the principles of land forming as enumerated above, have been accepted and applied. Standards are good and there is not a great deal of fresh interest to be derived from the literature.

2.4.2. Cane Remaining after Harvesting

A certain amount of cane will inevitably be left in the field after harvesting. 'Pick up' cane adds quite considerably to the cost of mechanical harvesting. GIBSON (1958) in Hawaii reviews 800 determinations of cane left in the field from three different methods of harvesting. The amount left was close to 8 tons an acre for all three methods, equal to US \$90 per acre regular cane. He gives no details of how these figures were determined. There is little information of 'pick up' cane in other countries. In Australia mechanical harvesting is often supported by manual labour so that the 'pick up' of residual cane is probably not considered as a separate operation.

CLAYTON, (1960) describes one of the machines designed in Hawaii to deal with this problem, comparing it with a truck brooming crew. The machine has many limitations but works better than the hand gang in optimum conditions with a manpower saving of 85%.

In Trinidad at present, manual labour is used to load and cart 'pick up' cane and the job is done effectively, albeit with a certain amount of labour dispute. In consequence the problem will assume increasing importance as labour costs rise. The literature is not forthcoming on measures for solution of it.

2.4.3. Extraneous Matter Content of Mechanically Harvested Cane.

According to HUMBERT (1963) milling of cane with trash causes a loss of 10% sugar. GIBSON (1959) in Hawaii estimates an annual loss of US \$22 million for the same reason, \$13 in the field and \$7 in the factory. WATT (1960) estimates that dirty cane costs Hawaii \$11.02 per ton of sugar, taking into account the cost of cleaning plants, dirt and trash disposal equipment and extra haulage equipment.

GIBSON (1960) reports on quite an extensive study of trash content. On two estates in Hawaii he compares the trash content of different methods of harvesting, soil moisture and success of burn being taken into account. Net cane per cent gross material ranges between 60-70% as would be expected from the unsophisticated methods of harvesting. One estate was better than the other, probably due to soil type.

From Australia VALLANCE (1966) reports that extraneous matter was approximately 3% from chopper harvesters, a figure that is hard to believe. HARKNESS (Personal Communication 1968) explains that two factors account for this low figure. Firstly the factories allow 20% lost time for shutting down when the weather makes harvesting of clean cane impossible. Secondly topping is done in the row adjacent to the row actually being harvested and manual labour is provided to clean up tops and trash missed before cutting. Methods of field cleaning by revolving drums and dessication of leaves by the herbicide paraquat are also reported from Australia.

The literature is somewhat unsatisfactory on this major problem of mechanical harvesting. Generally it appears that expensive cleaning plants are necessary but the composition of extraneous matter, dirt, trash, roots etc. and the effect of each of these on milling efficiency have rarely been reported. PETERSON (1966) maintains that soil is much worse than vegetative residues. He suggests that it is better to remove extraneous material at the factory rather than on the harvester to avoid cutting down the productivity of the harvester in bad conditions. Trash content is always greater, the less the burn and the greater the moisture content (ANON 1968).

There is a marked contrast between the Australian and the Hawaiian approach to this major problem. Obviously the Australian approach is preferable if it is compatible with plantation style production existing in Trinidad.

2.4.4. Cane Deterioration

Cane starts to deteriorate in sugar content from the time that it is burnt in the field. This deterioration increases when the cane is cut and more so if it is chopped during mechanical harvesting. BARNES (1964) reports on a study of cane deterioration made by WADDELL in 1957. For example, unburnt trashed cane lost 2% sucrose content in 10 days while burnt cane lost 4½%. Accelerated deterioration sets in 48 hours after cutting.

The specific problem that concerns mechanized harvesting is the accelerated deterioration caused by chopping cane into short lengths. The Australians have come on this problem first as some of their mills receive 90% mechanically harvested cane (WHITTAKER 1962). VALLANCE (1966) states that deterioration depends on the weather but can cost 10% sugar in 2-3 days. He suggests that the problem was so bad that a search for a better whole stalk harvester should be made. However reports suggested that organization of transport in 1967 was so improved as to minimise deterioration (ANON 1968).

It is reported that the bacterial genus Leuconostoc is responsible for deterioration, this bacterium being found on green cane and in the soil. 80% of chopped cane left over a week end deteriorated compared with 2% of unchopped cane. (ANON 1964). KENIRY et al (1967) report on extensive research into the deterioration problem and showed that a delay of 18 hours in dry weather and 14 hours in wet weather was all that could be tolerated. The increased deterioration of chopped cane over long cane is due to:-

- i. the greater area of exposed stalk tissue,
additional sites for the entry of micro organisms.

- ii. extra juice and dirt around the ends providing a good medium for bacteria.
- iii. greater activity of bacteria due to higher relative humidity of storage.

Mechanized harvesting in Trinidad is at present free of this problem due to direct field to factory transport and priority at the mill but it is likely to become of some importance with the introduction of transload stations.

2.4.5. Field Damage

Mechanized harvesting can damage the crop by ripping up stools and by puddling and compaction caused by heavy equipment. HUMBERT (1959) puts forward a figure of 3 tons sugar per acre lost in infield road-ways due to compaction and puddling. Damage to soil physical properties are often severe. GIBSON (1960) discusses field damage with particular respect to stools removed but unfortunately does not correlate this with subsequent yields.

Once again the literature is somewhat unrewarding and serves only in calling attention to possible problems.

2.4.6. Transport

PETERSEN (1966) states that sugar cane is a high volume - low cost product and is therefore particularly vulnerable to transport costs. The major problem is how to rationalize the different requirements of infield and road transport. The requirements for infield transport will depend on soil and climate and those of road on distance to the factory.

As previously mentioned MAYEUX (1967) maintains that it is cheapest to use infield, 3-5 ton, transport direct to the factory, up to a distance of 5 miles. Beyond this distance, transloading to high capacity, high speed vehicles is cheaper. HUMBERT (1963) reviews the advantages of high flotation tyres comparing them with both conventional tyres and tracks. They offer better trafficability and cause less compaction and puddling. The high capacity transport in use in Hawaii is reported (HUMBERT, 1963; BARNES, 1964) but the economics of this method are not examined closely.

Once again the literature is disappointing when searching for guide lines on the correct approach to transport. There is an overall unwillingness to get down to facts and figures, possibly due to the infancy of mechanized harvesting in most areas.

2.4.7. Mill Reception and Factory Planning

STORRAR (1964) covers various aspects of this subject, discussing various types of cleaning apparatus, the advantage of chopped cane in its ease of flow and the capacity and unloading methods of various forms of transport. PAYNE (1968) is quoted as saying that cleaning of mechanically harvested cane is absolutely essential, presumably for Hawaii. The steps involved in wet cleaning are:- thinning, rock removal, washing, detrashing; the method generally removing 75-80% extraneous matter. Dry Cleaning is

receiving more attention. Hawaiian engineers originally tried to implement this on the harvester but soon found it to be more economic at the factory.

2.5. The Social-Economic Problems of Sugar Production

The introduction of mechanization into the sugar industry inevitably results in reduction of labour requirements. The industry must have very certain knowledge of the benefits of mechanization and be aware of the repercussions of its policy.

2.5.1. Economic Problems

SMITH (1967), discussing the Puerto Rico sugar industry, says that, it is widely recognized both within the industry and without, that growers must make a number of changes in sugar cane production to recover an economic position. These changes are loosely termed mechanization. He points out the importance of sugar in the island's economy and maintains that stabilization of production can be achieved by consolidation of small holdings into large ones to facilitate mechanization. RIOLLONO (1967) suggests a nucleus estate approach to the same problem; the estate providing the necessary agricultural services for the surrounding cane farmers. A three stage plan for the rehabilitation of the sugar industry of the Dominican Republic is proposed and mechanization is given priority. (BARRANCO 1967). MOLLET (1961) gives a comprehensive review of labour and capital changes in the Hawaiian sugar industry, massive capital injection occurring at the time of acute labour shortage in the 1940's. EFFERSON (1965) compares the mechanized and thriving rice farming of Guyana with the declining industry in Ecuador, causing the country to change from an exporter to an importer and foreign exchange wasting commodity. He also cites Louisiana as an industry where mechanization was achieved without unemployment problems because of many alternative jobs particularly in the agricultural services industry. REUBENS and REUBENS (1962) examine the sugar industry in Guyana. Because of world surplus of primary products, competition for markets is intense particularly in the case of sugar, having an inelastic demand. There are three determinants that encouraged mechanization and reduction in the labour force; firstly, unwillingness of labour to work possibly leading to labour shortages, secondly, cheapening of capital goods relative to the price of the product and thirdly improvement in management standards. However much aware of the employment problems the hand of the industries management is likely to be forced towards mechanization by the underlying economic and social pressures.

2.5.2. Social Problems

Most primary producing countries face a heavy and increasing pressure of population on an economy whose rate of growth is inadequate and may even be slowing down. HUMBERT (1963) warns 'Mechanization must of necessity proceed slowly not to create more problems than it solves'. No reference was found which actually discussed the repercussions of unemployment in a community of traditional sugar workers. Full employment is generally a high priority objective of any society and displacement is serious when there is no other absorption. REUBENS and REUBENS (1962) list three ways in which the problem may be alleviated, by limiting labour

retrenchment, by aiding retrenched workers and by expanding the economy and employment opportunity. Ultimately what is required is rapid economic expansion and the limitation of population growth.

2.6. The Sugar Industry in Trinidad

'The sugar industry, is the largest private employer in Trinidad and Tobago and any substantial reduction in numbers of its work force would have an impact on the entire nation. Yet, this country is one of the highest cost producers in the world and is facing a situation where only the premium Commonwealth and American prices are profitable' (CARONI LTD. 1966).

2.6.1. The size and importance of the industry.

Caroni Ltd., which produces 90% of Trinidad's sugar, employs 14,000 people. It provides 7% of all exports and 42.8% of non petroleum exports. It earns an export revenue of between \$35 and 50 million dollars and saves a yearly import of \$10 million for sugar which is consumed in Trinidad and Tobago. (CARONI LTD. 1967). The land under sugar cane is 7.1% of total land area and 27.0% of crop land (EDWARDS 1962).

2.6.2. The cost of production

The best method of comparing industries producing similar products in different parts of the world is to compare the labour productivity; especially in sugar which is labour intensive. Then, by taking into account wage differences some idea of the relative cost of production can be obtained. Productivity in the Trinidad Sugar Industry is very low in relation to other areas:-

UNITED STATES	man days/ton sugar
Louisiana	3.5
Florida	2.5
Hawaii	1.94
Puerto Rico	10.03
TRINIDAD	15.21

(Sources - United States U.S.D.A. 1964
Trinidad Caroni Ltd. 1966)

Furthermore over the last 8 years there has been very little increase in productivity as is shown by man day requirements per ton of cane harvested. Wages have risen quite steeply in the same period. A combination of these two factors resulted in a steadily increasing cost of harvesting until 1966. In 1967 productivity per man increased so that, inspite of the recurrent rise in wages, cost of harvesting a ton of cane was reduced (see Fig. 1). The reason for the increase in productivity was partly that, for the first time, self loading trailers and mechanical harvesters played a significant contribution in harvesting.

