An Investigation of the Loss in Value Attributable to Bruising for the Postharvest Handling System of Apples

A thesis presented in partial fulfilment of the requirements for the degree
of Master of Applied Science
in Agricultural Systems and Management
at Massey University

Hamish Jackson

1997

ABSTRACT

Bruising has been identified as one of the major sources of harvest and postharvest fruit damage in New Zealand operations. Using Porter's (1985) value system as a framework, a model was developed to investigate the value of apples lost due to bruising from harvest to ship–side, in the Hawkes Bay District. The cost of bruising was identified using the model for the apple varieties Braeburn, Fuji, Granny Smith, Pacific Rose™, and for both large and small packhouse based operations.

The initial problem statement was developed by applying the "rich" pictures approach which is part of Checkland's (1975) soft systems methodology. To achieve the research objectives, two case studies based on three orchards and two packhouses were investigated to model the value system for apples. The first case study involved two large orchards supplying a large commercial packhouse that packed more than 350,000 TCEs per season. The second study involved a small orchard, that supplied its own on–orchard packhouse, which packed less than 100,000 TCEs per season. Two value systems were developed for the fruit handling systems of the two case studies.

An important factor in calculating the value of fruit on the orchard was the inclusion of an allowance for the grower's return on equity. The value system began once the on–orchard costs of producing apples, including operating costs, fixed costs and return on equity (set at 20%), were covered. Once the initial value of fruit had been established, commercial rates for picking, trucking, and other steps in the processing and distribution chain, were used to establish the value system. This approach enabled the losses attributable to bruising to be costed. Losses increased through the system steadily and were greatest at the market end of the value system than on the orchard. Losses due to bruising, up until and including packing, were found to be much higher for the grower than for any other participant in the value system. This was because the grower forfeited export earnings, as well as paying the direct costs of producing and handling reject fruit. For the Braeburn, Fuji, and Pacific Rose™, varieties the total cost of 1% bruising was equivalent to approximately a 3% loss in export earnings. The loss in value attributable to bruising for Pacific Rose™ was more variable due to limited amount of data available collected. The total cost for 1% bruising of the most bruise susceptible variety, Granny Smith, was estimated to exceed 4% of export earnings.

The total loss to the growers of the apple industry needs to be minimised to ensure the growth of the industry. Since the growers are suffering high losses of returns and small, if any, return on equity due to fruit bruising, it is unlikely that the growers can afford to invest in strategies that can reduce bruising. If new strategies are to be implemented, the returns need to surpass the investment made.

Keywords:	Value system, Porter process, bruising, fruit value.
Title:	An investigation of the loss in value attributable to bruising for the postharvest handling system of apples.
Author:	Hamish Jackson, 1997.
Degree:	Master of Applied Science.

ACKNOWLEDGEMENTS

This research was supervised under the ever vigilant eye of Ewen Cameron, of the Department of Agricultural and Horticultural Systems Management, and Dr. Linus Opara of the Department of Agricultural Engineering. Many thanks to them for their extreme patience, excellent support, and perseverance which helped me complete this work. I cannot thank them enough for the many late nights of correcting they provided me, and I hope this work will help to dispel their belief, that I am totally linguistically challenged. Thank goodness for spell check on the computer, otherwise they would have really believed I was beyond help.

Thanks to Catherine Richardson of ENZA New Zealand (International) in Hastings, who provided assistance by giving me a list of contacts in the district. I greatly appreciate the cooperation of the growers and packhouse operators who participated in this study by providing their valuable time.

Thanks to Massey University, and the Academic Board, for providing financial assistance by approving my recommendation for the Helen E Akers Scholarship.

Many, many thanks to my parents, and my in-laws, for providing support (moral and nutritional), and financial assistance when most needed.

A very special thanks to my wonderful wife Amy, for all her support and believing in me.

THANK YOU EVERYONE!

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1.1 Introduction

In 1996, for the first time, the value of New Zealand's fresh fruit exports surpassed \$1 billion. This was an improvement of 14.5% over the value exported in 1995. Apples brought in \$516 million of this, well above kiwifruit, the next closest fresh fruit earner (\$320 million) (Mirams 1996). This makes apple growing New Zealand's most valuable horticultural industry. The success of New Zealand's fruit industry has been through the production of good quality and high value fruit (McCliskie 1991).

Also in 1996, of the 29.5 million 18.5 kg TCEs[1] (54,7750 tonnes) of apples produced, 17.3 million TCEs were exported, and 9.2 million TCEs were processed (Mirams 1996). The remaining 3.0 million cartons were sold on the local market. The production and delivery of high quality export fruit is therefore crucial for the continuing success of the New Zealand pipfruit industry.

1.2 Development of the Apple Industry

Apples were first produced in New Zealand in the early 1840's, when the first settlers arrived (Nicholson 1990). The potential for growing apples in New Zealand was soon recognised, so that by 1885, commercially grown fruit was being exported, and in that first year, 2000 TCE were exported (NZDS 1995). This steadily expanded, so that by 1914 the amount exported was 68,000 cases (Nicholson 1990).

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[1] TCE - tray carton equivalent. This is the name given to the carton of fruit in which apples are placed in trays. The net weight of a filled carton is 18.5 kg. This is also equivalent to the imperial system of 40 lb. bushel carton.

