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## **Redefining economic efficiency using a case study of sugarcane harvest-transport systems.**

### **A job for pluralist thinking.**

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### **Abstract**

Despite the Queensland sugar industry's status as a low-cost producer of sugar, there appears to be considerable scope to reduce costs by improving the efficiency of the cane harvesting and transport process, especially in the Mackay district. The key areas of inefficiency result from poor utilisation of both harvesting and mill transport equipment. Insights from the research approach used to address the key issues of this problem - the potential savings from raising the efficiency of sugarcane harvest-transport systems, and the failure of the Mackay district to adopt measures to improve the efficiency of its harvest-transport systems – are discussed in this paper.

There are multiple drivers and constraints to change in the Mackay harvesting and transport system, and multiple objectives and visions of the desired future need to be accommodated. This is the classic problem of managing complex systems, and it warrants the embracement of pluralist thinking. Methodologies with different strengths and weaknesses were used in combination to address a complex problem to gain a richer appreciation of the nature of the harvest transport system. The three perspectives explored in this paper, that of 'traditional' economic analysis, the exploration of social drivers and constraints of change, and the consideration of the historical context, contribute a different understanding of the situation and of the desired and desirable future. While there is a tendency for a neo-classically inspired view to dominate - ie 'rationalised' harvest-transport systems are a desirable future, the results from this study suggest that 'economic efficiency' needs to be redefined.

### **Introduction**

The Australian sugar industry is economically significant. Australia is the world's sixth largest sugar-producing nation and in 1994/95 became the world's largest exporter of raw sugar for the first time. Sugar is one of Australia's four largest farm export commodities, along with beef, wool and wheat, and is one of the nation's top ten merchandise exports (Boston Consulting Group, 1996). Because the industry, with its heavy export dependence, is directly exposed to the volatility of world sugar prices, this has resulted in an industry which is efficient, competitive, and a low-cost producer of high-quality sugar (Anon., 1996). A significant investment in research and development has enabled the industry to remain competitive through the adoption of innovations aimed at increasing sugar yields, lowering production and milling costs, and improving arrangements for shipping and handling of raw sugar.

Despite the sugar industry's status as a low-cost producer of sugar, there appears to be considerable scope to reduce costs by improving the efficiency of the cane harvesting

and transport process. Recognition of harvest-transport inefficiency became widespread during the 1980s, when a number of studies (eg Petersen *et al.*, 1984; Page *et al.*, 1985; Ridge and Dick, 1985; Connell and Borrell, 1987; Ferguson, 1987; McWhinney *et al.*, 1988) suggested that cane harvesting and transport costs incurred by the Queensland sugar industry could be substantially reduced if fewer cane harvesters were used to cut the cane crop. Harvesting and transport inefficiencies have also been recognised more recently (Brennan *et al.*, 1997; Boston Consulting Group, 1996). The Australian sugar industry has little control over world sugar prices and long-term, real sugar prices are projected to fall at well over 2 per cent per annum (Fry, 1997). The sugar industry must continue to respond to the challenge of productivity increasing, or cost reducing, innovations. There is therefore a powerful argument to target harvest-transport for cost reduction. While harvest-transport inefficiencies have since been addressed in some areas, they have been difficult to overcome in others, especially in the Mackay district.

Given the adjustment processes that have already taken place in other cane production regions in Australia, the structure of the harvesting sector has not changed as rapidly as might be expected. Change has been particularly slow in the Mackay district. Although there is a tendency for a rationalised, low cost system to be viewed as the desirable future, it is worth questioning this view given that the Mackay sugar industry is clearly resistant to a change that has already taken place in several other cane producing regions.