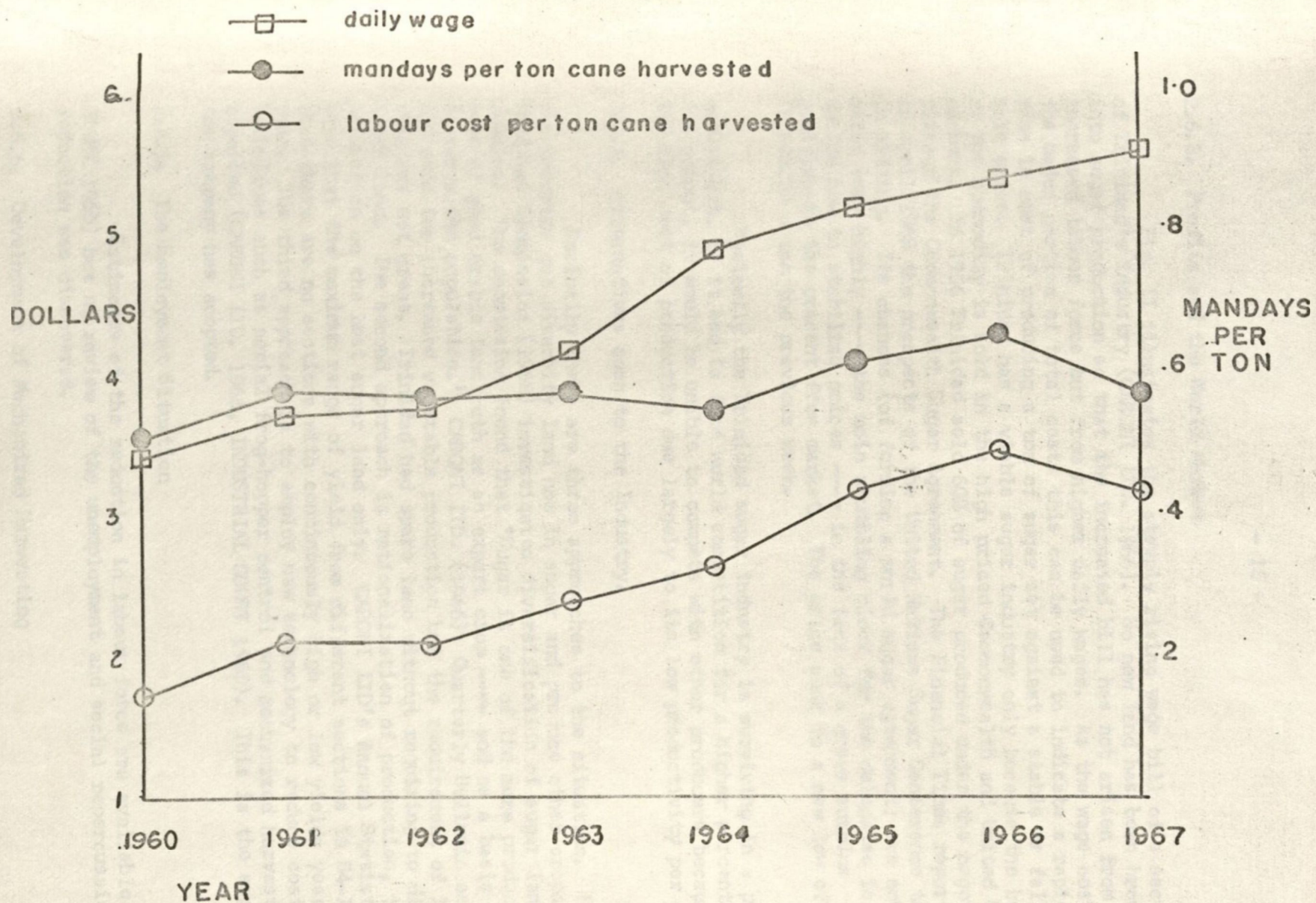


FIG I. HARVESTING STATISTICS

2.6.3. Profits and the World Market

Fig. II illustrates the steeply rising wage bill of a section of Trinidad's industry (CARONI LTD. 1966). No new land has been brought into sugar production so that the increased bill has not arisen from an increased labour force but from higher daily wages. As the wage cost is the major portion of total costs this can be used to indicate a rapid rise in cost of producing a ton of sugar set against a stable or falling sale price. Trinidad has a viable sugar industry only because the bulk of the commodity is sold in the high priced Commonwealth and United States markets. In 1966 Trinidad sold 60% of sugar produced under the negotiated price of the Commonwealth Sugar Agreement. The Financial Times reported in April 1968 the prospects of the United Nations Sugar Conference then in sitting. Its chances (of forming a world sugar agreement) are not rated very highly ---- the main stumbling block for the delegates is to decide how to stabilize prices ---- in the face of a grave surplus position in the present free market. The price sank to a new low of TT \$93.60 a ton the previous week.

Basically the Trinidad sugar industry is surviving in a protected market but, if it had to face world competition for a higher percentage of its output, it would be unable to compete with other producers because of its high cost of production due largely to its low productivity per man.

2.6.4. Alternatives open to the Industry.

Basically there are three approaches to the situation. Firstly the industry can diversify land now in sugar and produce other crops. The Mordecai Commission (1968) investigated diversification of sugar lands in Jamaica. The commission found that 'Sugar is one of the more productive uses of good arable land both as an export crop ---- and as a basic food to serve the population.' CARONI LTD. (1966) Quarterly Bulletin accepted the need for increased vegetable production but the requirement of land for this was not great. Trinidad had spare land without requiring to diversify sugar land. The second approach is rationalization of production, to continue production on the best sugar land only. CARONI LTD's Annual Statistics (1967) show that the maximum range of yield from different sections is 84-114% and that there are no sections with continuously high or low yields year after year. The third approach is to employ new technology to reduce costs. Techniques such as aerial frog-hopper control and mechanized harvesting are reported (CARONI LTD. 1966, INDUSTRIAL COURT 1965). This is the approach that the company has adopted.

2.6.5. The Employment Situation

Estimates of the reduction in labour force are available (INDUSTRIAL COURT 1965) but no review of the unemployment and social repercussions of this reduction was discovered.

2.6.6. Development of Mechanized Harvesting

HARKNESS (1967) reviews the development of mechanized harvesting recounting experiences with the Massey Ferguson 515 and the Cary Combine. The latter was more robust and more able to stand up to Trinidad conditions.

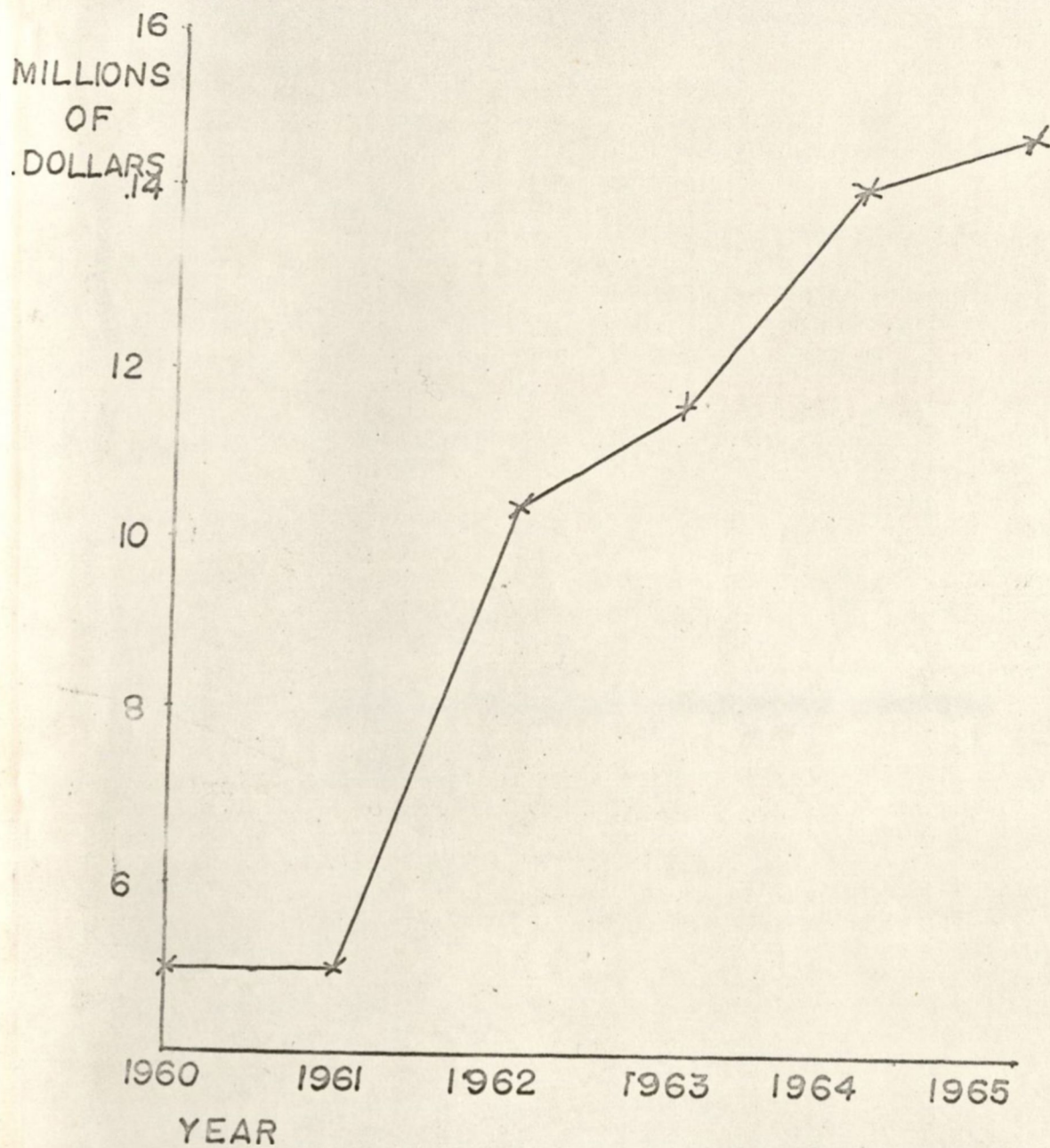


FIG. II. INCREASE OF TOTAL WAGES IN SUGAR PRODUCTION.

(Source : Caroni Ltd. 1966.)

METHODS OF HARVESTING & EXPERIMENTAL TECHNIQUES

RESULTS

3. Methods of Harvesting and Experimental Technique

3.1. Methods of Harvesting

A comprehensive description of harvesting methods is unnecessary for an understanding of the project but a brief sketch of each method is given as background knowledge.

- A. Manual harvesting. After burning, a cutting gang enters the field and cuts and cleans a task of cane, the task being set according to the estimated yield. A loading and carting gang follow with buffalo or mule drawn carts and move the cane to the trace for weighing and loading. Transport to the factory is by rail or road.
- B. Mechanized harvesting. The harvesting group consists of two operational machines and possibly a reserve plus attendant infield transport. After burning the first harvester cuts down the centre of the field and then round either the left or the right hand block, the infield transport shuttling trailers to the trace. The group is supported by a mechanic and a breakdown truck. After harvesting any cane remaining is picked up by hand and carted in the conventional manner. The operation is carried on 24 hours a day by two shifts of operator.

3.2. Experimental techniques

Basically the study is concerned with balancing the advantages which accrue to the sugar company from mechanization against the social problem of unemployment that may result directly from mechanization.

Mechanical harvesting should reduce cost of production of sugar. The first step is to find out how much cost reduction will be achieved, not at the present time, when the operation is in its infancy but in 5 years time or so when an acceptable degree of efficiency is more likely to have been reached. To do this, it is not possible to rely on historic costs. The operation must be examined technically to see how well it is performing now and what potential for improvement there is. Field recording included:-

- i. determining the field efficiency of the harvester.
- ii. measuring transport cycle times.
- iii. determining cane left in the field after harvesting.
- iv. weighing extraneous matter in the harvested cane.

Further details of the techniques employed will be found in the results.

With the additional data supplied by the company a matrix of information on harvesting efficiency was developed. Consideration was then given to the likely future trends of these efficiencies. Where evidence justified, adjustments were made in drawing up a table of expected future production characteristics. From this table, general costings were produced and compared with the historic costs of manual harvesting.

A questionnaire formed the basis for consideration of the social problem.

Discussion and evaluation were assisted by keeping a project log book and diary in which both subjective and objective information was recorded.

4. Results.

4.1. Determination of Field Efficiency

Field efficiency was calculated by timing interruptions in harvesting over a total period of just under 24 hours for the Cary and 4 hours for the Duncana. Table I shows the amount of operating lost time from various causes, a third column presenting what is considered to be a potentially obtainable value. (For full results see Appendix 1.)

TABLE I.
Field Lost Time

	CARY		ESTIMATE	DUNCANA	
	Mins.	%	%	Mins.	%
Length of Time Trial	1365	100.0	100.0	230	100.00
Number of Samples	12			3	
Lost Time - Turn	96.7	7.1	7.1	40.4	17.5
Wait	16.9	1.2	1.2	4.9	2.2
Choke	44.2	3.2	3.2	1.1	0.5
Unload	19.8	1.4	1.4	3.3	1.4
Adjustments	22.2	1.6	1.6	0.9	0.4
No Trailers	240.7	17.6	8.4	51.4	22.3
Interruptions	34.3	2.5	2.5	7.6	3.3
TOTAL	474.8	34.6	25.4	109.6	47.6
FIELD EFFICIENCY		65.4	74.6		52.4
SPEED (MPH)		1.95	1.95		1.65

Notes (1) The figures for the Duncana were not taken over a long enough period of time to be considered accurate. However they do reveal some characteristics of the machine. Firstly, there is more time spent waiting because there is no storage capacity in the elevator for the harvester to be able to continue cutting while the trailer is moving into position. Secondly the machine does not choke so often as the Cary in Recumbent cane.

(2) Lost time 'waiting for trailers' is high, a point that will be further discussed. This category is the only one that is adjusted

for the estimate, reducing it to a figure of 5 minutes for every hour of operation. This allows over 1 minute per trailer and is considered quite adequate when it is remembered that it is theoretically possible to change trailers without stopping due to the Cary's storage capacity.

(3) 'Adjustment' lost time is low and it might be encouraging to see this increased to prevent break downs.

Calculation of field capacity

DATA Yield per acre = 33.2 tons (28 field sample)
 Pick up = 11.7% (Cumulative Harvesting Statistics CARONI
 LTD. March 29th, 1968)
 Harvested = 29.3 tons/acre
 Width of cut = 5' 6"

Field capacity = $\frac{\text{Speed (mph)} \times \text{Width of Cut (ft)} \times \text{Field Efficiency}}{825}$

(1) (1968)	(11) (ESTIMATE)
F.E. = 65.4%	F.E. = 74.6%
F. Capacity = $\frac{1.95 \times 5.5 \times 65.4}{825}$	F. Capacity = $\frac{1.95 \times 5.5 \times 74.6}{825}$
= <u>0.85</u> acres/hour	= <u>0.97</u> acres/hour
= <u>24.9</u> tons/hour	= <u>28.4</u> tons/hour

Conclusion

These determinations show that harvester output this year should be 24.9 tons/hour rising to 28.4 tons/hour in future. From the daily harvester reports, average output this year has been 22.0 tons from the period of 11th January to 30th March. A discrepancy of 3 tons exists which has arisen partly from inaccurate recording of lost time and partly from a bias in the time trial, predominantly stop watch incentive to the operator. The high field efficiency of 74.6% is considered attainable because most fields are well adapted to mechanical operations and because the harvester has a relatively slow forward speed and small width of cut.

4.2. Determination of Mechanical Efficiency

For the period 11th January to 30th March the daily harvester reports recorded lost time due to breakdowns and repairs as follows (Table II).

..... Table II

TABLE II.
Breakdown lost time

Harvester No.	C A R Y					DUNCANA	
	403	404	405	406	407	TOTAL	408
Hours Worked & Lost Time	391	1202	1163	1230	1226	5212	264
Hours Lost for Repairs	116	329	491	196	178	1124	90.8
% Hours Lost for Repairs	29.7	26.8		15.2		21.6	34.5
Mechanical Efficiency %	70.3	73.2		84.8		78.4	65.5

Notes (1) In 1966 the mechanical efficiency was 94.3%, in 1967 it was 82.5% (HARKNESS, 1967). A lower figure was to be expected this year due to the initiation of 24 hour operations.