Growers combined together in 1916 and formed the New Zealand Fruitgrowers Federation (Nicholson 1990). At this stage the industry was rather fragmented even though fruit was exported through the newly formed (1926) New Zealand Fruit Export Control Board. Following the outbreak of war in 1939, and the associated problems with limited shipping space, the Government took control of the industry (Nicholson 1990).

The New Zealand Apple and Pear Marketing Board was established with the Apple and Pear Marketing Act of 1948 in order to set up a central organization to acquire and market all apples (and pears) grown in New Zealand. For the purpose of this thesis, The New Zealand Apple and Pear Marketing Board will be referred to as ENZA[2]. The mission statement of ENZA is:

"*to maximise sustainable export returns to New Zealand and pipfruit growers*".

(Deloitte and Braxton 1995)

1.2.1 Some Characteristics of the Apple Industry

For the year ended June 1996 world apple production was estimated at 37 million tonnes (Mirams 1996). New Zealand's production of 550,000 tonnes, represents one percent of the world production. However, only 6%, or 2.2 million tonnes, of the world production is exported (excluding production within the European Union) so New Zealand accounts for about 14% of world trade (Mirams 1996). This is important, because it shows that New Zealand may only produce a small amount of world apples, but it is actually quite a large world export market supplier. This export from New Zealand is accomplished despite heavy competition of other Southern Hemisphere suppliers, such as South Africa, who

[2] ENZA is the trade name of the marketing division of the NZAPMB. It is also referred to as ENZA New Zealand (International).

supply fruit to Northern Hemisphere markets at approximately the same time as New Zealand fruit.

The success of the New Zealand apple industry has been partly attributed to the market demand for highly sought after varieties such as 'Gala', 'Royal Gala', 'Fuji', and 'Braeburn' (Nicholson 1990; McCliskie 1991). For the 1995 season, Braeburn earned $194 million and Royal Gala earned $164 million. Both had approximately doubled their export earnings since 1993 (Mirams 1996). For the 1995 season 80% of the industry's export income was from Braeburn, Fuji, Gala, and Royal Gala. These products are unique to New Zealand (ENZA 1996b), although other competing countries are starting to produce them in large quantities.

Since New Zealand's pipfruit are produced a long way from their principal markets (U.K. and Europe), and substantial investment is made at each stage in the handling system, from picking to final sale, it is particularly important that losses be minimised. One source of fruit loss, and hence value loss, through this system is fruit bruising. Estimates have placed the cost of bruising at $25 million (Banks, Mowatt, Studman, and Boyd 1993), and such losses are of a major concern to industry participants.

1.2.2 Supplier Payments

Suppliers are paid for the amount of fruit that is packed into cartons. Payment varies according to the size and quality of fruit. The initial payment to growers, made on submission of fruit, generally represents about 50% of the variety's forecast return (ENZA 1996a). This percentage will vary by variety depending on ENZA's assessment of market risks. All market prices may vary for a variety over a season, therefore payments are pooled, then the average is paid out. Fruit which does not meet ENZA's specifications for export is either sold to the local market, or processed. Both these options provide growers with substantially lower returns than can usually be obtained from export fruit.

1.3 The Postharvest Chain

Once considered mature, following maturity guidelines set up by ENZA apples pass through a fruit handling system as illustrated in Figure 1.1. The handling system begins with fruit harvested by hand, and emptied into field bins[3]. The bins are transported from the orchard to loading areas using tractor–mounted forklift or trailer, from here they are usually either taken directly to the packhouse, or placed into a pre–cooler. Trucks are used for off–orchard transportation (Pang 1993). Once fruit has arrived at the packhouse, it is graded, packed into cartons, and palletised. The pallets are placed into coolstores until they can be transported to the port (for export), or local distribution centres (for local market).

The following five sections provide a more detailed description of the handling system of the postharvest chain, which starts with fruit harvesting and finishes with shipping from the port of export.

1.3.1 Field Operations

The harvest period is one of the most important times of the year for fruit growers. According to Funt and Cameron (1995), the success of an orchard is a combination of good management and sound business practices, and management of harvest labour plays an important economic role in setting the total returns to the grower. If the fruit are not harvested at maturity levels appropriate to their use, damage in terms of bruising and senescence during storage, and poor shelf life are more than likely to occur (Fidler, Wilkinson, Edney, and Sharples 1973). Furthermore, if bruising occurs as a result of poor handling, the grower will receive a lower return as a consequence of loss in fruit value.