This situation warrants further exploration of the factors that reduce the impetus for the Mackay industry to change to more 'efficient' harvesting systems. With this in mind, two alternative perspectives of harvest-transport systems are discussed in this paper. Compared with 'traditional' economic analysis, these alternative perspectives – that of the social impact of measures identified as having potential to lower the costs of the cane harvesting and transport process and, secondly, consideration of the historical development of harvest-transport systems – contribute a different understanding of the harvest-transport problem and of the desired and desirable future. The discussion of the historical context receives the most detailed treatment in this paper. The sociological dimension has been previously reported by the author (Brennan, 1997a, 1999). Both perspectives are considered in the discussion of the research implications of the use of multiple perspectives in addressing complex problems.

## **Reducing harvest-transport system costs in Mackay**

The Mackay sugar industry comprises approximately 1 300 growers supplying four mills and occupies over 70 000 hectares in the Pioneer Valley, west of the Queensland city of Mackay. There is a mutually dependent relationship between growers and millers and the harvest-transport system is the physical and financial interface between the cane growing and milling sectors. Key inefficiencies in harvest-transport systems occur where practices of one part of the system affect the costs in another part of the system. Consequently, components of harvesting systems cannot be viewed in isolation but rather as a single process commencing at the point of cutting in the field through to the delivery of cane at the mill gate. To achieve major reductions in harvesting and transport costs for the Mackay sugar industry, it must be recognised

that the harvest-transport system is an entity and both the milling and the growing sectors must be considered jointly when addressing future directions.

The key areas of inefficiency in the Mackay sugar industry's harvest-transport system include restricted harvest hours, small harvest group sizes (a group is the farm or farms harvested by a single operator), and slow diffusion of new harvesting technology. These practices lead to higher than necessary costs resulting from poor utilisation of both harvesting and mill transport equipment. Opportunities to improve efficiency appear to lie in changes to the organisational basis of harvesting in Mackay, mainly involving the amalgamation of harvesting groups. This would result in fewer but larger groups operating for longer hours each day.

Brennan (1997b,1999) conducted a detailed assessment of costs to the Mackay sugar industry of harvesting and transporting cane from fields to the mill under a wide variety of potential harvesting and transport configurations. Changing the number of harvesting groups, spreading the hours for group harvesting, and increasing investment in mill transport infrastructure, as well as improving in-field harvesting conditions, appeared to impact on the efficiency of harvest-transport systems. The analysis of costs for case study mill area in Mackay revealed that fewer, but larger, harvesting groups operating high-capacity equipment over an extended cutting period, coupled with upgraded locomotive capacity and fewer cane collection points on the mill transport network, could significantly reduce the costs of in-field harvesting operations and mill transport procedures. The total cost saving to the one mill area, alone, could amount to almost \$2.5 million per annum. Other studies have reported similar findings (Boston Consulting Group, 1996).

While the bulk of the savings identified by Brennan (1997b, 1999) would be captured by the in-field sector, individual gains by those operating in the infield sector would vary considerably. A reduction in the number of harvesting groups would require considerable adjustment effort by the in-field sector, involving group enlargements and widespread disbanding of existing groups. There is therefore the issue of transaction costs, which must be weighed up against the savings achievable by rationalising harvest-transport systems.

The social costs of group amalgamation also need to be weighed up against the savings achievable by rationalising harvesting and transport systems. Group amalgamation would force many harvesting group operators out of harvesting and would effectively prevent many cane farmers from harvesting their own cane. For those operators who remain in harvesting, larger groups and extended harvesting hours may mean longer operating times during harvesting periods which may be disruptive to the lives of harvester operators, their families and the local community.

## **Alternative views of the harvest-transport problem**

### **Goals and preferences of individual stakeholders**

If the Mackay sugar industry wishes to implement effective adjustment strategies designed to improve the efficiency of harvesting in the future, present practices must be understood. Research into the goals of growers and harvesting-group operators, attitudes and decision-making criteria, was conducted to provide the basis for

understanding their preferences for and choices among various harvesting alternatives. A detailed appreciation of the motivation of growers and harvesting-group operators was sought to explain the strong resistance to change in the district as well as the extent to which personal, situational, and managerial constraints were involved. Data was obtained via interaction with industry stakeholders during 1994 to 1997 through focus groups, a workshop, personal interviews and a postal survey. Detailed findings are reported in Brennan (1997a, 1999). Key insights are summarised below.