(2) There is a considerable range of efficiencies and the figure of 84.8% returned by 406/407 is encouraging although it is difficult to understand why this is so superior to 404/405. Against this 403 is recorded at 70.3% and this does not include a number of whole days out of action due to breakdown. Admittedly there has obviously been less urgency to repair 403 which has operated as a reserve machine but, none the less, it does seem to indicate repair time increasing with age, 403 having seen an extra year's operation.

(3) The Duncana was only an experimental machine and its mechanical efficiency is low due to operator and mechanic inexperience.

Conclusion

A mechanical efficiency of 78.4% was achieved in the first three months of 1968. In considering adjustments to this figure the following factors were taken into account.

- a. 406/407 achieved a mechanical efficiency of 84.8% this year.
- b. Modifications are to be made to the first conveyor which caused a lot of lost time.
- c. Repairs and maintenance crews will be more experienced and better equipped.
- d. With most machines, breakdown time increases sharply with age. (ASAE Yearbook 1965).

At the present state of knowledge, it is felt that there is no justification for adjusting mechanical efficiency.

4.3. Reliability of harvesting System

Owing to the fact that there was only one reserve machine for two groups, the reliability of the system was worked out for the four operational harvesters. The increased reliability resulting from having a reserve was calculated separately. Table III shows the time lost from various causes for the period 11th January to 30th March. (see Appendix II for full data)

TABLE III.

Reliability of 4 operational harvesters

	HOURS	%
Hours Worked & Lost Time	4821	100.0
Lost Time - Fuelling	95.6	1.98
Travelling	174.0	3.60
Servicing	295.8	6.13
In Field Transport	93.6	1.94
Trailers	594.0	12.30
Repairs	1008.4	20.92
Weather	156.4	3.20
Stuck Trailers	36.1	0.75
Others	126.0	2.61
TOTAL -	2580	53.5
Operating Time	2241	46.5

The reliability of the 4 operational harvesters is 46.5% compared with 78.4% in 1966 and 58.7% in 1967 (HARKNESS 1967). Main causes of this downward trend are inadequate trailers and increased repairs. The following adjustments are made to these lost times according to likely future development.

- (a) Fuelling and travelling remain unadjusted - immediate improvements are unlikely.
- (b) 'Servicing' lost time should be cut with the proper use of a spare harvester. A reduction of 50% is suggested as a 'guestimate'. It will be some time before the advantages of a spare harvester can be evaluated.

- (c) 'Infield transport' lost time is unadjusted. Possibly the introduction of cane buggies will improve this but it must be remembered that these will be travelling some distance from the field with consequent less control. The costings that follow assume 2 infield transports to one harvester as against $1\frac{1}{2}$ 'infields' in 1968 but it is presumed that they will have to cope with a considerably increased tonnage per hour from the harvesters so that, again, no adjustment is considered justifiable.
- (d) 'Road transport' lost time can obviously be cut to a minimum depending on capital availability for purchasing carriers: 5% lost time is accepted for the future reducing to 3.5% if buggies and a transload station are introduced. It is important that only a small tonnage is allowed to be stockpiled at the transload station or deterioration problems will arise.
- (e) Repairs have already been discussed (Section 4.2.)
- (f) Lost time from weather, on days on which some operating is possible, is reduced to 1% if buggies are introduced. Equally no lost time from trailers getting bogged will occur with buggies due to their high flotation.
- (g) Lost time from other reasons is unadjusted.

Before summarising these adjustments an examination of the rationale behind having one reserve machine for two operational ones is necessary. In the first three months of 1968 the spare machine harvested 3239 tons and achieved 168 hours operating time. (See Appendix II). It must be assumed that two reserves would have operated for 336 hours, raising the operating time of both groups to 2577 hours, 53.4% of total time. Therefore, with present organization, the availability of a reserve machine increases the reliability of the system by 6.9%. It should be noted that the reserves lost time is not included in the calculation and that the percentage is of the total time of the 4 operational machines only.

The discussion must be pursued further because this calculation does not take cognisance of the possibility that some of this 'extra' would have been achieved by the operational harvesters anyway if no reserve had been available. In a survey of 20 days on which one group had a reserve, the other none, the group of three only achieved an extra 17 hours operating time and 8 tons of cane over the period (see Appendix III). In this survey, the reserve was 11 days with one group and 9 days with the other so that this poor showing cannot be explained by the efficiency of the group with which it was operating.

For the sake of cost comparison, an upper limit of increase in reliability to be derived from a reserve machine will be calculated.

The time when the spare machine should operate is when either of the operational machines are broken down or being serviced. As far as can

be predicted at present, this is equal to 27% of available time. The problem is to predict how much of this available time, the reserve can utilize. The reliability of the reserve will be no better than the operational harvesters - possibly worse. Equally the reserve can replace only one operational harvester if both breakdown together. At present the reserve is taking up about 25% of utilizable time. From these considerations it seems unlikely that the reserve will take up more than 50% of available time which is equal to increasing the reliability of the system by 13.5%.

Summary of System Reliabilities

Table IV summarizes the adjustment to reliability that have been discussed in section 4.2 and 4.3.

TABLE IV.
System Reliabilities %

	1968	ESTIMATE	Estimate with Buggy Transport
Lost Time - Fueling	1.9	1.9	1.9
Travelling	3.6	3.6	3.6
Service	6.1	6.0	6.0
Infield	1.9	1.9	1.9
Trailers	12.3	5.0	3.5
Repairs	20.9	20.9	20.9
Weather	3.2	3.1	1.0
Stuck Trailers	0.8	0.8	-
Others	2.6	2.6	2.6
TOTAL -	53.5	45.8	41.4
RELIABILITY	46.5	54.2	58.6
'RESERVE'	6.9	13.5	13.5
RELIABILITY WITH RESERVE	53.4	67.7	72.1

Note 'Reserve' denotes the increase in reliability to be achieved with a reserve machine.

4.4. Weather Influence.

When some harvesting is done on wet days, time lost due to rain is recorded in the daily report. This time loss has already been taken into account (Section 4.3.) However there are also times when rainfall has been intense enough to halt harvesting altogether for a day or two. In the

first three months of 1968, the following time was lost from both causes:-

January 2.27" - 220 hours

February 2.14" - 660 hours

March 2.42" - 120 hours

Obviously the intensity of rainfall is more important than the total amount for, in February, nearly all the rain fell in a space of 3 days causing complete stoppage of harvesting for a period. This fact makes it very difficult to assess the average number of days that will be lost each year until there is enough data to determine the critical intensity. At present harvesting is stopped during rain because infield transport fails and this will be affected by soil type as well as rainfall intensity.

Some indication of the influence of weather may be gained from a study of total rainfall. Rainfall for the last ten years is as follows (Table V).

TABLE V.
Rainfall 1957-1967 (Ins.)

Month	Average	Highest	Lowest
January	2.11	4.71	0.69
February	1.11	1.79	0.28
March	0.67	1.40	0.13
April	2.06	4.53	0.21
May	3.89	9.17	0.91

May has an average about twice any other month with two years in the period up to 8-9". Therefore a harvesting season from January to mid May is considered, a period of 135 days; 11 Sundays and 3 Public Holidays included. The problem is to decide how many of the total days available will be lost through weather. The record so far is:-

1966 January - May 9.07" 12 days lost

1967 January - May 12.28" 13 days lost

1968 January - March 6.83" 4 days lost

Average rainfall for the period January to May over the last ten years was 9.8" with a range of 3.88" to 17.11". This is a tremendous range and suggests that anything from 0 to 24 days may be lost in the period. Obviously some harvesting system of great flexibility will be required if such a variation is actually experienced. Possibilities are discussed in Chapter 7.

For the purpose of this study it will be assumed that 110 days

harvesting are available with the present infield transport system. 10 days will be added if cane buggies are introduced. This is thought to be the maximum additional days that the buggy might achieve.

4.5. Transport Cycles

4.5.1. Infield Transport Cycles

Cycle times were recorded on 8 separate days (see Appendix IV). Table VI shows the average figures obtained.

TABLE VI.
Infield Cycle Times (Mins.)

	AVERAGE	LONGEST	SHORTEST
Loading Time	15.17	15.80	12.80
Travelling Time	6.62	13.70	3.20
Unhook & hook up	0.80	0.90	0.70
Total Cycle Time	22.58	30.40	17.25
Weight of Cane (Tons)	5.97	6.00	5.56

An important point to note is that very little delay time was recorded ~~from~~ for infield transport. This arises from two reasons, shortage of infield transport ($1\frac{1}{2}$ units per harvester) and short supply of trailers. In future some delay in infield cycles will be necessary so that the harvester is kept fully employed. The figures generally indicate a rate of loading of 6 tons every 15 minutes or 24 tons/hour which agrees quite well with rate expected from field capacity determinations (see section 4.1.) On one day average loading time for 7.8 tons was recorded at 10.5 minutes (trailer weight average for whole day). Obviously higher yielding cane will decrease the loading time providing the harvester can maintain its forward speed.

4.5.2. Road transport cycles.

Although road transport systems were not considered in detail in this study, some cycles were recorded on one day to throw some light on the problem. Unfortunately the day was not representative because it was one of the few days on which the harvesters were working slowly and there were always trailers and transport standing at the trace. None the less large variations both in cycle time to the factory and in delay in the field were recorded as shown in Table VII.

..... Table VII

TABLE VII.
Road Cycle Times

	CYCLE	DELAY
Average (mins.)	82	97
Longest (mins.)	101	233
Shortest (mins.)	43	29

4.6. 'Pick up' Cane

From data collected from three sections, the following figures for amount of cane picked up after the harvester were determined as shown in Table VIII.

TABLE VIII.
Pick up Cane

Number of fields	28
Total area	460 acres
Average yield	33.2 tons/a
Average 'pick up'	3.2 tons/a
Highest 'pick up'	7.2 tons/a
Lowest 'pick up'	1.6 tons/a

(Data in Appendix Va)

'Pick up' cane is therefore 10.6% of harvested cane. Caroni Ltd's cumulative data shows pick up cane as 11.7% of harvested cane. In chapter 5 10% is taken as a convenient figure.

Various attempts were made to determine pick up cane by field sampling. In the most successful, a strip of four ridges was taken right across the field and divided into 15 blocks 50' x 22'. The cane on the ground was separated into five categories and weighed, giving the following results. (Table IX)

TABLE IX.

Lost Cane

Type	lbs.	%
Long cane	1638	57.8
Chopped cane	672	23.7
Tops	248	8.7
Stubble	232	8.2
Mashed cane	45	1.6
TOTAL	2835	100.0
Lost cane -	3.5 tons/acre	

(Data in Apprndix Vb)

Explanatory note. 'Long Cane' denotes whole stalks which the harvester missed altogether. 'Chopped cane' has been fed into the machine but was thrown out again before reaching the trailer. 'Tops' denotes cane that has been topped too low, leaving good cane with the trash. This cane has a low sugar content and it is probably better to reduce trash by topping low then to try to incorporate the highest possible yield. 'Stubble' arises from cutting too high. Here again a compromise has to be reached between leaving good cane and incorporating roots and soil. Mashed cane occurs when the machine chokes. The block nearest the entry trace had over double (407 lbs.) the weight of pick up cane of the average of the other 14 blocks (180 lbs.). This emphasizes the importance of careful entry of the machine. On a later occasion roughly the same method was employed with only three plots picked at random rather than a strip across the field. Lost cane worked out at 10.9 tons/acre with a much higher (42%) proportion of chopped cane. It is felt that not enough of the field was sampled in this case. A third method was tried, weighing cane from a length of 100 feet of a single ridge. The first three readings gave values of 43.67.140 lbs. indicating that a very large number of such samples were required to obtain an accurate figure for the field.

As can be judged from the above, difficulty was experienced in field sampling of lost cane. The first method was obviously the most satisfactory but reveals variations in the length but not the width of the field and was extremely time consuming. The third method was also very time consuming because lack of trailers made harvester cycle rounds very slow. However it is less labour consuming and might give a more complete picture than method I if a strip is taken across the field near each end.

4.7. Trash Content of Cane

According to Watt (1960) dirty cane costs Hawaii U.S. \$11 per ton of sugar. Therefore, in determining the reduction of costs to be achieved by mechanical harvesting, some assessment of the dirty cane problem is

required. Sampling mechanically harvested cane is not easy. The most accurate method is obviously to empty a whole trailer on to a clean surface and sort the contents but this involves a lot of labour and time. A method was devised spreading a tarpaulin on the top of a full trailer and delivering about $\frac{1}{2}$ a ton of cane into it. The tarpaulin could be rolled off on to the ground for sorting. Three determinations were made using this method, as shown in Table X.

TABLE X.
Extraneous Matter Content

	CARY I		CARY II		DUNCANA	
	lbs.	%	lbs.	%	lbs.	%
Whole Cane	643.0	86.7	789.0	86.5	768.0	81.4
Roots	38.9	5.2	18.0	2.0	38.0	4.0
Tops	17.1	2.3				
Trash	17.2	2.3	87.0	9.5	74.0	7.8
Soil	25.8	3.5	18.0	2.0	64.0	6.8
TOTAL	742.0	100.0	912.0	100.0	94.4	100.0
Total Extraneous Matter		13.3		13.5		18.6

Conditions. Cary I 1st Ratoon: Variety 41227
Output: 31.3 tons/hour
Harvesting Conditions: good.