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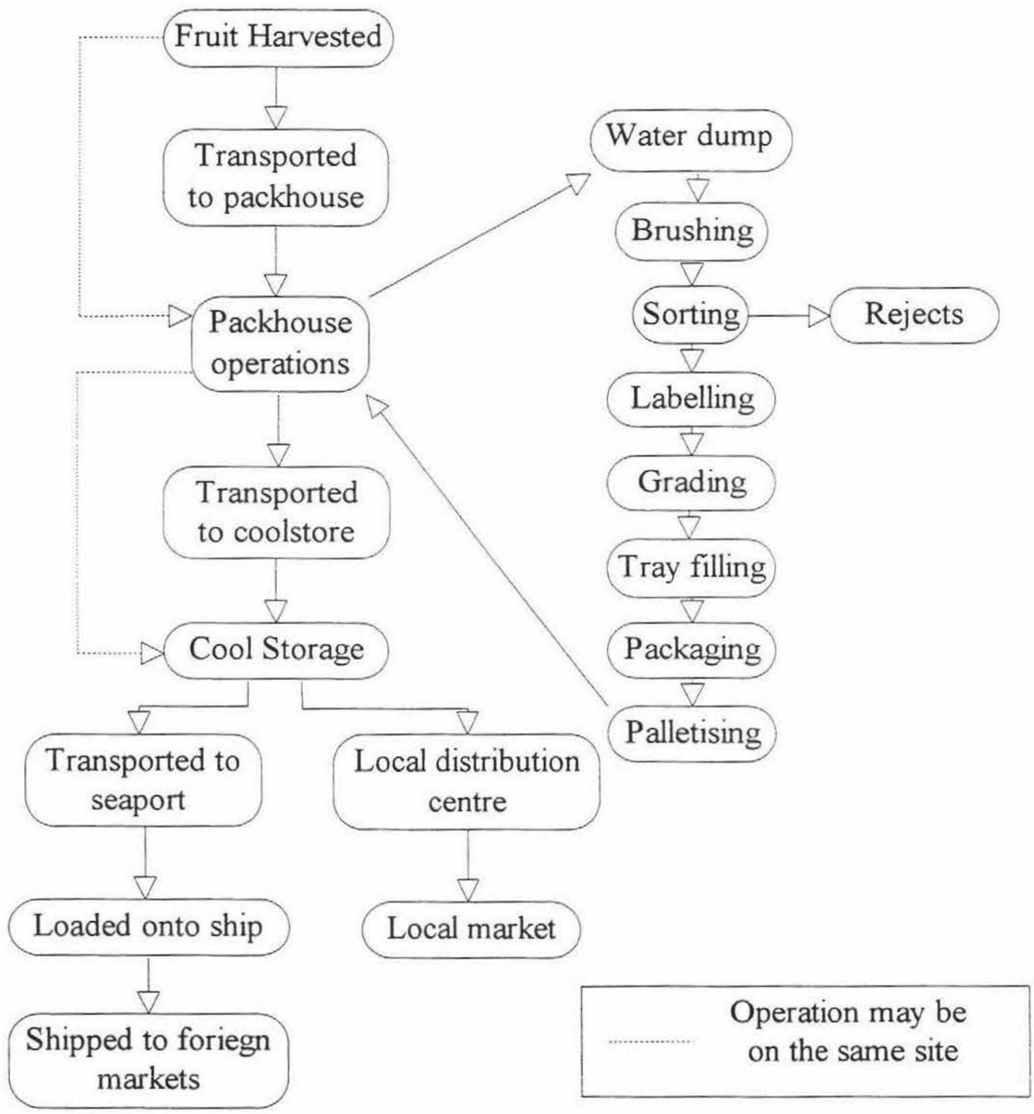
[3] Field bins are usually 1.2m square by 0.8m deep. These bins hold approximately 380 – 400 kg of apples (equivalent to 20 TCEs).

Figure 1.1 Diagrammatic model of the apple postharvest handling system used in New Zealand.



Fruit on an orchard is picked once it is considered to be mature according to ENZA standards. Before the 1996/97 season, ENZA monitored blocks in a district to determine "opening" and "closing" harvest dates, now, it is becoming the growers', or packhouse's responsibility to undertake this maturity testing (Waites *pers. comm.* 1997).

On most orchards, due to large scale fruit production, additional labour is usually required to complete the harvest within the time frame fruit available to meet maturity standards. Picking is usually carried out by workers who are paid hourly, or by contract (on a dollar per bin basis). In some small orchards, however, the owner/manager is able to provide sufficient labour to do the task.

The pickers harvest the fruit by hand, and place it into picking bags/aprons or buckets. From the picking bags, the fruit is transferred into field bins. Mature apple trees vary considerably in height and training system (Tukey 1964); however in New Zealand, mature tree heights can range from 3 metres (semi-dwarf) to a maximum of 7 metres (standard). Fruit that cannot be reached from the ground can be either picked using ladders, or mechanical cherry pickers.

1.3.2 Transportation

Apples are subjected to a number of methods of transport during their movement throughout the handling system. The two main methods of transport used in New Zealand are: in the field by tractor; and on the road, by truck.

Binned fruit, in the field, is usually moved from place to place with tractors (Pang 1993). The bins may be loaded on to trailers that can carry between 2 – 4 bins all the time, or they may be moved using tyne forks on the front or back of the tractor. The tractors are able to move up and down rows between the trees, and along tracks to an orchard loading point. The orchard loading point is where the bins of fruit are loaded onto trucks to be carted to the packhouse. Orchards with adjacent packhouses often supply fruit bins directly to the packhouse.

Fruit may be subjected to road transport several times as it passes through the handling system. Fruit is first trucked from the orchard to the packhouse. This can be undertaken by the orchard owner, or a contractor working either for the orchard, or packhouse. Fruit is transported in the field bins where it was placed after being harvested. Once the fruit is packed into cartons and palletised, it may then be trucked to a coolstore if one is not on the packhouse site. The final movement is when the fruit is transported from the coolstore to the port of export, where it is then shipped to its country of consumption.