Opinions about large harvesting groups and structural adjustment in the harvesting sector varied widely among individuals in the Mackay sugar industry. A number of factors influenced harvesting-group operators' decisions about group size and structure. These included financial and social goals in addition to constraints, such as physical in-field operating conditions and mill policies relating to harvesting and transport of cane.

Harvester-operators appeared to have multiple goals that were combined in complex and individual ways. Despite the heterogeneity of the harvesting-group operators in Mackay in terms of group size and structure, they shared many goals, but often with different approaches to fulfilling these goals. Achieving the lowest possible harvesting cost was generally related to achieving other goals which included a desire to manage perceived risks, pursue a particular lifestyle, achieve flexibility in farm management, and maintain independence. Harvesting-group operators appeared to make decisions that were compatible with other farm and personal objectives and therefore the failure to adopt large groups could have represented a considered response by these individuals to their environmental circumstances. These findings revealed that any future measures aimed at improving the efficiency of harvesting systems in Mackay must reconcile 'economically' efficient outcomes reported earlier in the paper with socially acceptable outcomes.

Without some form of intervention, the expectations of the harvesting-group operators about the future of harvesting in Mackay suggest it is unlikely that groups would continue on a steady adjustment path towards amalgamation. Many Mackay harvester-operators were not convinced that groups must enlarge for future viability. Concern about variable sugar prices and rising costs, lack of opportunities outside harvesting, and other perceived negative socio-economic effects of large harvesting groups led to a strong resolve by many harvesting-group operators to resist pressure to move into larger harvesting groups.

It is highly unlikely that simply promoting information about the improvements in economic efficiency that might be achievable from a radical change to harvesting and transport systems will overcome inhibitions to change. Presenting the most cost-efficient combination of harvesting activities will be of limited value if these options are perceived by industry participants to be in conflict with their social goals. To reach a satisfactory outcome for all the stakeholders, the goals, attitudes and decision-making criteria of the stakeholders need to be revealed and incorporated into the plan for the future. Where conflicting objectives exist, especially where there are trade-offs between financial benefits and social preferences, the industry needs to extensively negotiate their set of objectives.

## **An evolutionary view of harvesting systems**

Technological change and structural adjustment in the harvest-transport sector in the Australian sugar industry have been inseparable processes. Mechanical harvesting was a major technical innovation and diffused rapidly throughout the Australian sugar industry following its introduction in the 1950s. As new technology became available, the industry made adjustments to incorporate it into harvesting systems, but such adjustments have not occurred uniformly throughout the industry. The Mackay district has lagged behind other districts in terms of the extent and rate of incorporation of new technology into harvesting systems. However, an integral component of the lower-cost harvesting arrangements reported earlier is the incorporation of high-capacity harvesting machinery coupled with upgraded mill transport infrastructure. The obvious question is 'why hasn't the industry incorporated the technology necessary to permit it to operate in a low cost way?' A relatively recent theory of technical change from the sub-discipline of 'evolutionary economics' provides unique insights.

### **What's different about evolutionary theories of technical change?**

Within the economics discipline, a number of research traditions which attempt to explain the manner in which technology has been incorporated into economic systems have emerged. The scope of such studies encompasses industry and firm scales, factors affecting the rate of diffusion, and the impact of historical events on the technological status of industries. Theories of technical change fall into three main categories - neoclassical, Schumpeterian and evolutionary (Elster, 1983; Kasper, 1980).

Neo-classical theory dominates contemporary economics and extends its dominant influence in theories of technical change. In the theory, land, labour and capital are viewed as the primary sources of economic productivity. Neo-classical foundations for explaining technical change rest on the concepts of factor bias based on Hick's 1932 *Theory of Wages*. The theory essentially states that a high price of labour (respectively capital) leads to labour-saving (capital saving) innovations.