Cary II 1st Ratoon: Variety 41227
Duncana Output: Cary 25.2 tons/hour
Duncana 13.3 tons/hour
Harvesting conditions: weather good
cane moderately recumbent
soil 'blocky'

Extraneous matter content was higher than expected especially for the Cary I determination when conditions were very good. The Duncana is likely to have a high soil content because of the ridge shaving action of its cutter. It should be noted that the weight of roots is slightly high because the sample contained a small amount of cane to which the roots were attached. This basal cane has a good sugar content.

Further figures on extraneous matter content were obtained from Woodford Lodge factory where trash comparisons were made between the three types of cane that the mill receives. These comparisons were made by taking samples of about 10 lbs. from the cane after knifing. Each sample was placed in a drum of water and amount of trash determined by flotation (SCHUMACHER Personal Communication 1968).

	1st Period	2nd Period
Farmers' Cane	6.0%	6.6%
Estate Hand Cut	6.6%	5.8%
Mechanical Harvesting	8.8%	5.2%

It can be seen that these figures are in reasonable agreement with the two field determinations for combined tops and trash.

In discussion with the factory manager, the following points emerged. Trash content increases with mechanically harvested cane if the cane is recumbent. But the major problem with mechanized harvesting is the relatively large amount of soil that enters the mill. This soil may have the following effects:-

1. Mill and pumps wear out much quicker due to abrasion.
2. Quality of unrefined sugar is reduced.
3. Clarification takes much longer so that tons ground per day is reduced.

Particular trouble arises with soils with high clay content as this fraction takes a long time to settle.

The trash and dirt content of mechanically harvested cane is going to be of major importance as mechanical harvesting is increased. Every effort should be made to avoid the necessity of expensive cleaning equipment by better field support and close attention to height of cutting and topping.

4.8. Summary of Results

1. Field efficiency 1968: 65.4%
Estimates: 74.6%
2. Mechanical efficiency 1968: 78.4%
Unadjusted: 78.4%
3. System reliability 1968: 46.5%
Estimates: 54.2%
67.7% with reserve
58.6% with buggies
72.1% with buggies and reserve
4. Harvesting period 1968: 110 (for costing)
Estimate: 110 days conventional trailers
120 days cane buggies
5. Transport cycles (infield)
1968: 6 tons 15 minutes
Estimate: 7.5 tons 15 minutes
6. Pick up cane: 10%
7. Extraneous matter content: 13%

The following table shows the estimated cost of mechanized harvesting for various crops in the United States, based on data from the Bureau of Agricultural Economics, U.S. Department of Agriculture, for the year 1934. The costs are given in dollars per acre, and are based on the assumption that the land is well prepared for the crop, and that the machinery is in good working order.

Crop	Harvesting	Threshing	Winnowing	Stacking	Unloading	Total
Wheat	1.00	1.00	1.00	1.00	1.00	5.00
Barley	1.00	1.00	1.00	1.00	1.00	5.00
Oats	1.00	1.00	1.00	1.00	1.00	5.00
Rye	1.00	1.00	1.00	1.00	1.00	5.00
Timothy	1.00	1.00	1.00	1.00	1.00	5.00
Alfalfa	1.00	1.00	1.00	1.00	1.00	5.00
Hay	1.00	1.00	1.00	1.00	1.00	5.00
Grain Sorghum	1.00	1.00	1.00	1.00	1.00	5.00
Soybeans	1.00	1.00	1.00	1.00	1.00	5.00
Peas	1.00	1.00	1.00	1.00	1.00	5.00
Beans	1.00	1.00	1.00	1.00	1.00	5.00
Flax	1.00	1.00	1.00	1.00	1.00	5.00
Linseed	1.00	1.00	1.00	1.00	1.00	5.00
Canola	1.00	1.00	1.00	1.00	1.00	5.00
Sunflower	1.00	1.00	1.00	1.00	1.00	5.00
Cotton	1.00	1.00	1.00	1.00	1.00	5.00
Wool	1.00	1.00	1.00	1.00	1.00	5.00
Sheep	1.00	1.00	1.00	1.00	1.00	5.00
Goats	1.00	1.00	1.00	1.00	1.00	5.00
Pigs	1.00	1.00	1.00	1.00	1.00	5.00
Cattle	1.00	1.00	1.00	1.00	1.00	5.00
Horses	1.00	1.00	1.00	1.00	1.00	5.00
Donkeys	1.00	1.00	1.00	1.00	1.00	5.00
Mules	1.00	1.00	1.00	1.00	1.00	5.00
Chickens	1.00	1.00	1.00	1.00	1.00	5.00
Ducks	1.00	1.00	1.00	1.00	1.00	5.00
Geese	1.00	1.00	1.00	1.00	1.00	5.00
Swine	1.00	1.00	1.00	1.00	1.00	5.00
Poultry	1.00	1.00	1.00	1.00	1.00	5.00
Bees	1.00	1.00	1.00	1.00	1.00	5.00
Ants	1.00	1.00	1.00	1.00	1.00	5.00
Termites	1.00	1.00	1.00	1.00	1.00	5.00
Spiders	1.00	1.00	1.00	1.00	1.00	5.00
Flies	1.00	1.00	1.00	1.00	1.00	5.00
Beetles	1.00	1.00	1.00	1.00	1.00	5.00
Grasshoppers	1.00	1.00	1.00	1.00	1.00	5.00
Crickets	1.00	1.00	1.00	1.00	1.00	5.00
Frogs	1.00	1.00	1.00	1.00	1.00	5.00
Toads	1.00	1.00	1.00	1.00	1.00	5.00
Salamanders	1.00	1.00	1.00	1.00	1.00	5.00
Snakes	1.00	1.00	1.00	1.00	1.00	5.00
Lizards	1.00	1.00	1.00	1.00	1.00	5.00
Turtles	1.00	1.00	1.00	1.00	1.00	5.00
Monkeys	1.00	1.00	1.00	1.00	1.00	5.00
Apes	1.00	1.00	1.00	1.00	1.00	5.00
Elephants	1.00	1.00	1.00	1.00	1.00	5.00
Rhinos	1.00	1.00	1.00	1.00	1.00	5.00
Giraffes	1.00	1.00	1.00	1.00	1.00	5.00
Zebras	1.00	1.00	1.00	1.00	1.00	5.00
Antelopes	1.00	1.00	1.00	1.00	1.00	5.00
Deers	1.00	1.00	1.00	1.00	1.00	5.00
Stags	1.00	1.00	1.00	1.00	1.00	5.00
Bears	1.00	1.00	1.00	1.00	1.00	5.00
Wolves	1.00	1.00	1.00	1.00	1.00	5.00
Coon	1.00	1.00	1.00	1.00	1.00	5.00
Skunk	1.00	1.00	1.00	1.00	1.00	5.00
Possum	1.00	1.00	1.00	1.00	1.00	5.00
Badger	1.00	1.00	1.00	1.00	1.00	5.00
Beaver	1.00	1.00	1.00	1.00	1.00	5.00
Muskrat	1.00	1.00	1.00	1.00	1.00	5.00
Weasel	1.00	1.00	1.00	1.00	1.00	5.00
Ermine	1.00	1.00	1.00	1.00	1.00	5.00
Otter	1.00	1.00	1.00	1.00	1.00	5.00
Sea Lion	1.00	1.00	1.00	1.00	1.00	5.00
Walrus	1.00	1.00	1.00	1.00	1.00	5.00
Manatee	1.00	1.00	1.00	1.00	1.00	5.00
Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Whale	1.00	1.00	1.00	1.00	1.00	5.00
Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
Sperm Whale	1.00	1.00	1.00	1.00	1.00	5.00
Blue Whale	1.00	1.00	1.00	1.00	1.00	5.00
Fin Whale	1.00	1.00	1.00	1.00	1.00	5.00
Gray Whale	1.00	1.00	1.00	1.00	1.00	5.00
Black Whale	1.00	1.00	1.00	1.00	1.00	5.00
Minke Whale	1.00	1.00	1.00	1.00	1.00	5.00
Harbor Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
Common Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Spinner	1.00	1.00	1.00	1.00	1.00	5.00
Striped Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Atlantic Humpback	1.00	1.00	1.00	1.00	1.00	5.00
North Atlantic Right Whale	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Minke	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Humpback	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Right Whale	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Elephant Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Lion Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Fur Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Walrus	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Manatee	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Elephant Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Lion Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Fur Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Walrus	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Manatee	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Elephant Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Lion Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Fur Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Walrus	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Manatee	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Elephant Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Lion Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Fur Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Walrus	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Manatee	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Elephant Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Lion Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Fur Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Walrus	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Manatee	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
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Antarctic Lion Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Fur Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Walrus	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Manatee	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Elephant Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Lion Seal	1.00	1.00	1.00	1.00	1.00	5.00
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Antarctic Manatee	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
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Antarctic Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Elephant Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Lion Seal	1.00	1.00	1.00	1.00	1.00	5.00
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Antarctic Manatee	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Elephant Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Lion Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Fur Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Walrus	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Manatee	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Elephant Seal	1.00	1.00	1.00	1.00	1.00	5.00
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Antarctic Fur Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Walrus	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Manatee	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Porpoise	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Elephant Seal	1.00	1.00	1.00	1.00	1.00	5.00
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Antarctic Dolphin	1.00	1.00	1.00	1.00	1.00	5.00
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Antarctic Lion Seal	1.00	1.00	1.00	1.00	1.00	5.00
Antarctic Fur Seal	1.00	1.00	1.00</			

5. Cost of Mechanized Harvesting

5.1. Output Potential

At present there are too many unknown factors to determine accurately what saving will result from mechanized harvesting. Potential field efficiency, reliability and weather influences are difficult to estimate from present experience. Instead a number of output potentials have been calculated ranging from the '1968' figures to carefully adjusted optima that could be achieved with present equipment and the introduction of cane buggies, Table XI.

TABLE XI.
Output Potentials

CATEGORY	1968	INT.	I	II	III	IV
Planned Working Time	20	24	24	24	24	24
Reliability %	46.5	54.2	54.2	58.6	67.7	72.1
Operating Hours/Day	9.3	13.0	13.0	14.1	16.2	17.3
Field Efficiency %	55	60	75	75	75	75
Output Tons/Hour	22	24	30	30	30	30
Output Tons/Day	205	312	390	423	486	519
Season : Days	110	110	110	120	110	120
Hours/Season	1023	1430	1430	1692	1782	2076
Output Tons/Season	22,550	34,320	42, 00	50,760	53,660	62,280

Notes 1. '1968' Some figures have been adjusted so that output in tons/day is the actual figure achieved even if the actual combination of factors is not correct through recording or experimental defects.

2. The intermediate figure is considered achievable next year.

3. I - IV are all worked from the reliabilities estimated in Chapter 4.

- I All harvesters operating; with existing infield transport.
- II All harvesters operating; with buggy type transport.
- III Groups of 2 harvesters operating with one in reserve, existing infield transport.
- IV Groups of 2 harvesters operating with one in reserve, buggy type transport

Highest level of production involves an output $2\frac{1}{2}$ times what has been

achieved this year, but is still below some of the original estimates of output potential made for example in the Industrial Court in 1965.

5.2. Methods of Costing

Two methods of costing have been used. In method I the cost per ton of cane at the various levels of productivity shown in Table XI has been determined. The costs so calculated are easily compared with the cost of harvesting one ton manually. This method is not particularly suitable for assessing the relative merits of different amounts of investment or the monetary loss that the industry will forego in slowing down its change over to mechanization.

Method II employs Discount Cash Flow (D.C.F.) The rationale of D.C.F. is discussed fully in Appendix VI A. According to DALTON (1967) the method is almost 'impeccable' judged by standards of economic theory. Basically D.C.F. takes account of the fact that the dollar realised from an investment today is worth more than the dollar realized tomorrow because, in the first situation, the money is available for consumption or investment in the intervening period. The method is particularly applicable to the sugar industry with its problem of rate of introduction of mechanization.

5.3. Method I

5.3.1. Assumptions

A. Cary Harvester - Initial cost \$85,000
Life 6500 hours

- depreciated on an hourly basis
- interest, insurance, tax and housing estimated at 10% of purchase price as recommended in the A.S.A.E. Year-book 1965
- repairs, an estimate of \$15 per hour
- fuel and lubricants \$0.8 per hour

B. 1. Infield Tractors - Initial cost \$15000
Life 12,000 hours

- depreciated on an hourly basis
- interest etc. as harvested
- repairs, an estimate of \$1.7 per hour
- fuel and lubricants \$0.3 per hour

2. Buggies - Initial cost \$30,000
Life 12,000 hours

- costed as infield tractors

C. Labour - The 1968 Labour cost per ton of cane

harvested was obtained from Caroni harvesting statistics March 29th 1968. This was proportionately reduced according to the increased productivity of each system.

- D. Transport Costs - No close investigation of transport costs was undertaken. Mechanically harvested cane is 20% less dense than whole stalk cane (HARKNESS Personal Communication 1968). Present transport costs have been increased by 20%.
- E. Pick up Cane - 10% pick up cane was assumed, 3 tons for every 30 tons harvested by machine. Cost of pick up cane is \$4.5 per ton, equal to \$.45 per ton mechanically harvested.

The saving per ton was then determined in comparison with manual harvesting costing \$5.2 per ton made up as follows:-

Reaping	\$1.9
Loading	1.7
Animals	0.8
Weighing	0.3
Transport	0.5
	5.2

Land forming costs, cane cleaning costs and overheads costs have been omitted from the calculation for the following reasons:-

1. Land forming. Caroni ridges are more expensive initially but will probably increase yields, facilitate all mechanized operations and reduce loss of growing surface in drains.
2. Cane cleaning costs. Hawaii spends TT \$22.0 per ton of sugar on cleaning. Therefore Trinidad, with 13% extraneous matter to Hawaii's 30% could be faced with a change of \$1 per ton of cane for cleaning. Clean cane is vital if mechanized harvesting is to reduce costs as hoped.
3. Overheads. Adjustment of overheads is too involved to make it worthwhile on present experience.