1.3.3 Packhouse Operations

In New Zealand there are 244 packhouses, which are grouped by industry sources (Richardson *pers. comm.* 1996) into 3 groups. The first group is the packhouses that pack less than 100,000 TCEs per season, the next group packs between 100,000 and 350,000 TCEs, with the final group each packing more than 350,000 TCEs per season (Richardson *pers. comm.* 1996). The different sizes of packhouses are also an indication of the amount of investment made in equipment. The larger packhouses tend to invest in new technologies, whereas the smaller operations are unable to afford new equipment. The implementation of new equipment, has been designed to eliminate problems that may damage fruit, as a result of bruising.

The aim within the fruit packhouses is to: eliminate substandard fruit; and to sort fruit to quality specifications, while making a reasonable return on the capital invested in the packhouse. To do this fruit follows a sequence of treatments for which suppliers are charged.

The usual path fruit takes as it passes through a packhouse is:

1. Bin storage if unable to be packed within 48 to 72 hours[4];
2. Bin dump (usually in water);
3. Elevator;
4. Brushes;
5. Sorting table;
6. Singulator and labeler;
7. Grading table (sizer);
8. Final size bin / tray filler;
9. Filled carton with "Friday Trays[5]", or equivalent; and
10. Palletisation.

(Nel 1980; Brown, Burton, Sargent, Schulte Pason, Timm, and Marshall 1989; Pang 1993).

1.3.4 Packaging

Prior to 1996, apples were packed in a "standard" 18.5 kg TCE. For ENZA, packaging used to be simply a convenient and cost–effective container for storing fruit until it had reached an overseas destination (ENZA 1995). Although placed onto pallets for transportation within New Zealand, the cartons were individually stacked into the ship's holds. This technique was know as "break bulk" storage. The cartons were then unloaded at their destination in similar fashion. Due to excessive handling caused by loading and unloading, problems such as bruising occurred (Jemson *pers. comm.* 1996). Markets, especially European, began to demand European Union (EU) standardised packaging which leads to smoother

[4] To meet ENZA export requirements, apples must be placed into coolstorage 48 or 72 hours after harvesting, depending on the variety, to maintain the fruit quality (ENZA 1995). If fruit is unable to pass through this process within the time specified by ENZA after harvest, the fruit has to be cooled before packing.

[5] Friday Trays are named after the American designer Mr. Friday (Heap 1995). They are made from recycled pulp paper, and are purple trays into which the apples are placed. The trays are then placed in the cartons. There are various count numbers to allow for the size of the fruit. Not all of the cartons require the Friday trays now that the design has changed.

handling. With these demands being placed on ENZA, a change in dimensions of the packs was needed so that cartons could be stocked on EU specification pallets. Last season, 1995/96, ENZA started phasing out the "old" standard 18.5 kg TCE, and is replacing them with different carton designs.

New carton designs have been adopted which meet customer's preferences in terms of palletisation requirements. A Z–Pack may hold the stated count of apples and is similar in size to the "standard" carton, where a RDT pack holds only about 12.5 kg of fruit, therefore having a smaller number of fruit (Anon 1995). For marketing purposes, the new cartons are printed with visually attractive labels (Anon 1995). The purpose of these, besides advertising ENZA and the products within, is so retailers at foreign markets can place the cartons directly on the shelves, without having to double handle the fruit onto displays. This reduces the risk of further damage to the fruit.

Apples packed for export are aggregated by count size. These count sizes are the number of apples that are packed into a carton, which are determined by an average weight for a particular size of apple. The higher the count number, the smaller the fruit is. Each type of export packaging (explained later in this report), has different counts sizes (Table 1.1). Although the packaging may hold fruit of a certain count size, it does not necessarily mean this is the amount it holds.

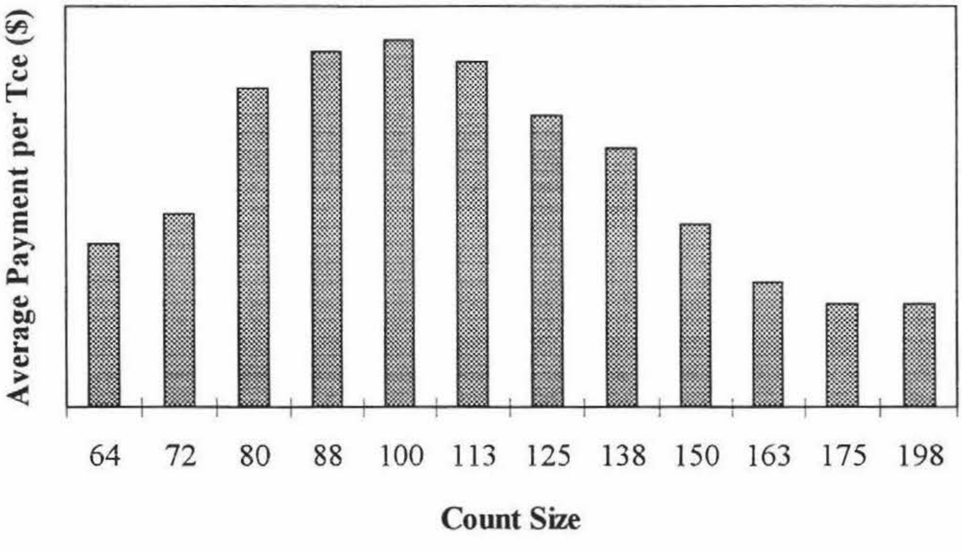
Since returns on fruit are grade and size orientated, growers aim for size count 100 (Kupferman 1996), as this count size generally receives the highest returns. This may be seen in Figure 1.2, which has been derived from the expected average ENZA payment for Braeburn, Fuji, Granny Smith, and Pacific Rose™ for the 1996 season.