The basic neoclassical tool for the study of technology and of technical change is the production function. Allocation of capital and labour determines which of the factor combinations will be realised based on the logic of rational choice and price induced substitution. This model rests on three assumptions. The most important is the behavioural postulate of profit maximisation. Secondly, all points along the isoquant are assumed to be equally accessible to the firm and the point corresponding to the actual practice is in no way 'privileged'. This means one can move along the isoquant without the isoquant itself being affected by the previous position on the isoquant. Finally the model rests on the assumption of perfect competition. It is beyond the scope of this discussion to review neo-classical theories in detail but Elster (1983) provides a good review of the basic tenants.

Neoclassical theory has been recognised as an appropriate tool for equilibrium analysis of economic systems, including intertemporal equilibria, steady-state growth, and other phenomena that take place in logical, as opposed to historical, time (Elster, 1983). However, the theory has been criticised for its inability to deal with dynamic

problems. David's (1975) assault on the explanatory power of neoclassical theory captures the essence of such criticisms:

“Economics repeatedly is attacked for embracing the fiction of man as a mechanism, a rational utility-maximising instrument whose behaviour with regard to economic affairs (if not to all intriguing aspects of life) is free of all habituating influences, and thus remains devoid of all cultural and social propensities. Although less explicitly decried, the implied timelessness of this fiction must be troubling to every historian” (p.12).

“The economist's now conventional conceptualisation of technological innovation as a change of a neoclassical production function - an alteration of relationships between inputs and outputs across an entire array of known techniques - has turned out to be less helpful than one might wish. On more than one occasion, regrettably, it has led historical discussions of invention and diffusion into paradox and confusion” (p.2).

Economists following the evolutionary research tradition have attempted to develop full-scale alternatives to the neo-classical orthodoxy, drawing on Schumpeterian theory. Evolutionary theories challenge a number of neo-classical assumptions, particularly the postulate of profit maximisation. They deny this postulate by assuming that the choice between the possible actions follows a different logic or by denying that there is any choice to be made. Economic and technological change are acknowledged as being causally intertwined – “that at any given moment the uses to which scarce resources are put in an economy depend heavily on the current technology” Hall (1994, p.1). Evolutionary theory asserts that there are some mechanisms of dynamic adjustment that are radically different in nature from those allocative mechanisms proposed by neo-classical theory. Also acknowledged is the role of the socio-institutional framework and the way it influences technical and structural change. The rate of technical and structural adjustment relates not only to market imperfections, but to the nature of markets themselves and the behaviour of their agents (Freeman, 1988). The institutions are therefore an inseparable part of the way markets work. Furthermore, the evolutionary approach starkly contrasts with the neo-classical approach by its explicit account of the observation that all members of a population are different from each other, rather than using the representative unit (Hall, 1994). Analyses conducted under the evolutionary approach recognise this variation because it is seen as a central means of explaining how systems change.

Evolutionary diffusion models attempt to remedy the perceived limitations of the equilibrium approach of conventional micro-economic, neo-classical models. Aspects of evolutionary technology diffusion models relevant to the analysis of diffusion of technology in harvest-transport systems are outlined below.

### **Path dependency**

A key concept dominating the evolutionary view of technology is *path dependence*. This refers to the historical dimension of the evolutionary approach. Both the theoretical and empirical literature reflect the growing recognition that history counts: past technological achievements influence future achievements via the specificity of the knowledge that they entail, the development of specific infrastructures and the

emergence of various sorts of increasing returns in technological options (Dosi, 1991). In other words, the events in the state at  $(t+2)$  depend at least partly on events specific to the state at  $(t+1)$ , and those at  $(t+1)$  to events at  $t$ . Outcomes at any given moment depend on how the system got there, that is, the path it took. What happens next is always heavily constrained by what has already happened; the future can only ever be built upon the past (Hall, 1994). David (1975, p.332) described a path-dependent sequence of economic changes as being “one of which important influences upon the eventual outcome can be exerted by temporarily remote events, including happenings dominated by chance elements rather than systematic forces”. In other words, the long-term structure of economic systems may depend on minor initial fluctuations, individual choices, institutions and policy measures.