5.3.2. Results

TABLE XII.
Costs Per Ton \$

	1968	INT.	I	II	III	IV
Tons/Hour	22	24	20	30	30	30
Tons/Day	205	312	390	423	486	519
Tons/Season	22,550	34,330	42,900	50,760	53,460	62,280
Cost of Harvester	1.52	1.32	1.06	1.04	1.08	1.06
Cost of Infield Transport	0.32	0.29	0.23	0.33	0.23	0.33
Cost of Labour	0.72	0.48	0.38	0.32	0.30	0.28
Sub TOTAL	2.56	2.09	1.67	1.69	1.61	1.67
Transport	0.55	0.55	0.55	0.51	0.55	0.51
'Pick up'	0.45	0.45	0.45	0.45	0.45	0.45
Sub TOTAL	1.00	1.00	1.00	0.96	1.00	0.96
TOTAL	3.56	3.09	2.67	2.65	2.61	2.63
Manual	5.20	5.20	5.20	5.20	5.20	5.20
Saving	1.64	2.11	2.53	2.55	2.59	2.57

Table XII summarizes the results so obtained. It appears that mechanical harvesting will reduce cost of production by from \$15-\$25 per ton of sugar. It must be pointed out that this is determined at present wage rates and that the influence of rising wages will be much greater on manual harvesting, the labour content being at least five times that of mechanized harvesting. Methods I to IV show only marginal differences. From this, it appears that there is not a very strong case for either a reserve harvester to two operational machines or the introduction of buggies. It will be remembered that alternatives were assessed at the best improvement to production that they might attain.

5.4. Method II

5.4.1. Assumptions.

- (a) Depreciation. Life Harvesters: 7,000 hours
 Tractors : 12,000 "
 Buggies : 10,000 "

No salvage value is accounted. The lives of the equipment have been adjusted to simplify the

determination.

- (b) Housing, Insurance and Tax. 2% of purchase price of harvesters and buggies, 2% of 7/12th of purchase price of tractors. Tractors would be employable on other jobs when not harvesting.
- (c) Repairs. Harvester and buggy repair costs are based on 120% and 60% of purchase price. Proportional charges per year are worked from graphical data in the A.S.A.E. yearbook 1965.

Tractors are charged at a flat rate of \$1.7 per hour because of their general purpose nature.

- (d) Labour. Manual harvesting labour cost is taken at \$3.75 per ton. Mechanized harvesting labour costs include 'pick up' and are taken from Table XII.

Other costs that might arise from mechanized harvesting have not been imputed for two reasons. Firstly, because of uncertainty, they would be inaccurate and secondly they are not essential for the comparisons that are being made in this section.

5.4.2. Results

(A) Comparison of different levels of output. Table XIII summarizes the estimated cash flows for three levels of productivity. In this section and the discussion, the three levels will be referred to as 1968, I & IV the characteristics of which can be seen in Table X. (See Appendix VIB for full D.C.F. calculations).

TABLE XIII.
Estimated Cash Flows (\$)

	1968	I	IV
Year 1	38,283	93,949	145,111
2	30,500	81,860	124,613
3	27,731	71,235	106,708
4	23,997	61,883	92,692
5	21,229	52,919	81,724
6	17,796	-	-
7	14,803	-	-
TOTAL P.V.	174,339	361,846	550,848
CAPITAL COST	102,500	102,500	187,500
N.P.V.	71,839	259,344	363,348
No. of units for 30,000 acres	40	20	14
N.P.V. for 30,000 acres	2,873,560	5,186,920	5,086,872

Level IV shows the best unit N.P.V. but is marginally less profitable than Level I over 30,000 acres.

(B) Comparison of different rates of introduction of harvesters. Introduction of harvesters may have to be retarded to alleviate unemployment. Even at low productivity levels mechanized harvesting saves a lot of money. The N.P.V. values derived above were used to calculate the monetary loss from a retarded rate of introduction. The present N.P.V. must be multiplied by the appropriate discount factor for each year after year I so that sums are again brought back to their present value. The loss will depend on what increase in productivity is achieved each year. These results were calculated at 1968 productivity, at Level I and at an intermediate level which was derived by taking the first three years at 1968 productivity and the last two at Level I. The estimates were based on a five year period comparing the introduction of 2 harvesters every year against 4. The results are shown in Table XIV.

TABLE XIV.

Rate of Harvester Introduction (\$)

			1968	I	INT.
N.P.V.			71,839	259,344	3 at 71,839 2 at 259,344
Year	Units	D.F.			
1	2	-	143,678	518,688	143,678
2	2	.909	130,604	471,488	130,604
3	2	.826	118,678	428,436	118,678
4	2	.751	107,902	389,534	389,534
5	2	.683	98,132	354,264	354,264
TOTAL			598,994	2,162,410	1,136,758

If 4 harvesters were introduced every year, the N.P.V. would be double in each case. Therefore the totals in Table XIV show the monetary loss from a retarded rate of mechanization over 5 years at three levels of productivity. Probably the intermediate figure is as close to the real loss likely to be experienced although the increase in productivity will be spread over the 5 years and will not occur suddenly in year 4.

6. The Unemployment Problem

6.1. Social Survey

A survey was conducted in three of the sugar workers villages near Waterloo with the assistance of a helper recruited locally. The interviewees were chosen without any conscious attempt to obtain a representative sample. However the data does cover a wide range of employment circumstances and seems to give a good general picture of the position. The total number of interviews was 65. For an outline of the questionnaire see Appendix VII. The information so obtained is summarized below.

(A) Age of interviewees

16-25 years 52%
26-35 " 28%
Over 35 years 20%

This proportion is in line with the pyramidal population shape which is a characteristic of developing areas.

(B) Sex

Male 75%
Female 25%

It must be remembered that, due to the rise in cost of living and lack of a subsistence life to fall back on, employment is often just as important to the female as it is to the male.

(C) Standard of Education

No education	10%
Primary school	72%
Secondary school	12%
Others, Art school	
Technical college	6%

(14% of Trinidad's total population received secondary education)

(D) Type of Employment

Interviewees were asked what employment they were in at present; and replied as follows:-

Unemployed	55%
Sugar Labourer	32%
Sugar Skilled Worker	3%
Others	9%

In this section the figures may be slightly biased with respect to unemployment because one set of interviews was conducted in the morning when unemployed persons are obviously most readily available. 27 of the 36 unemployed were in the 16-25 years age group in which group only 7 had found employment.

(E) Duration of Unemployment

Interviewees who were unemployed were asked how long they had been unemployed. The replies are shown below.

Always:	67%
For last 5 years:	25%
For last year:	8%

The bulk of the young age group had never had a regular job. According to their claims, 4 of the 36 unemployed had suffered retrenchment from the sugar industry.

(F) Satisfaction with Employment in the Sugar Industry

Of the 23 employed in the sugar industry 14 were content while 9 complained of low wages.

(G) Employment Required

Persons were asked whether they were prepared to work in the sugar industry, either as a labourer or skilled worker and what kind of work was required. Of the 36 unemployed 56% said that they were prepared to work as labourers and another 14% as skilled workers. Quite a number of those prepared to work as labourers were unmarried women with children for

whom the opportunity for other kinds of employment was strictly limited. Of those prepared to work as labourers 70% would work at present wage rates while 30% wanted higher wages. The important point is that, of the total sample, 20% were unemployed and were prepared to work as labourers at present wage rates. This 20% included young men with primary and, in some cases, secondary education.

(H) Marital Status

All interviewees were asked whether they were married or not. Replies were:-

Unmarried	38%
Married	49%
Unmarried with children	13%

The high percentage of unmarried persons with children is not regarded as exceptional in the district. The people are generally less concerned with the legality of marriage.

(I) Number of children

Number of children per married person was investigated in order to try and obtain some idea of the increase in working population which is occurring in the region. Of the persons with children

45% have 1-3 children
25% have 4-6 children
30% have over 6 children
Total number of children = 200
Average per married person = 5

These statistics are discouraging because, in spite of the high percentage of younger people interviewed, the average number of children per married person was 5 and there was an extremely high propensity to get married. Two girls of 17 and 18 had 2 and 3 children respectively. Those with only 1-3 children were invariably younger people. By the age of 30 most married persons had 7 children. The general conclusion is reached that the birth rate is still very high and the survival rate has doubtless improved resulting in a real population explosion. The only lightening of the gloom is that, as result of conversations with young single men, it is thought that knowledge and willingness to use birth control will be characteristics of the next generation to get married.

(J) Rising expectations

Parents were asked whether they were prepared to see their children work in the cane fields either as labourers or skilled workers. 7% of parents said that the decision was up to the children, 80% said that they would be happy for them to work as skilled workers but not as labourers and 13% wanted something better still.

Conclusions

The important facts to be derived from this survey are as follows:-

There is chronic unemployment in the area especially among young men up to the age of 25. A high proportion of the unemployed are quite prepared to labour in the cane fields. The rise of population is still great so that the unemployment situation is likely to deteriorate further. Eventually labour shortage may result from an unwillingness to do manual work - a situation of rising expectations.

6.2. Labour Displacement

6.2.1. Labour Requirements for Mechanical Harvesting.

For 24 hour operation, requirements are as follows:-

Senior Operators	2
Operators	8
Mechanics	4
General Labour	6
Infield Transport	12

TOTAL - 32

Number of harvesters 2
Labour per harvester 16

With a crop season of 110 days and an output per day of 390 tons 0.7 harvesters are required per thousand acres. Labour requirement of 1000 acres = $.7 \times 16 = 12$ men.

Pick up cane on 1,000 acres amounts to 3,200 tons, equal to about 30 tons/day. Assuming the productivity of the pick up gang is 4 tons/man day, another 8 men/day are required if lost cane is still being recovered manually.

6.2.2. Labour Requirements for Manual Harvesting.

It is assumed that 2.5 tons of cane are cut, loaded and carted per man day. Tonnage per 1,000 acres is 30,000 which equals 272 tons/day over a 120 day crop. Therefore $110 \left(\frac{272}{2.5} \right)$ men are required per day.

6.2.3. Labour displacement

per 1,000 acres - without pick up $110 - 12 = 98$

- with pick up $110 - 20 = 90$

Labour displacement on 30,000 acres = 2940 or 2700

Other estimates have generally been higher but these have minimized field labour required and have assumed a much higher productivity per harvester which is not justifiable at present. 'Trace' to factory labour requirements are likely to go up with mechanization because of lower density of cane and the likelihood of transload stations.

DISCUSSION

7. Discussion

7.1. Review of Literature

Quite an extensive review of literature was undertaken. It was felt that any new technique should be investigated with full knowledge of developments in other parts of the world. The review attempted to put operations in Trinidad into perspective. For example extraneous matter content of harvested cane is not at present hindering CARONI's mechanized operations to any great extent but Hawaii spends U.S. \$11 a ton cleaning cane. CARONI LTD must avoid this, possibly by better field support as is done in Australia.

Trinidad's sugar industry is reviewed in this section. Some of the information has been derived from unpublished sources but it was felt that the introduction of a separate chapter was unwarranted.

In general the literature on mechanized harvesting is disappointing because few production figures are given and very little information on methods of analysis is available. Perhaps lack of detailed analysis has itself slowed up the development of mechanized sugar cane harvesting.

7.2. Technical Evaluation

In Chapter 3 it was stated that the purpose of the technical evaluation was not so much to find the characteristics of production now but rather to determine the capabilities of the harvesting system in the future. In order to do this the present characteristics and the factors influencing them had to be investigated. These factors have been divided into primary and secondary, the former having direct influence on productivity and costs and being themselves influenced by the secondary factors. The major inter-relationships are shown in Figure IIL Field work had to be concentrated on the primary factors because of restricted time.

7.2.1. Primary factors

Discussion of primary factors is divided into two parts considering first results obtained for 1968 and secondly estimates of future potential.

1968 The overall limitation of 1968 results is the restriction of study to January, February and March when the harvesting season continues through April and May. A bias may well have been introduced in this case because April and May tend to be wetter months than the previous three. As can be seen from Figure II weather influences a large number of secondary and primary factors.