Table 1.1 **Type of packaging and the count size of fruit they hold (not necessarily the fruit number).**

Type of Packaging	Count Size Range	Weight of Carton with fruit (kg)
Standard Carton	64 - 198	18.5
Z - Pack	60 - 180	18.0 or 20.0
RDT Pack	63 - 94	12.5

(Adapted from Anon 1995).

Figure 1.2 **A graph representing the average grower payout per TCE of export for each count size in a 18.3 kg standard TCE for the 1996 season.**



(Adapted from ENZA 1996a)

1.3.5 Coolstore Operations

Fruit that has been palletised and is ready for coolstorage becomes the property of ENZA. Export fruit must be coolstored at ±0.5°C. Most fruit must reach these temperatures within 10 days of entry into the coolstore. In New Zealand most fruit is still kept in conventional air coolstores, but with the development of new technology, increasing quantities of fruit are now being stored in Controlled Atmosphere (CA) storage. This provides benefits of longer storage life, and improved quality, but is achieved at considerable cost.

When fruit is removed from storage, it is then trucked by ENZA to the port of export. Previously, with the break bulk packaging system, 90% of the export crop passed through Omni Port in Napier (Barker *pers. comm.* 1996). Due to the introduction of palletisation, very few cartons are stowed in ships this way.

To keep fruit in excellent condition it is now shipped under controlled atmosphere conditions. To lower the cost of shipping, ENZA use chartered ships to transport fruit to the markets (Steele 1995). This also gives ENZA improved flexibility to satisfy customers (Steele 1995), since they can redirect fruit to another market which provides better returns.

Once the fruit has arrived at its destination offshore, it is then distributed either directly to the markets, or to one of ENZA's partnership marketing companies. With the new packaging types, fruit can virtually go straight from the ship onto the supermarket shelf (NZAPMB 1995).

1.4 Fruit Bruising

A British book published in 1885, "The Herefordshire Pomona" detailed cultural practices to reduce bruising, where orchardists were advised to "*spread straw* *underneath their apple trees and then shake the boughs gently so that the ripe fruit would fall to the ground*". This would have to be undertaken several times during the summer (Anon 1989). Bruising is still a major problem for fruit growers today.

For the many millions of apples exported from New Zealand, there are also millions that do not meet the quality standards. For apples to meet the grade standards as set by ENZA, quality management must be maintained through all steps of the system, from orchard production to the consumer.

Bruising is often the single greatest cause of postharvest loss for a grower (Bollen 1993b). Banks, as cited by Bollen (1993b), reported that the cost to the New Zealand apple industry was in excess of $16 million due to bruising in the 1991 season. Later, Banks *et al.* (1993), proposed $25 million as a conservative estimate of the costs of bruising to the apple industry per year.

The ENZA marketing system directly rewards growers with higher returns for fruit that is of higher quality (Pang 1993). While it may do this, it works in the opposite direction by penalising growers who submit lower quality fruit. This is mostly done through the down grading of fruit, that is, fruit which is not up to export standards is either used for processing or for local market.

The cost of rejecting premium quality fruit after storage, due to post harvest damage, is the most expensive form of loss since production, storage, and handling costs have already been invested in the product (Wennergren and Lee 1961; Brusewitz and Bartsch 1989). For the grower, as costs are accumulated to the point of grading, the rejected fruit have incurred the same costs as export fruit, but receive only a fraction of the revenue. Expenses resulting from rejects after grading are then passed to the remaining fruit.

Quantification of the costs of losses to apples due to postharvest handling are difficult to obtain (Bollen 1993b), because for reasons of commercial sensitivity, figures for bruising have been hard to obtain. Most dollar values of bruising that are published have been estimates by industry knowledgeable people (Studman *pers. comm.* 1996).

For these reasons, and the additional lack of information available concerning the breakdown of costs of the postharvest handling chain for apples, it was established that research should be undertaken to investigate the loss in value attributable to bruising. This problem provided an interesting and challenging topic to undertake for a thesis, with results that could prove to be valuable for the participants of the New Zealand apple industry.

1.5 Thesis Outline

This thesis is laid out in six chapters. After this introductory chapter, the first part of Chapter Two introduces Soft Systems Methods and the use of Rich Pictures as part of this approach. This leads to the presentation and description of three rich pictures depicting the process of mapping out this research thesis. The last section of the Chapter is the problem statement derived with the help of the rich pictures.

Chapter Three contains a review of the methods used to collect data for projects such as this, together with a review of literature on value systems (Porter 1985), and bruising in the handling system

Chapter Four describes the methodology which this research used to collect data to meet the objectives. This chapter is followed by Chapter Five, which includes the results and a discussion of them. Finally, in Chapter Six, conclusions are drawn from the results, and the discussion of possible future research concerning the use of both the value chain and value system approach in the New Zealand apple industry is presented.