### **Lock-in**

Path dependency is associated with ‘lock-in’ - a set of conditions which make it either impossible, or highly unattractive, to move from one period to the next in more than a very narrow range of ways (Hall, 1994). Lock-in has the technological consequence of confining innovation to a narrow corridor of developments and it will favour firms with particular sorts of experience over those who lack it. Arthur (1989) and David (1985) pointed to potential inefficiency occurring from this in that a particular path might be inferior in terms of some welfare measure but the system may still be ‘locked’ in to it.

#### *Random events*

When more than one type of new technology arrives at the same time in the market, diffusion of the innovation involves a competition among the alternatives. Arthur (1989) explored the dynamics of competing technologies and how ‘random events’ occurring during adoption could influence the selection of successful technology, and how some sets of random historical events may cumulate to drive the adoption process towards a one-market share outcome. Two properties emerged from the dynamic approach of this study: *inflexibility* in that once a dominant technology begins to emerge it becomes progressively ‘locked in’; and *non-erodicity* meaning that historical ‘small events’ are not balanced out or forgotten by the dynamics but, rather, they decide the outcome. Historical ‘accidents’, therefore, cannot be ignored (David, 1985). Dosi and Orsenigo (1988, p.24) also examined how technological evolutionary paths could be affected by small “deviant” behaviour which, ‘under certain micro and/or macro economic conditions, become autocatalytic, progressively amplify and may end up being dominant’.

#### *Increasing returns*

Arthur (1989) also examined how increasing returns might drive the adoption process into developing technology that has inferior long run potential, even when superior options might be available. He proposed that lock-in arises because of increasing returns to scale in knowledge, noting that modern, complex technologies often display increasing returns to adoption. The more they are adopted, the more experience is gained with them and the more they are improved. A related concept is increasing returns to adoption meaning that the probability of adoption rises with the market share of the technology. The relative advantage may come about through externalities



brought about by a larger group of users, as well as the improvements in performance generated by cumulative learning. Other scholars in the field of diffusion research have reported on 'learning by using' (Rosenberg, 1982; Arrow, 1962; David, 1975). Arthur (1989) suggested that this could explain why one technology could dominate over competing technologies. With increasing returns, the advantage gained from individually insignificant events during adoption may give it an initial advantage over the other technologies.

*Interrelatedness* is another reason why lock-in may occur. Existing production skills associated with a technology build up over time and abandoning an existing production method to adopt new ways of doing things implies abandoning other technologies as well. Interrelatedness describes the dependence of benefits from adoption on a firm-specific environment in which the innovation is to operate. As Metcalf (1988) states:

“A new capital good typically has to be operated in conjunction with the existing equipment of the firm, and if the latter must be altered in any way to accommodate the innovation, the additional costs of adjustment must be added to the capital cost of the innovation. In this way, interrelatedness limits the scope for adoption. Interrelatedness factors should not, however, be limited to physical effects alone. Account should be taken of interrelatedness between an innovation and existing labour and management skills and their organisational context, and between an innovation and the composition of the adopter's output.” (Metcalf, 1988, p. 565)

David (1985) provides a classic illustration of a path-dependent sequence of economic changes using the current layout of keyboards, the top line of which has the sequence of keys QWERTYUIOP. He used the concept of interrelatedness to explain the dominance of QWERTY. *Technical interrelatedness* referred to the need for system compatibility between the keyboard and a touch typist's memory of a particular arrangement of keys, such that the expected present value of a typewriter was dependent upon the availability of touch typists familiar with a particular arrangement of keys.