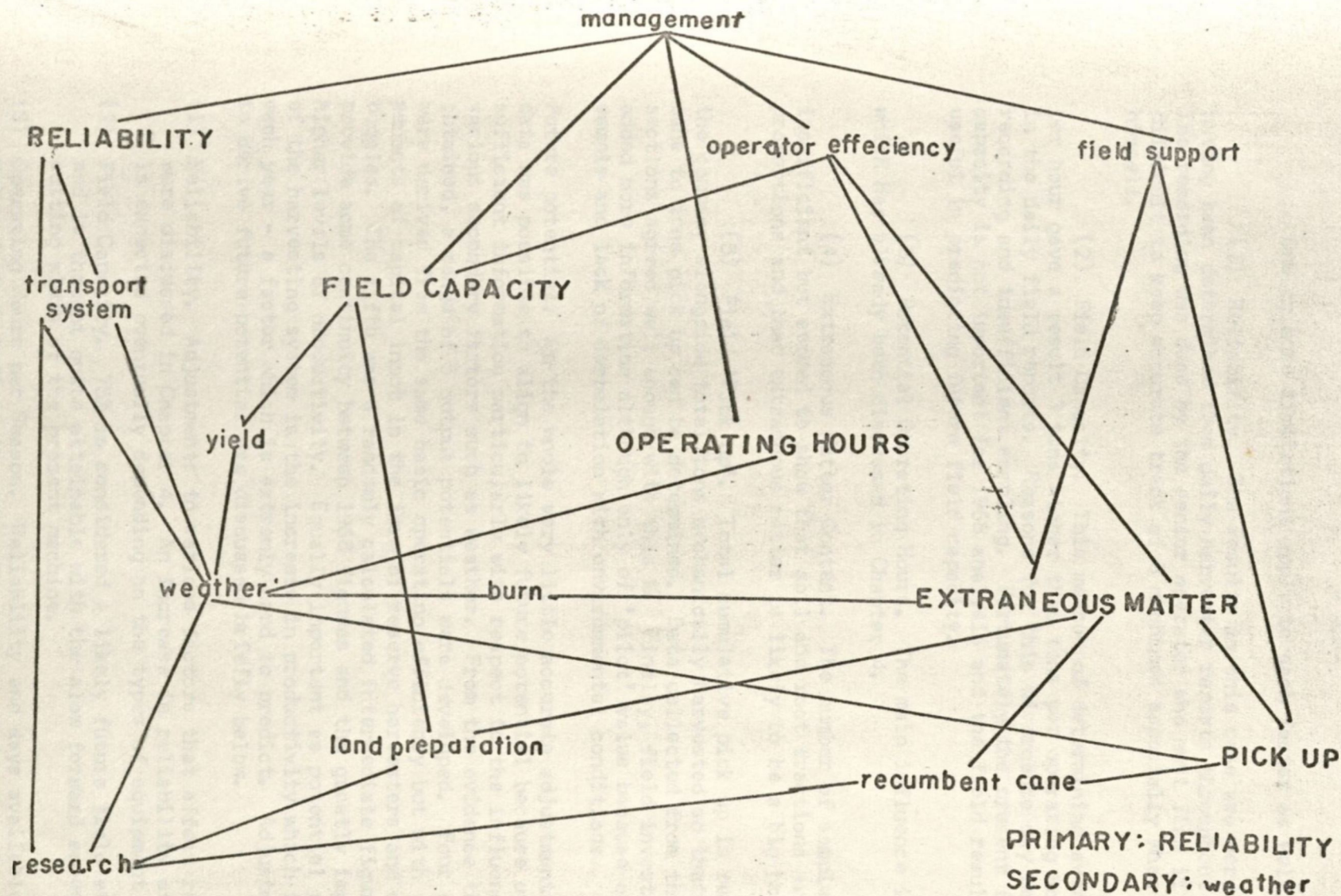


FIG III. PRIMARY AND SECONDARY FACTORS OF MECHANIZED CANE HARVESTING.

One or more limitations apply to each factor as well.

(1) Reliability. The results in this case are very comprehensive having been determined from daily harvester reports throughout the period. The recording was done by the senior operator who must find it a little difficult to keep accurate track of 3 machines especially when operating himself.

(2) Field Capacity. This method of determining average output per hour gave a result 3 tons higher than tons per operating hour recorded in the daily field reports. Reasons for this divergence may be inaccurate recording and insufficient sampling. Fortunately the present field capacity is not important for 1968 analysis and the field results were useful in predicting future field capacity.

(3) Potential Operating Hours. The main influence is weather which has already been discussed in Chapter 4.

(4) Extraneous Matter Content. The number of samples was insufficient but served to show that soil and root fractions are of sizeable proportions and that extraneous matter is likely to be a big problem.

(5) Field 'Pick up'. Total cumulative pick up is recorded by the company alongside total tons mechanically harvested so that a % tons cane to tons pick up can be determined. Data collected from three sections agreed well enough with this %. Finally, field investigations added more information although only of 'pilot' value because of size of sample and lack of correlation with environmental conditions.

Future potential. On the whole very little accurate adjustment to 1968 data was possible to align to likely future potential because of lack of sufficient information particularly with respect to the influence of various secondary factors such as weather. From the evidence that was obtained, a range of 5 output potentials were developed. Four of these were derived from the same basic operating efficiency but with varying amounts of capital input in the form of reserve harvesters and cane buggies. The fifth was a randomly calculated intermediate figure to provide some continuity between 1968 figures and the greatly improved higher levels of productivity. Equally important as potential productivity of the harvesting system is the increase in productivity which is attained each year - a factor which is extremely hard to predict. Adjustments made to derive future potential are discussed briefly below.

- (1) Reliability. Adjustments to various factors that affect reliability were discussed in Chapter 4. An increase in reliability of 20-25% is expected eventually depending on the types of equipment used.
- (2) Field Capacity. 75% is considered a likely future field efficiency and is thought quite attainable with the slow forward speed and small cutting width of the present machine.
- (3) Operating Hours per Season. Reliability and days available are the major factors influencing operating hours per season. Reliability has been discussed (1 above). Days available depend on weather, the influence of which is very uncertain at present. Predictions were

made to enable costings to be determined.

- (4) & (5) Extraneous matter content and field 'pick up' of cane need a lot of investigation before any kind of upward trend in efficiencies can be estimated.

7.2.2. Secondary factors. Figure III shows the more important secondary factors affecting efficiency of harvesting. A mainly subjective review of these factors follows.

- I Human Elements. The top half of Figure III sums up the influence of the human element in mechanized harvesting. None of the three components were studied. The author did, however, gain the impression that the industry was a little over obsessed with the machine and its capability, in consequence somewhat neglecting the very critical human input involved. For example it is possible that the introduction of field labour to work with the machine might achieve advantages worth more than the wages involved and alleviate the redundancy problem a little at the same time. It is generally true to say that, at the start of development, machines need a lot of human assistance which is slowly dispensed with as the machine becomes more refined. Operator efficiency may also need attention. As far as was observed, once the new operator could actually drive the machine, he was left much to his own devices, hardly ever having to bear a penalty either for cutting badly or for failing to detect a mechanical fault when it could be rectified. Lastly, now that a harvesting system has been developed that is reasonably successful technically, the crux of future progress depends largely on the quality of management organization and supervision.
- II Technical Elements. The major technical elements are summarized on the bottom half of Figure I.
- (A) Trailer supply. With the present transport system production can be curtailed either by lack of road transport or by failure of infield transport. Lack of road transport cost about 600 hours operating time, a potential reduction in output of 12,000 tons. The road transport system is probably affected by a driver's 'go slow' policy caused by social pressure against mechanized harvesting. This must be taken into consideration when matching up transport to output. Calculations should take cognisance of the fact that excess transport capacity is not expensive, trailers having a low rate of depreciation and tractors being multi purpose machines.

Failure of infield transport can arise either from shortage of infield haulage or through weather causing trailers to get stuck. The latter has prompted the trial of a 'high flotation' infield vehicle called a cane buggy. This should be able to operate as long as the harvester can in wet conditions. There are a large number of 'pros' and 'cons' for cane buggies and the problem would warrant a separate study. Basically they will increase potential operating time but cost more, cannot be put to other uses as a tractor can and require a transload station. Stock piling at the transload station may result in cane deterioration.

Further they will increase the likelihood of field damage and of dirty cane problems through operations being continued in wet weather. Two obvious alternatives present themselves, high flotation tyres on conventional trailers and using the tractor P.T.O. to drive a modified rear axle of the conventional trailer. Research is necessary if the best system of transport is to be introduced.

For the purpose of evaluation cane buggies have been credited with reducing lost time from road transport to 3.5%, from weather to 1%, from stuck trailers to zero and of increasing the harvesting season by 10 days, probably the maximum advantage that might be attained from them. With conventional trailers lost time from road transport has been reduced to 5% with no other adjustments.

- (B) Weather. Weather has already been discussed in Chapter 4. Easily another whole chapter could be written on its influence on mechanized harvesting. Its most important direct influences are, firstly on the potential number of operating hours available and, secondly its effect on extraneous matter content. Apart from this, it influences every single factor shown in Figure III to a lesser or greater extent, (only the more obvious influences are traced).

Weather influences every agricultural operation in the world to some extent. It will be some years before the problem with respect to Trinidad's sugar cane harvesting can be fully evaluated and probability factors determined. Until this has been done great flexibility must be maintained in the system.

For this study weather influence has been evaluated as follows:- reduction of harvesting season to the period January - Mid May, 135 days including Sundays and Holidays, reduction of total days available by 10 with continued use of present infield transport system and reduction of reliability by 4% with conventional infield, by 1% with cane buggies, four days on which some operation is possible. The influence on extraneous matter content needs urgent investigation.

- (C) Burn. The quality of the burn obviously influences trash content of cane. The extent of its influence needs determining in both standing and recumbent cane. Then the possibilities of achieving a better burn or of using a dessicant can be investigated.
- (D) Recumbent cane. Mechanized harvesting is quite successful in upright cane. In recumbent cane it often approaches a complete failure, extraneous matter content and quantity of pick up cane soaring. In Australia yield has been sacrificed in some cases for good harvestability and this might be necessary in Trinidad if costs are to be kept down. Initially the causes and effects of recumbent cane should be investigated. Is recumbence entirely a function of variety, or of weather, or of land preparation, or a combination of any or all of these? Solving the problem of recumbence might save directly \$1.50 a ton of cane by avoiding pick up (\$0.45) and cleaning (\$1.00) as well as improving the output of the harvester.

No quantitative information on the recumbent cane problem was obtained in this study so that the major factors it influences were not adjusted.

- (E) Land Preparation. As shown in Figure III land preparation influences three of the major determinants of harvesting efficiency and possibly an important secondary one. Land formation is generally of a high standard so that there are no obvious grounds for adjustment. Reduction of recumbent cane remains the major uncertain influence of land preparation. For the study no adjustment has been considered.
- (F) Research. Research is obviously the key to solving the major problems of mechanized harvesting.

7.2.3. Summary. The technical evaluation undertaken in this project has been limited for a number of reasons such as, lack of time, travelling distance and in spite of considerable assistance from the company in the form of labour and materials. However the study has served to highlight the factors of most importance in the operation. The way is now open for research work to sort out the roots of various problems and provide some answers.

7.3. Economic Evaluation

The costings derived in Chapter 5 are not accurate costings of Caroni Ltd's operations. The purpose of the study was to reach as far as possible an independent assessment of the savings to be derived from mechanized harvesting. The author has concentrated on comparisons between (a) mechanical harvesting and manual harvesting, (b) various possible inputs of equipment and (c) various rates of introduction of mechanical harvesting. In no case was it necessary to calculate a total cost figure which, at the present state of uncertainty, would be a waste of time.

However any industry undertaking capital investment must apply some kind of formal analysis in reaching decisions. In this study two methods of analysis have been used, methods I and II. Method I arrives at figures that are easily understood, i.e. mechanized harvesting will reduce cost of harvesting by \$15 at the minimum, \$25 at the maximum, per ton of sugar. The lay man might well consider this sufficient evidence to plunge into mechanization without further analysis. But this type of analysis is of no value when dealing with such problems as capital equipment input, capital formation and the effects of phased introduction of harvesters. Method II, using discount cash flow, is the best method of analysis available for solving these decision requiring problems. Even this method has its limitations that must be remembered in utilizing results.

The two problems of applying D.C.F. are that the objectives of investment may be other than maximization of profit and that uncertainty may be too severe to estimate the magnitude of future cash flows (DALTON 1967).

- (A) Objectives. Ultimately Caroni Ltd's objectives must be to maximise profits. At present there are probably five objectives in the decision

to mechanize cane harvesting

- i To reduce costs and improve profits.
- ii To improve competitiveness in relation to other industries.
- iii To avoid retrenchment of labour and labour unrest.
- iv To prepare for future labour shortage.
- v To balance labour demand throughout the year.

Fortunately none of these objectives nullify the use of D.C.F. because the decision to mechanize is not an all or nothing decision. Harvesters can be introduced gradually so that in theory all these objectives can be attained. What cannot be attained is maximization of profit.

(B) Uncertainty. Decisions to invest require the prediction of future outcomes which will be uncertain to a lesser or greater extent. Theoretically three conditions may exist.

- i A single outcome is supported by sufficient evidence to be conclusive
- ii There are a range of possible outcomes
- iii The degree of uncertainty is so severe that it is impossible to quantify outcomes

As far as the Trinidad sugar industry is concerned the first condition certainly does not apply. The following uncertainties exist with respect to mechanical harvesting:-

- i The development of the world sugar market especially with respect to the Commonwealth Sugar Agreement and the possibility of Britain's entry into the Common Market.
- ii Government interest.
- iii Labour interest.
- iv Continued manufacture of harvester.
- v Economic life of a machine.
- vi Output of the machine.
- vii Rise in labour costs.
- viii Influence of weather.
- ix Quality of harvesting.

These uncertainties could be rationalized to some extent by Shackle's theory of potential surprise (see Dalton 1967) but such an approach was outside the scope of this study. However with the use of information accumulated on mechanical harvesting up to the present it was possible to develop a matrix of likely developments upon which to base a D.C.F. analysis. In other words condition (ii) exists in that there are a range of possible outcomes which

can be analysed in turn to aid decision making.

In this study D.C.F. has been used in two ways, firstly to determine whether a high investment high output system is more profitable than a low investment, low output system and secondly to determine the monetary loss from a retarded rate of mechanization.

The results show that there appears to be very little advantage in a high output system especially when it is remembered that the maximum advantages have been conferred on the system from the use of cane buggies and a reserve harvester. This conclusion applies only when the whole area is under mechanization. In the initial stages the high output system derives an advantage from cutting a larger area by itself which it would lose in a system of total mechanization.

With respect to the monetary loss which will accrue from a retarded rate of mechanization the actual figure is entirely dependant on the productivity which is attained. However maximum and minimum parameters have been calculated so that the social problem can be seen in the perspective of the financial implications of retarded mechanization.

At the present state of mechanized harvesting investment in harvesters yields 25% return on capital and this yield will increase considerably with increased efficiency.

7.4. The Unemployment Problem.

'To work is hard, not to work is harder'
Greek Proverb.