Chapter Two Rich Pictures and the Problem Statement Development

2.1 Introduction

To enable the researcher to better understand the issues involved, a rich picture of the initial understanding of the problem was created. This approach was found to be an effective way to depict a complex situation. Lewis (1992) states that researchers using soft systems methodology (SSM) may at times, during a study, produce pictorial representations of their current understanding of the problem situation, in order to develop a better understanding. Daellenbach (1994) writes that,

> *"the first step when approaching a problem situation is to familiarize yourself with the situation, its processes and structures, people involved, their aims and desires, the relationships between them, the hierarchy or power structure, the resources available, the sources of data, and information – in short, get a 'feel' for anything you discovered that seems relevant for describing the problem situation".*

Therefore, the purpose of this chapter is to describe SSM and the place of rich pictures in this approach. From these rich pictures a problem statement was formed.

Soft system approaches or methodologies (SSM) are approaches that investigate systems which have poorly defined goals, ill–structured problems, and uncertain decision–making procedures (Reid 1996). The SSM is a process of inquiry which can be thought of as a number of distinct stages. The path through these stages is usually circular and repetitious rather than linear. Due to the unpredictable manner of fruit treatment in the handling system which apples must move through, and the involvement of human activity, it could be seen that a soft systems approach was needed to help clarify the problem of the research.

2.2 Rich Pictures

A rich picture is a cartoon–like summary of everything (or almost everything) the observer knows about the situation studied (Daellenbach 1994). It is similar to the process of brain–storming, except that the aspects are captured in pictorial form. The methodology is concerned with getting from *finding out* about a problem situation, to *taking action* to improve it (if the finding–out process has led to the conclusion that action can be taken), and the idea is to get from finding out, to action, by doing some systems thinking about the situation (Naughton 1984).

The term "rich picture" has developed into a pictorial diagram over time, and was not at first described as a diagram. Checkland (1975) described a "rich picture" as a rich appreciation of a problem situation rather than any particular form of diagram, and to gain such an appreciation many different methods and many diagrams may be used. Some other structures and processes Checkland (1975) outlined which would be helpful to appreciate the problem, besides a picture, are system dynamics models, to simulate operational systems, and cashflow models. For the purpose of this study, a rich picture was developed.

There are various methods of compiling a rich picture, and different people do it in different ways, but a few general rules have been found useful over the years (Naughton 1984; Lewis 1992; Daellenbach 1994). These are:

- Look for the elements of structure. These are all aspects or components of the situation that are relatively stable or change very slowly over time. They include things like physical structure, buildings and layout, numbers of products, etc.

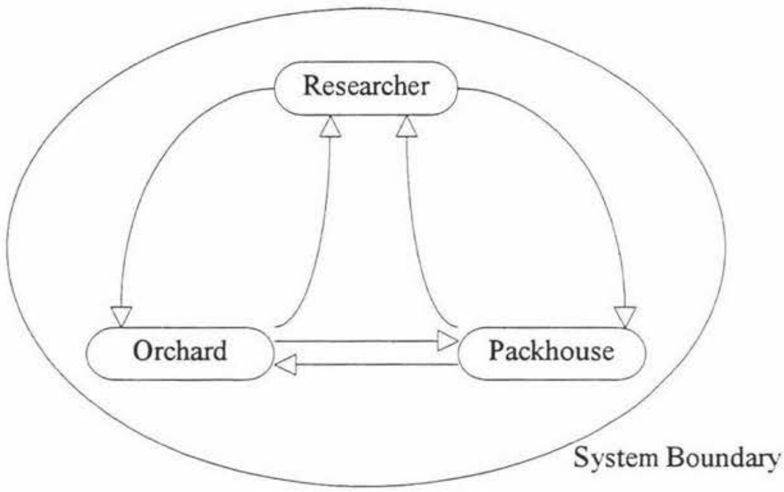
- Next, look for elements of process within the situation. These are the things which are in a state of change, such as the flow and processing of material or information, and decision making that goes on.
- Finally, look for the relationship between structure and process and between processes. How does the structure affect or condition the process? How does one process affect or condition other processes? What things or aspects are direct or indirect results of such relationships?

Using the principles already described, a rich picture was developed concerning the apple handling system. Particular emphasis was made to locate the places in the chains where bruising is likely to (and does) occur, and to find the ways in which information could be collected and compiled to achieve the goals of the research.

2.3 Rich Picture Description

The rich picture depicting the researcher's position, in relation to the problem identification of bruising in the New Zealand pipfruit industry, has been broken into three separate parts, and is represented in Figure 2.3. This Figure is a simplified version of how the three main factors, researcher, orchard, and packhouse interact, and how each is a separate identity. Each of the main variables have been identified as having many individual parts influencing how they react and relate to the problem of bruising. Since the rich picture was developed in the early stages of research, it has been drawn from the researchers point of view with limited knowledge. The purpose of developing this early in the research was to highlight places of missing information, and assist in the problem statement development.

Figure 2.3 Diagram depicting the interactions between the three rich pictures.



The soft system boundary that surrounds the rich picture is the incidence of bruising and the loss of value it brings to the apple value system. The arrows in Figure 2.3 also represent communication channels, in which data was sought. This means, the arrows extending from the researcher to the orchard and packhouse, and back again, represent the researcher interviewing and collecting information from the two sources. The two arrows between the orchard and packhouse represent the personal communication the two have concerning the handling of the crop.