David (1985, p.336) noted that the case of the QWERTY keyboard is one of an industry driven “prematurely into standardisation *on the wrong system* - where decentralised decision making subsequently has sufficed to hold it”. Other features which caused QWERTY to lock-in were economies of scale and quasi-irreversibility. Arthur (1988), David (1985) and Landon (1975) recognise that lock-in is irreversible, or quasi-irreversible, to the extent that it is measurable by the transition, or adjustment, cost to change over. The relevance of economies of scale was that the overall user costs of a typewriter system using QWERTY would tend to decrease as it gained acceptance relative to other systems. The main consequence has been the tendency for the process of competition between manufacturers to lead towards defacto standardisation through the predominance of a single keyboard design

### **Evolutionary adjustment in the Mackay harvesting-transport sector**

Since mechanisation of the harvesting process, the Australian sugar industry has made ongoing adjustments to incorporate new technology into harvesting and transport

systems. These adjustments have been characterised by rapid technological innovation, a high level of sectoral interdependency, significant structural change, intensified capital investment, revised transport arrangements, and significant labour displacement. Another feature of this adjustment has been the entrenchment of regional trends that emerged in the 1950s which, in summary, involved the continuation of small group harvesting in Mackay while other regions generally adjusted to larger groups. Those regions that adjusted did so in unique ways in terms of timing, impetus for adjustment and organisational arrangements put in place to permit large group harvesting. A detailed discussion of these trends is contained in Brennan (1999).

The evolutionary economic concepts of path dependency and 'lock in' by historical events provide a useful framework to consider the development of harvesting systems, and the role of technology in shaping them. It is hypothesised that the dynamic process of incorporating new technology into harvesting systems, and the industry's response to technology takes on an essentially historical character, much like the development of the QWERTY keyboard (David, 1985).

In Australia, regional trends that emerged in the 1950s have become entrenched in modern harvesting systems. It appears that the arrangements set in place during the transitional period from manual to mechanical harvesting have 'locked' the Australian harvesting sector into regionally distinct harvesting systems. Two features of the harvesting system facilitated this: *technical interrelatedness* and *quasi-irreversibility*. Before the advent of mechanical harvesting the mills were able to operate efficiently by allowing the individual farmers to arrange their own manual harvesting groups. Manual harvesting usually involved hand-cutters which travelled in teams from farm to farm. Cane supply was slow, cane deterioration was not recognised as a serious problem and it was not crucial for a tight control be kept on the movement of these groups. Cane could be left in the field until the collection wagon arrived. Using temporary infield tramways, a large number of wagons could be left waiting until a locomotive was available to haul them away. The transition to mechanical chopper harvesting was a major departure from wholestalk harvesting. The realisation that deterioration of cane was much more rapid and severe with chopped, burnt cane necessitated greater coordination between mills and growers. Mill transport systems evolved to keep pace with harvester development (Ridge, 1987). Controlled schedules were devised to collect cane. The rail network expanded in most mill areas, bins were designed for chopped cane and portable line disappeared from cane blocks to be replaced by permanent railway sidings (a siding is a collection point on the rail network) and roll-on/roll-off trailers or road transport.

The relationship between the harvesting groups and the mills played a large part in shaping regional harvesting systems. The mill had to develop transport systems and relied on close coordination with infield activities, and the system interrelatedness contributed to the development of regionally distinct evolutionary paths. The construction of mill transport infrastructure had to occur more or less simultaneously with rapid diffusion of chopper harvesting. Mill infrastructure to accommodate chopped cane during the 1960s was set up to accommodate the prevailing group structure. The capital infrastructure required was expensive and *quasi-irreversible* to the extent that the location and capacity of sidings was a long-term investment not likely to be significantly changed. Railway networks, in many mill areas, have not

changed in terms of siding locations. Capacity upgrades or construction of new sidings are an infrequent event and long-term investment.