Full mechanized harvesting will reduce the labour force on the flat land by 3,000. In the near future no more general labour will be taken on, although there will be a demand for semi-skilled workers such as tractor drivers. In the sugar cane belt, there are a large number of unemployed, many of whom are finding the truth of the Greek Proverb and are prepared to cut cane. What justification has the Government to step in and halt further harvest mechanization? Chapter 5 was confined to proven facts as far as possible. In this discussion, a certain amount of impressions and postulates will be put forward.

7.4.1. Description of the Area

The main areas affected by mechanized harvesting are Couva and the villages near to Waterloo; about equally distant between the Port of Spain and San Fernando metropolises. The villages in this region are 'strip' villages - long struggling lines of houses on either side of the all weather roads. 'Everyday' provisions are supplied by small grocers which also serve as bars. Electricity is generally available but, in one or two villages, the water supply is inadequate. There are a number of schools inevitably with large classes and insufficient buildings. Taxis and public buses travel through the area. Employment is largely in the sugar industry but fishing provides another source of work and a small

percentage travel to the city each day.

Travelling through the area, one would not be struck by poverty or any obvious discontent. To be sure, there are a few dilapidated wooden huts but the majority of houses are made of brick and supported on piles, providing a garage and 'liming' (= idling) area underneath. The estates management's landrovers may be greeted with sullen stares but there is no general feeling of animosity towards the 'sugar capitalists'. However there is one factor that cannot escape notice; the large number of 'youths' lounging around bars and houses in the morning.

The author made friends with one group of youths and discovered some interesting facts. Age range was 17-25 and education was 'primary' at the least, several years secondary in some cases and technical education in others. None had had regular work and maintained that getting a job anywhere depended on knowing somebody or using a bribe. Apparently the position was so bad that a high proportion were prepared to work as labourers in the cane fields, contrasting with CAMPBELL and EDWARDS (1965) experiences in Antigua. This affirmation was made not only in front of the author, when it could have been said for effect, but also to the temporary assistant that was employed. Equally there were some who said that they would not work in sugar at any price.

A total of 3,000 was suggested as a likely figure of unemployed in this age group, an exaggeration maybe but illustrating a point. As far as politics were concerned, these people would vote for any party that offered them a job although communism was not seriously considered. All these 'perennial' limers were living at home and therefore reasonably fed with even a certain amount of pocket money to buy drinks. No real resentment was harboured against the sugar companies. Resentment in that direction was more prevalent among sugar employees who said that the wages were not high enough for the cost of living. The government was more often blamed for the lack of employment rather than the sugar industry.

There are two ways of looking at a social problem of this sort. Many people will hold that these are not unemployed but 'unemployables', not prepared to take menial jobs, considering themselves worthy of something better. 'A good kick up the backside is what they want'. The author does not entirely agree with this view while not advocating 'kid glove' treatment. Employment is hard to find especially when living a long distance from the urban centres. There is also a certain amount of truth in the bribery and corruption charge. Whatever the reason for the situation, the fact is that the situation exists and that something will eventually have to be done to alleviate it.

7.4.2. The Population Explosion

The social survey gave very strong indicators that growth rate of population in the sugar cane belt was very high. One anecdote will illustrate the situation. The author gave 4 women labourers a lift back to their village after a day's work. On questioning, it turned out that they had 43 children between them. Probably this was an exceptional case but it

illustrates the point that there are, say six young people to replace one retired person. In other words, even if the sugar industry maintained its labour force, a chronic unemployment situation would still exist. It is not a question of cure then, but one of alleviation. A rough estimate of satisfying 1/6th of the job demand might be near the mark.

This 1/6th must be balanced against the fairly definite certainty that the sugar industry will go bankrupt if new techniques are not introduced. Collapse of the sugar industry could be a staggering blow to the island's economy. Even if the 1/6th are considered worth not merely the risk of bankruptcy but the certainty of loss of competitiveness, is it fair still to encourage the population to look to the sugar industry as a source of employment. Firstly wages provide only a bare subsistence. Secondly is the prolonging of the eventual 'crunch' going to gain anything? It might be argued that a boom in development may occur and demand for labour increase. But, by then, world and Caribbean competition will demand really high efficiency only achievable with a skilled labour force. The labour force will be the disillusioned 'limers' who have been standing on the street corners for years. Thirdly if it is admitted that what is really required is a more rapidly growing economy, then the best way to achieve this is to encourage the development of a 'technician' class whose salary is sufficiently high to enable them to invest, in a taxi, a fishing boat or possibly a local industry. The harvester operators can be considered to fall into this category of people.

7.4.3. Solutions to the problem

There is no denying that a very serious problem exists. REUBENS & REUBENS (1962) list three alternatives that a government can adopt when faced with retrenchment problems. It should be noted that Caroni Ltd are bound by the Industrial Court not to retrench so that the problem is one of reduction of job opportunity. Firstly a government can adopt various measures to maintain the size of labour force in the industry. Secondly it can provide aid for the unemployed and thirdly it can encourage an expansion of the economy and employment opportunities.

The controversy rages around the first possibility. Generally it is accepted that mechanization must eventually be employed so that the argument turns on the rate of introduction. The two sides of the coin are the losses that the industry will sustain through a slow rate of introduction against the amelioration of the unemployment problem. Calculations indicate that the introduction of 2 instead of 4 harvesters each year over the next five years will cost the company at least \$600,000 at present prices. This is calculated at the present level of productivity. At a higher level of productivity a sum of \$2,162,000 would be forfeited. If the expected increase in productivity is provided for by charging the first three years at 1968 productivities and the next two at the higher productivity the cost could be \$1,137,000.

Apart from this direct cost there is also the considerable risk of bankruptcy of the whole industry if the introduction of advanced methods is retarded.

At the end of five years, at the higher level of productivity mechanization of harvesting of 30,000 acres would be just about complete with the introduction of 4 harvesters a year and there would be 3,000 less jobs in the industry. At 2 harvesters each year mechanization would be half completed and there would be 1,500 less jobs. Therefore the slower rate of mechanization would provide another 300 job opportunities a year.

As an agriculturist the author would not be prepared to risk the existence and competitiveness of the sugar industry for a temporary alleviation of the employment problem. The sociologist might reach another decision. Whatever happens, the problem is far too serious to be treated as a political gambit.

'A fool can throw a stone into the sea
A hundred clever men cannot pull it out'
Greek Proverb.

CONCLUSION

8. CONCLUSION

The world sugar market is unsettled and the free price of sugar is tending to fall. At present the hope of a sugar agreement is not good. Trinidad sugar remains a viable industry because the bulk of production is sold on Commonwealth and United States guaranteed prices. But cost of production is very high due to chronically low labour productivity. This means that the island's industry is not sufficiently competitive to maintain itself in a more open market situation which might arise, for instance, if Britain entered the Common Market. The industry is the largest employer of labour and contributes 7% of G.N.P. Its bankruptcy would be a major disaster.

Mechanized cane harvesting stands to reduce the cost of production by \$15 to \$25 per ton of sugar. Restriction of harvesters would only provide temporary alleviation for a small part of the unemployment problem. The Government has a large unemployment situation on its hands in the sugar belt. It has to decide whether to risk the sugar industry in alleviating the problem temporarily.

Further work. This project covered a very large subject, of necessity, superficially. There is a fundamental need for research work on the technical and social problems of mechanized harvesting. As regards the technical problems, various areas of research have been suggested in the discussion (Chapter 7). The author considers that, apart from mechanical efficiency, the most critical aspect of the present harvesting system is the "extraneous matter pick up cane" complex. Research would involve establishing routine analysis of harvested cane and determination of lost cane. These could then be correlated with the quality of land preparation, severity of burn, recumbance of cane, weather and soil conditions, tied in with operating standards. Such a study could only be done effectively by someone full time on the job with good technical assistance and would also involve sacrifice of harvester output. These disadvantages must be weighed against the possibility that the complex might add \$1.50 to harvesting cost of one ton of cane, thereby largely eliminating the benefits of mechanized harvesting.

A pilot survey of the unemployment situation was undertaken and pointed to the existence of serious problems. The author is firmly of the opinion that this needs following up with a full scale social survey of the region investigating family incomes, sources of employment, trends in living standards etc. Such a survey could be jointly sponsored by the sugar industry and the Government. It should aim at an accurate analysis of the situation and should investigate methods of alleviating it.

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APPENDICES

APPENDIX I

Results of Time Trials for Field Efficiency Determinations

CARY

Date	Field	Mins Turning	Mins Waiting	Mins Choking	Mins Unloading	Mins Adjustment	Mins Lack of Trailers	Mins Interruptions	Mins Total Loss	Mins Period	Mins Cutting	Efficiency %
27.1.1968	Waterloo - 331,332,333	2.50	1.30	5.25	1.65	-	4.85	0.25	15.80	108.00	92.20	85.4
27.1.1968	Waterloo - 331,332,333	2.00	1.50	16.70	0.30	-	57.35	0.40	78.25	125.00	46.75	37.4
29.1.1968	Waterloo - Baraneo 11	5.95	0.20	-	1.50	-	40.00	0.30	47.95	102.00	54.05	53.0
3.2.1968	Perseverance 127/142	12.75	8.20	0.20	1.65	-	4.10	-	26.90	103.00	76.10	73.9
3.2.1968	Perseverance 127/142	4.75	-	1.50	0.45	15.40	0.95	10.45	33.50	110.00	76.50	69.5
10.2.1968	Felicity - Estate 9	19.95	5.30	9.35	2.65	-	2.30	8.60	47.85	126.00	78.15	62.1
13.2.1968	Felicity - Estate 32,33, 34	12.24	-	0.60	1.80	-	25.50	1.50	41.60	143.00	101.40	70.9
15.2.1968	Exchange 4,5	9.95	-	3.45	2.55	-	11.30	7.75	35.00	209.00	174.00	83.2
15.2.1968	Bay Road 9,10	7.85	-	0.90	1.20	6.80	2.30	4.90	23.95	64.00	40.05	62.7
17.2.1968	Wyaby, 15,16,17	7.00	-	3.30	3.45	-	73.00	2.20	88.95	170.00	82.05	48.3
5.3.1968	Exchange C28,29	7.55	.45	1.95	1.55	-	19.00	-	29.95	72.00	43.05	59.9
12.3.1968	Macbean - Estate 28	4.50	-	0.95	1.05	-	-	0.10	6.60	33.00	24.40	73.9
TOTAL	(Mins)	96.70	16.95	44.15	19.80	22.20	240.65	34.25	474.70	1365.00	1299.00	65.4
%		7.1	1.2	3.2	1.4	1.6	17.6	2.5	34.6	100.0	65.4	65.4
<u>DUNCANA</u>												
5.3.1968	Exchange C28,29	19.05	2.10	0.40	1.55	0.40	15.75	4.95	44.20	93.00	48.70	52.7
11.3.1968	Exchange D35/36	11.45	1.80	-	1.70	0.50	13.60	0.15	29.20	75.00	45.80	61.3
21.3.1968	Exchange 10	9.85	1.05	0.70	-	-	22.00	2.45	36.05	62.00	25.75	41.9
TOTAL	(Mins)	40.35	4.95	1.10	3.25	0.90	51.35	7.55	109.45	230.00	120.45	52.4
%		17.5	2.2	0.5	1.4	0.4	22.3	3.3	47.6	100.0	52.4	52.4

APPENDIX II

Production Records for Period 11th January - 30th March 1968

CATEGORY	CARY 403				CARY 404				CARY 405				CARY 406				CARY 407				DUNCANA 408			5. CARY TOTAL	%	Operational Cary TOTALS	%
	J	F	M	Total	J	F	M	Total	J	F	M	Total	J	F	M	Total	J	F	M	Total	F	M	Total				
PRODUCTION																											
Tons Harvested	631	952	1656	3239	2681	3701	4309	11091	2927	3575	4806	11328	3261	4636	5535	13432	3728	4698	5993	14419	562	1059	1621	53,509	-	50,270	-
(Hours) Operating Time	39	52	77	168	161	165	178	504	169	167	175	491	182	205	225	612	201	200	233	634	25	54	79	2429	-	2241	-
Tons/Hour	16.2	18.3	21.5	19.3	16.7	22.5	26.5	22.0	17.3	21.5	27.5	23.1	12.9	22.6	24.6	21.9	18.5	23.5	25.7	22.7	22.5	19.6	20.5	22.0	-	22.5	-
LOST TIME																											
(Hours) Fueling	1.0	0.3	3.0	4.3	5.6	8.5	6.3	20.4	4.9	7.7	7.5	20.1	5.3	9.8	13.3	28.4	5.4	9.0	12.3	26.7	0.8	5.8	6.6	99.9	1.9	95.6	1.98
(Hours) Travelling	1.2	5.8	6.3	13.3	10.5	8.3	12.5	31.0	12.8	10.2	15.1	38.1	17.4	19.0	18.7	55.1	14.9	16.1	18.8	49.8	4.6	11.1	15.7	187.3	3.6	174.0	3.60
(Hours) Servicing	2.8	2.5	9.6	14.9	31.8	22.8	22.8	77.4	29.3	21.6	25.2	76.1	70.4	21.9	29.6	71.9	20.7	21.9	27.8	70.4	4.0	12.5	16.5	310.7	6.0	295.8	6.13
(Hours) Infield Transport	1.3	1.0	4.3	5.6	7.2	5.8	10.1	22.3	4.1	5.7	12.4	22.2	10.8	4.8	7.7	23.3	5.5	4.8	15.5	25.8	1.5	5.9	7.4	99.2	1.9	93.6	1.94
(Hours) Out of Trailers	3.8	14.0	23.3	41.1	43.6	39.5	44.8	127.9	40.5	48.0	41.7	130.2	45.3	67.6	55.2	168.1	52.5	61.3	53.0	167.8	10.6	24.5	35.1	635.1	12.2	594.0	12.30
(Hours) Repairs	9.4	-	106.4	115.8	95.9	129.7	103.2	328.8	74.0	129.5	102.4	305.9	62.8	54.1	78.6	195.5	38.1	72.0	68.1	178.2	32.7	58.1	90.8	1124.2	21.6	1008.4	20.92
(Hours) Weather	0.4	2.5	1.0	3.9	5.7	15.3	14.0	35.0	5.4	15.2	13.0	33.6	9.2	11.2	22.8	43.2	12.8	11.2	20.6	44.6	5.3	4.4	9.7	160.3	3.1	156.4	3.20
(Hours) Stuck Trailers	-	-	-	4.8	-	-	-	9.0	-	-	-	3.3	-	-	-	11.0	-	-	-	12.8	-	-	-	40.9	0.8	36.1	0.75
(Hours) Other Reasons	2.3	4.8	10.8	17.9	3.0	10.5	35.8	46.3	7.5	7.2	28.0	42.7	-	19.4	1.8	21.2	-	13.3	2.5	15.8	3.4	-	3.4	143.9	2.8	126.0	2.61
(Hours) Total Lost Time	22.2	30.9	164.7	223.4	203.3	240.4	249.5	698.1	178.5	245.1	245.3	672.2	171.2	207.8	227.7	617.7	149.9	209.6	218.6	591.9	62.9	122.3	185.2	280.3	53.8	2579.9	53.53
(Hours) 'In' Time	61	83	172	391	214	257	267	1202	348	412	420	1163	353	413	445	1230	351	410	452	1213	88.0	176.3	264	5212	100.0	4821	100.00