The following discussion relates to the three rich pictures Figure 2.4, 2.5, and 2.6.

2.3.1 The Orchard (Figure 2.4)

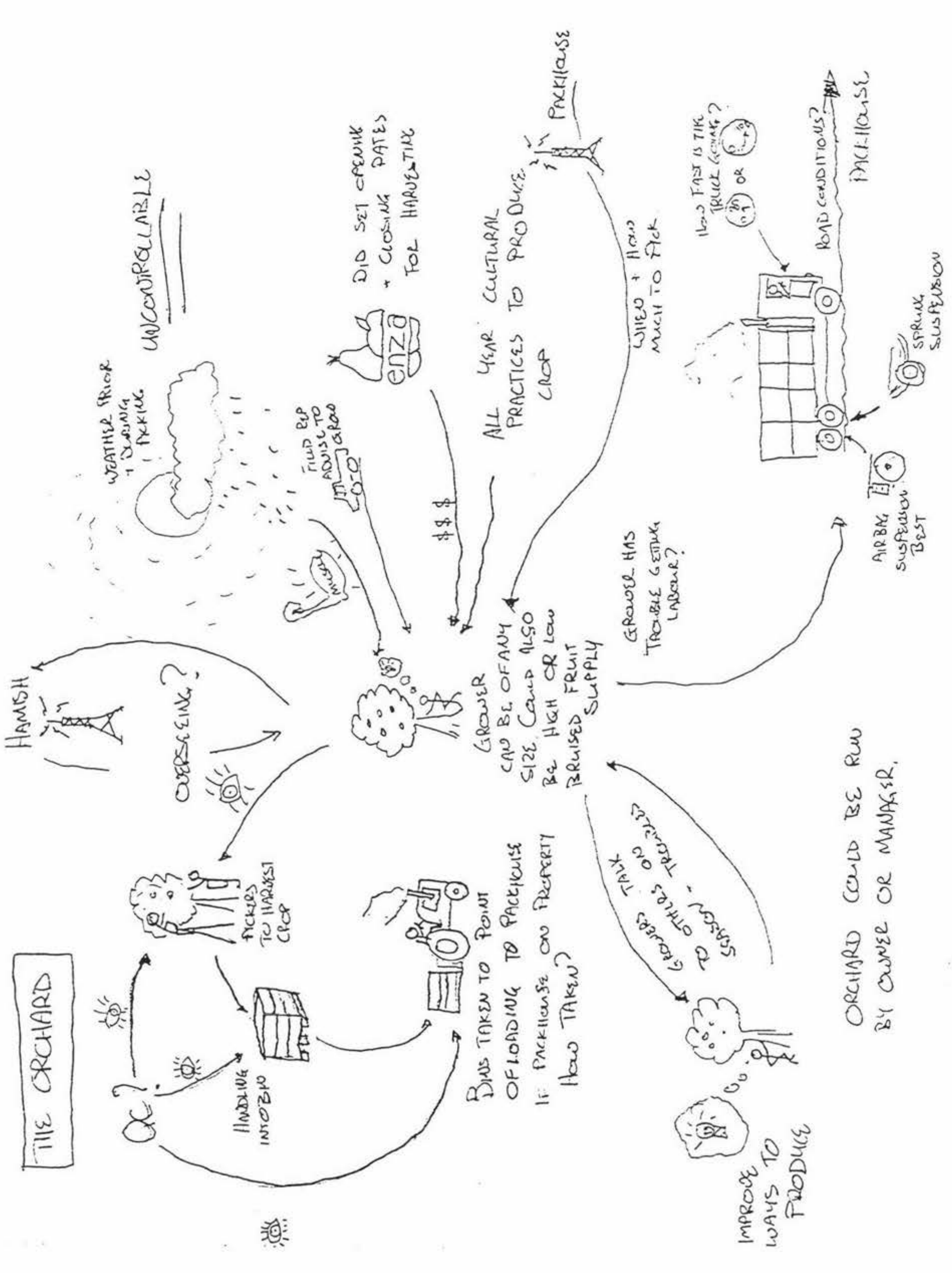
The rich picture concerning the orchard is centered around the orchard owner/manager, since most crop decisions are made by this person. In this picture the condition of the crop can be affected by the weather, pickers, tractor drivers, and general decisions made by the manager. The muscle indicates the weather which has a very strong effect on the crop, and one the manager usually cannot control. All operations concerning harvest have to be overseen by the manager to ensure that they are being completed to a satisfactory standard. If not, the manager has to modify the system to correct this, possibly by dismissing a bad picker. Postharvest handling is generally out of the manager's control, depending on who carts the fruit to the packhouse.

Growers tend to pass ideas amongst themselves if they find methods of improving some aspect of apple cultivation. They also use information about one another as a way of comparing their operation against what is happening to others in the district.

ENZA is a main feature in the picture since they pay the supplier for the fruit they submit each season. As previously stated, they used to set the "opening" and "closing" dates for harvest in an area, and now they set the maturity indices as guidelines for the packhouse and the orchard managers.