The rapid investment in mechanical harvesting equipment changed the industry from a labour-using to a capital-using system; and group harvesting evolved as a structural response to this. A major feature of harvest-systems evolution has been the formation and gradual amalgamation of mechanical harvesting groups, resulting in fewer but larger groups in the industry. Prior to mechanisation, harvesting groups were small in all regions because manual harvesting was a slow process. However, with widespread adoption of mechanical harvesting in the late 1960s, group sizes began to increase, mainly because the capital cost of the equipment was large relative to the tonnages that were cut manually. A major stimulus for structural change has been the rising cost of purchasing and maintaining harvesting equipment. Groups enlarged to take advantage of innovative harvesting technology, which involved expenditure on large capital items that are indivisible, making their purchase difficult to economically justify for smaller enterprises (Brennan *et. al*, 1997). Mechanical harvesters cut cane much faster than manual labour, and groups also had to enlarge to provide sufficient cane supply for the harvesters.

Historically, there was a strong tendency toward individual group harvesting in the Mackay district. Prior to mechanisation, most cane production regions had teams of cutters that moved from farm to farm. In contrast, Mackay always had a high proportion of resident farm labour participation in the harvest. This arrangement appeared to militate against the formation of large harvesting groups. With the introduction of mechanical harvesters, a large proportion of growers in Mackay continued to cut their own cane, simply replacing manual labour with machinery. This group structure meant that machine throughput was low compared to other regions. Two main types of harvesters were available during this time; *wholestalk harvesters*, which gather, top and cut the cane into preparation for separate loading, and *chopper harvesters*, which, in addition to topping and cutting, chop the cane into 12-15 inch lengths (billets) and load it into trailer bins ready for transport to the mill. This harvester combines the cutting and loading operation. Although wholestalk machines established an early lead, the large-capacity, more expensive chopper harvester became established as the dominant design and by 1972 and almost all areas had 100 per cent chopper harvested cane (Churchward and Belcher, 1972). Although conditions were suitable for chopper harvesters in the Mackay district, there was high retention of wholestalk harvesters (which preceded the chopper harvester), apparently encouraged by the small size of groups and the popularity of individual ownership of harvesters.

In Mackay, tramway sidings were never large, because the mill transport infrastructure did not have to service large groups. In contrast with other regions, this meant railway sidings did not have to be very long. The construction of small railway sidings encouraged the continued supply small cane batches because the sidings could not accommodate large groups.

Another example of the problem of interrelatedness is that the rate of diffusion of harvesting technology was significantly affected by the interaction of the technology with the geography. Infield harvesting conditions had the effect of slowing the rate of diffusion of harvesting technology in some regions, especially the Burdekin region,

and completely precluding it from the NSW region until solutions had been developed to overcome infield operating difficulties. Both regions now have the largest harvesting groups in Australia. The NSW system could not accommodate mechanised groups on an ad hoc basis. The transition to mechanical harvesting occurred in a short period and involved a radical systems change because the previous mill transport arrangement could not be incrementally refined and upgraded to accommodate chopped cane. The NSW industry embarked on mechanical harvesting after the large capacity chopper harvester was established as the dominant design. In this case, the industry had the benefit of hindsight; 'old habits' of manual harvesting days could not be carried through to the new system.

To use the words of Dosi and Orsenigo (1988), the way in which Mackay adjustment patterns stemmed from pre-mechanical harvesting arrangements provides an example of *non-erodicity* - ie how a technological evolutionary paths could be affected by small 'deviant' behaviour which became autocatalytic, progressively amplified and became dominant. The available harvesting and transport technology, and the administrative arrangements set in place when the industry changed from manual cutting to a mechanised system, nurtured the continuation of small-group harvesting. In later years, the interdependent nature of the components of the harvest-transport system, mill policies, and industry regulations continued to enabled harvesting arrangements in each cane producing region of Australia to become deeply entrenched over time Brennan (1999). The manner in which technological innovations have evolved has been a key feature in the development of complex, present-day mechanical harvesting systems.