APPENDIX III

Use of Reserve Harvester

NO RESERVE

WITH RESERVE

Date	Group	Planned Hours	Operated Hours	Tonnage	Group	Planned Hours	Operated Hours	Tonnage	ADVANTAGE Hours Tons	OPERATING OF RESERVE Hours Tons
30-3	I	44	16.50	467	II	44	17.25	449	+0.35 -18	5.30 141.
29	I	48	16.35	357	II	48	23.30	571	+7.05 +214	2.20 38
27	II	48	13.05	219	I	48	10.00	179	-3.05 -40	- -
2.	II	44	21.40	558	I	48	18.45	624	-3.55 +66	3.25 45
1	II	48	16.45	420	I	43	17.00	376	+0.45 -44	2.00 43
29.2	II	48	20.00	487	I	48	20.55	475	+0.55 -12	2.00 48
26	I	32	13.00	343	II	32	13.50	400	+0.50 +57	1.00 25
24	II	44	14.40	388	I	44	19.50	565	+5.10 +167	2.50 85
23	II	48	23.30	787	I	48	18.35	558	-4.55 -229	3.00 78
22	II	48	20.30	713	I	48	13.15	402	-7.15 -311	1.50 55
17	I	48	11.40	335	II	48	14.35	306	+2.55 -29	1.00 22
16	I	48	20.05	381	II	48	21.55	291	+1.50 -98	2.00 38
15	I	48	22.25	366	II	48	27.30	477	+5.05 +111	3.00 61
3	II	48	22.30	431	I	48	25.45	404	+3.15 -27	1.20 14
2	II	48	22.30	406	I	48	23.55	423	+1.25 +17	0.30 7
27.1	I	36	20.55	287	II	48	24.55	430	+4.00 +153	2.00 36
24	I	48	23.45	415	II	48	25.25	359	+1.40 -56	4.00 102
23	I	48	20.35	391	II	48	22.10	360	+1.35 -31	2.00 29
22	I	48	18.50	324	II	48	17.50	350	-1.00 +26	2.00 58
20	I	48	25.55	423	II	48	27.55	519	+2.00 +92	5.00 23

TOTALS.

I Operation of reserve

Number of days = 20
Hours operated = 46.45
Tons harvested = 948
Hours/day = 2.3
Tons/day = 47.5

II Extra production of group with reserve harvester

Number of days = 20
Group I = 29
Group II = 11
Extra operating hours = 16.95
Extra tons harvested = 8.

APPENDIX IV
Cycle Times (Minutes)

Date	Section	Loading Time	Travelling Time	Unhook & Hook up Time	Delay	Cycle Time	Av. Weight of Trailer Tons
19.1	Perseverance	18.50	3.80	0.30	0.75	23.25	5.56
		17.60	3.55	0.25	-	21.40	
		17.65	3.55	0.25	-	21.45	
		18.55	3.65	0.30	-	22.60	
20.1	Perseverance	8.45	6.50	0.90	-	21.50	5.80
		13.20	8.25	1.15	-	22.60	
		20.50	7.55	2.20	-	30.25	
		19.75	7.60	1.40	-	28.75	
27.1	Waterloo	13.95	5.05	0.60	-	19.40	5.12
		13.75	8.25	0.35	-	21.35	
		14.35	4.95	0.35	0.20	19.70	
		13.60	7.00	0.35	-	20.95	
3.2	Perseverance	17.95	8.35	0.55	-	26.85	6.00
		15.80	13.70	0.90	-	30.40	
		16.65	8.95	0.75	-	26.35	
10.2	Felicity	15.20	4.75	0.70	-	20.65	4.27
		17.75	6.55	0.95	-	25.25	
13.2	Felicity	13.80	9.65	1.30	-	24.75	7.38
		15.60	4.90	0.80	-	21.35	
15.2	Exchange	10.15	7.10	0.95	-	18.20	7.82
		11.35	6.25	0.90	-	18.50	
		10.80	13.65	1.10	-	25.55	
		9.95	6.75	0.85	-	17.55	
17.2	Wyaby	16.85	3.85	70	-	23.60	5.56
		12.80	3.20	75	-	17.25	
		19.80	5.35	95	-	26.10	
AVERAGE		15.17	6.62	0.80	-	22.58	5.97

Note. On all of these dates considerable lost time was experienced due to lack of trailers. This explains why very little delay time was recorded in these cycles.

APPENDIX V A.

Pick Up Cane Sample from 3 Sections

Date	Section	Variety	Rotation	Acres	Tons Yield	Tons Pick up	Tons Pick up/ Acre
4-8/1	Felicity	41227	3rd	9.1	30	24	2.64
"	"	"	"	9.3	34	20	2.15
"	"	"	"	7.2	35	25	3.47
8-10/1	Exchange	41227	1st	23.0	29	110	4.78
11/1	Waterloo	41227	1st	21.8	27	23	1.60
17/1	Felicity	41227	3rd	9.6	28	33	3.44
10/2	Felicity	41227	4th	11.0	34	17.4	1.58
11-14/2	Felicity	41227	3/4	8.3	38	31	3.74
"	"	"	"	6.3	38	11	1.71
"	"	"	"	6.8	35	28	4.12
"	"	"	"	11.0	28	41	3.73
14-15/2	Exchange	49119	Plant	10.5	35	50	4.76
"	"	"	"	6.9	37	50	7.24
15-17/2	Waterloo	41227	3rd	23.9	33	99	4.14
19-21/2	Exchange	41227	Plant	18.0	28	33	1.83
"	"	"	"	19.4	31	34	1.75
20-21/2	Exchange	49119	Plant	17.4	33	33	1.87
23-24/2	Felicity	41227		6.7	36	31	4.63
"	"	"	"	9.0	37	45	5.00
"	"	"	"	11.2	30	45	4.02
24/2	Waterloo	41227	4th	8.4	32	42	5.0
24-29/2	Waterloo	41227	1st	41.0	32	108	2.81
1/3	Waterloo	41227	4th	9.0	31	33	3.75
2/3	Waterloo	41227	1st & 4th	25.0	35	63	2.52
5-6/3	Exchange	41227	1st	23.7	33	100	4.21
7-9/3	Waterloo	41227	1st	27.8	36	112	4.00
9/3	Exchange	41227	Plant	14.4	33	65	4.51
12-16/3	Waterloo	41227	1st	64.9	41	167	2.57
	TOTAL			460.6		1473	
	AVERAGE				33.2		3.2

APPENDIX V B.

Field Measurement of Lost Cane (lbs)
Field Forest 10 Waterloo Section 29th February 1968

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15*	Total	%
Long Cane	335	110	105	123	65	145	40	70	58	72	95	115	150	105	50	1638	60
Chopped Cane	52	35	50	45	50	44	38	47	34	23	63	58	40	63	30	672	22.5
'Tops'	10	15	10	12	18	18	28	35	18	20	3	10	25	11	7	248	8
Stubble	10	5	12	17	10	23	20	20	20	15	13	20	32	12	3	232	8
Mashed Cane	-	-	-	-	22	23	-	-	-	-	-	-	-	-	-	45	1.5
TOTAL	407	165	177	197	165	253	126	172	130	130	174	203	247	199	90	2835	100

* 12'x 20' only.

APPENDIX VI A.

Discount Cash Flow (D.C.F.)

The principle of D.C.F. is to estimate the annual cash flows resulting from the investment under investigation. These cash flows are then discounted at an increasing rate according to the elapse of time from the year of investment. The Present Values (P.V.) so obtained are added together. Substraction of the capital invested gives the Net Present Value (N.P.V.) of the system which can be compared directly with the N.P.V.s of other systems.

- Procedure 1. Estimates of the working life of the harvesters and infield vehicles were made.
2. Operating hours per annum were taken from Table XI for the various levels of productivity. Divided into total hours this gave years in operation.
 3. The variable costs of the equipment were determined for each year of life. With respect to repair costs, a yearly increasing charge per hour was computed to take account of increased repairs as the equipment gets older. This principle was not applied to infield tractors which were considered general purpose and likely to be operated throughout the year. Other costs were charged on a standard hourly basis.
 4. The reduction in labour costs (= return from capital) was determined. Manual Labour costs were charged at 1968 levels, mechanized labour costs at the various levels of productivity.
 5. Variable costs were subtracted from the yearly return to obtain an annual cash flow.
 6. The cash flows were discounted at the 10% level. No attempt was made to determine what price the industry would have to pay for capital. The sugar industry must generally be a high risk proposition but mechanized harvesting itself is a good risk, yielding high returns even at low productivity.
 7. The N.P.V.s of the various investments were determined by adding the annual P.V.s together and subtracting the capital employed.

The yield method of D.C.F. was not considered applicable because the differences between systems are small compared with the overall yield.

In the determination of monetary loss from the retardation of mechanization the N.P.V.s for each year were determined by applying a discount factor to the N.P.V. of year I.

APPENDIX VI B.
D.C.F. Determinations

YEAR	HOURS	% LIFE	% REPAIRS	FUEL \$		REPAIRS \$		H.T.I. \$		TOTAL \$	RETURN \$	Net	Discount	Cash
				CARY	TRANSPORT	CARY	TRANSPORT	CARY	TRANSPORT	Variable		Cash \$	Factor	Flow \$
										Cost		Flow		
(1968) 1	1023	14	10	818	767	8950	3478	1700	350	16063	58179	42,116	.909	38,283
2	1023	29	25	818	767	14141	3478	1700	350	21254	58179	36,925	.826	30,500
3	1023	43	40	818	767	14141	3478	1700	350	21254	58179	36,925	.751	27,731
4	1023	57	57	818	767	15931	3478	1700	350	23044	58179	35,135	.683	23,997
5	1023	71	75	818	767	16826	3478	1700	350	23939	58179	34,240	.620	21,229
6	1023	86	96	818	767	19511	3478	1700	350	26624	58179	31,553	.564	17,796
7	1023	100	120	818	767	22211	3478	1700	350	29324	58179	28,855	.513	14,803
													P.V. =	174,339
													Capital =	102,500
													N.P.V. =	71,339
I 1	1430	20	15	1162	1090	12750	4862	1700	350	21914	125,268	103,354	.909	93,949
2	"	40	35	"	"	17000	"	"	"	26164	"	99,104	.826	81,860
3	"	60	60	"	"	21250	"	"	"	30414	"	94,854	.751	71,235
4	"	80	90	"	"	25500	"	"	"	34664	"	90,604	.683	61,883
5	"	100	120	"	"	30750	"	"	"	39914	"	85,354	.620	52,919
													P.V. =	361,846
													Capital =	102,500
													N.P.V. =	259,344
IV 1	2076	20	15	1661	1557	19125	3,600	2550	1200	29,693	189,331	159,638	.909	145,111
2	"	40	35	"	"	25500	6,000	"	"	38,468	"	150,863	.876	124,613
3	"	60	60	"	"	31875	8,400	"	"	47,243	"	142,088	.751	106,708
4	"	80	90	"	"	38250	8,400	"	"	53,618	"	135,713	.683	92,692
5	"	100	120	"	"	40950	9,600	"	"	57,518	"	131,813	.620	81,724
													P.V. =	550,848
													Capital =	187,500
													N.P.V. =	363,348

1. Name:
2. Male/Female:
3. Education:
4. Employment:
 - (a) Unemployed
 - (b) Employed in sugar
 - (i) as a labourer
 - (ii) as a skilled worker
 - (c) Employed elsewhere
5. If unemployed
 - (a) When was your last job?
 - (b) Was it sugar/not?
6. If in sugar, why did you leave?
7. If now employed in sugar
 - (a) are you content?
 - (b) if not, why?
8. If unemployed
 - (a) what kind of work is desired?
 - (b) are you willing to work in the cane fields as a
 - (i) labourer?
 - (ii) skilled worker?
9. Readiness to work as a labourer
 - (a) Yes
 - (b) If nothing else offers
 - (c) Not at present wages
 - (d) Not at double wages
 - (e) Not at any price
10. Marital Status
11. Number of children:
12. Are you willing for your children to work in the cane fields as
 - (i) labourers?
 - (ii) skilled workers?