### **Messages from the evolutionary perspective**

Adjustment in the harvesting sector in Mackay has been much more than a response to changing input and commodity prices. The factor-price approach of neo-classical economics cannot adequately explain regional variations in diffusion rates for harvesting technology, particularly when the regions have been faced with similar market signals. The evolutionary approach, which starkly contrasts with the neo-classical approach, provides a unique perspective on adjustment patterns, particularly with its explicit account of the observations that all members of a population are different from each other, rather than using the representative unit. Analyses conducted under the evolutionary approach recognise this variation because it is seen as a central means of explaining how systems change. Current harvesting systems are a result of path dependent sequences. The preference for operating small groups in Mackay has a deeply rooted historical dimension and increasing returns to the use of familiar, small-group harvesting arrangements may be contrasted with the uncertain and often less attractive returns from changing to a larger group. These factors have locked much of the Mackay harvest-transport sector into an organisational state that may have an inferior long-run potential.

### **Conclusions**

Cane harvesting and transport systems are extremely complex. Although significant cost savings in cane harvesting and transport procedures are achievable, there remain

major challenges to coordinate the in-field adjustment process with the other dimensions of the harvest-transport system to enable the industry to progress towards its desired future. The Australian sugar industry faces a future of steadily worsening sugar prices and must respond to this challenge to remain viable in a highly competitive world market. While many economic studies have traditionally argued for industry adjustment on the grounds of cost savings, the message presented here is that it is not acceptable to argue for changes in harvesting and transport systems on this basis.

There are clearly multiple drivers and constraints to change in the Mackay harvesting and transport system, and multiple objectives and visions of the desired future need to be accommodated. This is the classic problem of managing complex systems, and it warrants the embracement of pluralist thinking. The point of pluralist thinking is to make the best use of different tools and methodologies by using them in a way that allows us to continuously improve them through research and, at the same time, improve our ability to tackle diverse and difficult problems (Jackson, 1997).

This paper summarises a detailed look at the existing sugarcane harvesting and transport systems in the Queensland Sugar Industry and at the forces affecting change in that system. Methodologies with different strengths and weaknesses were used in combination to address a complex problem to gain a richer appreciation of the nature of the harvest transport system. The three perspectives explored in this paper, that of 'traditional' economic analysis, the exploration of social drivers and constraints of change, and the consideration of the historical context and the evolutionary path of development which has led to the existing situation, contribute a different understanding of the situation and of the desired and desirable future. Standard analyses in the context of standard, neo-classical, economic theory to identify economically optimum harvest-transport configurations could not be used, alone, to explain, or gain insights from, the observed pattern of structural adjustment in the harvest-transport sector. An attempt was made to integrate what can be learned from alternative perspectives to advance understanding of the decisions that drive adjustment processes in the Mackay sugar industry.

It is most likely that change will involve a compromise between achieving maximum cost savings and complying with some conflicting non-pecuniary objectives. The current status of harvesting and transport systems in the Mackay district is the unique reflection of a set of historical events which have enabled harvesting systems to persist along certain organisational lines over a long period and will continue to impact on adjustment patterns. A majority of harvesting-group operators and growers have become familiar with operating in the current system and are reluctant to 'adjust' out of them unaided. An understanding of growers' and harvesting-group operators' goals, attitudes and decision-making criteria is essential to provide the basis for understanding their preferences for and choices among more efficient harvesting alternatives.

Only with an enhanced understanding can the Mackay industry define a desired future for the harvesting and transport system and plan a process to move towards it. If change is to occur, facilitation of the change process will be needed. With a broader look at the harvest-transport problem, the policy issues shift from how to move the industry to a least-cost position to how to involve stakeholders in a process which

involves highlighting the problems with the current arrangements, identifying technically, financially and socially feasible improvements, and an agreed plan for implementation. The results of this study suggest that the rate and direction of future adjustment in the Mackay harvest-transport sector will depend on the extent to which all stakeholders participate in, and have ownership of, the direction-setting process for their industry. The key elements in achieving this involve providing the right information, using it to negotiate objectives, and facilitating the desired change. Change processes imply an additional set of transition costs which need to be calculated and considered as an addition to the financial analysis of the benefits of a more efficient system.

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