Although the truck at the bottom of the picture shows the cartage of fruit to the packhouse, it represents all transportation of fruit by trucks in the apple handling system.

Figure 2.4 Rich picture depicting the Orchard situation.



2.3.2 The Packhouse (Figure 2.5)

Although the packhouse system appeared very simple, there were many factors that had to be considered concerning the costs of the operations, and management of the entire operation. The grading machine is prominent in the packhouse, because it is what the fruit pass over for inspection, and it has been identified in the literature as a potentially large source of bruising in the apple handling system.

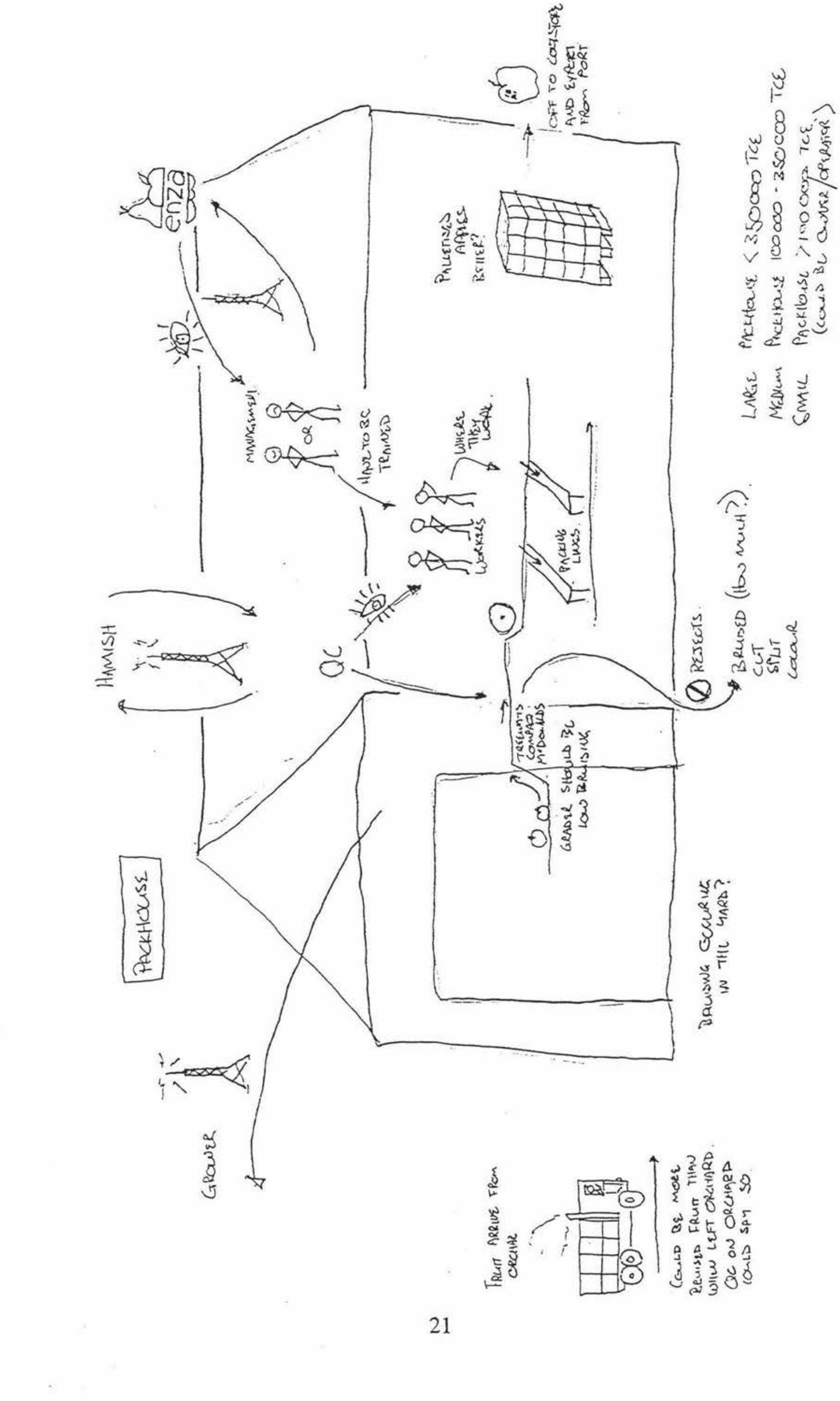
Management of a packhouse need to keep staff satisfied with their work conditions so the work rate does not deteriorate, and affect the quality of fruit passing through the packhouse. The deterioration of quality could occur either by, not removing out of grade fruit, or mistreating the fruit, which results in damage.

Constant communication between the fruit suppliers and the packhouse is needed, to match the input volume of fruit, to the rate of packing. The packhouse is able to provide feedback to the suppliers, concerning the quality of fruit, which they can use to alter management practices to maintain, or improve the quality of fruit they supply.

ENZA staff keep regular communication with the packhouse as to the variety and volume of fruit the packhouse is packing. ENZA staff also monitor the packed fruit to ensure that it is up to export specifications.

A large amount of literature was found concerning bruising of apples in packhouse operations (Nel 1980; Banks *et al.* 1993; Pang 1993), so this helped simplify the picture into a few broad areas which needed to be investigated in this research report.

Figure 2.5 Rich picture depicting the Packhouse situation.



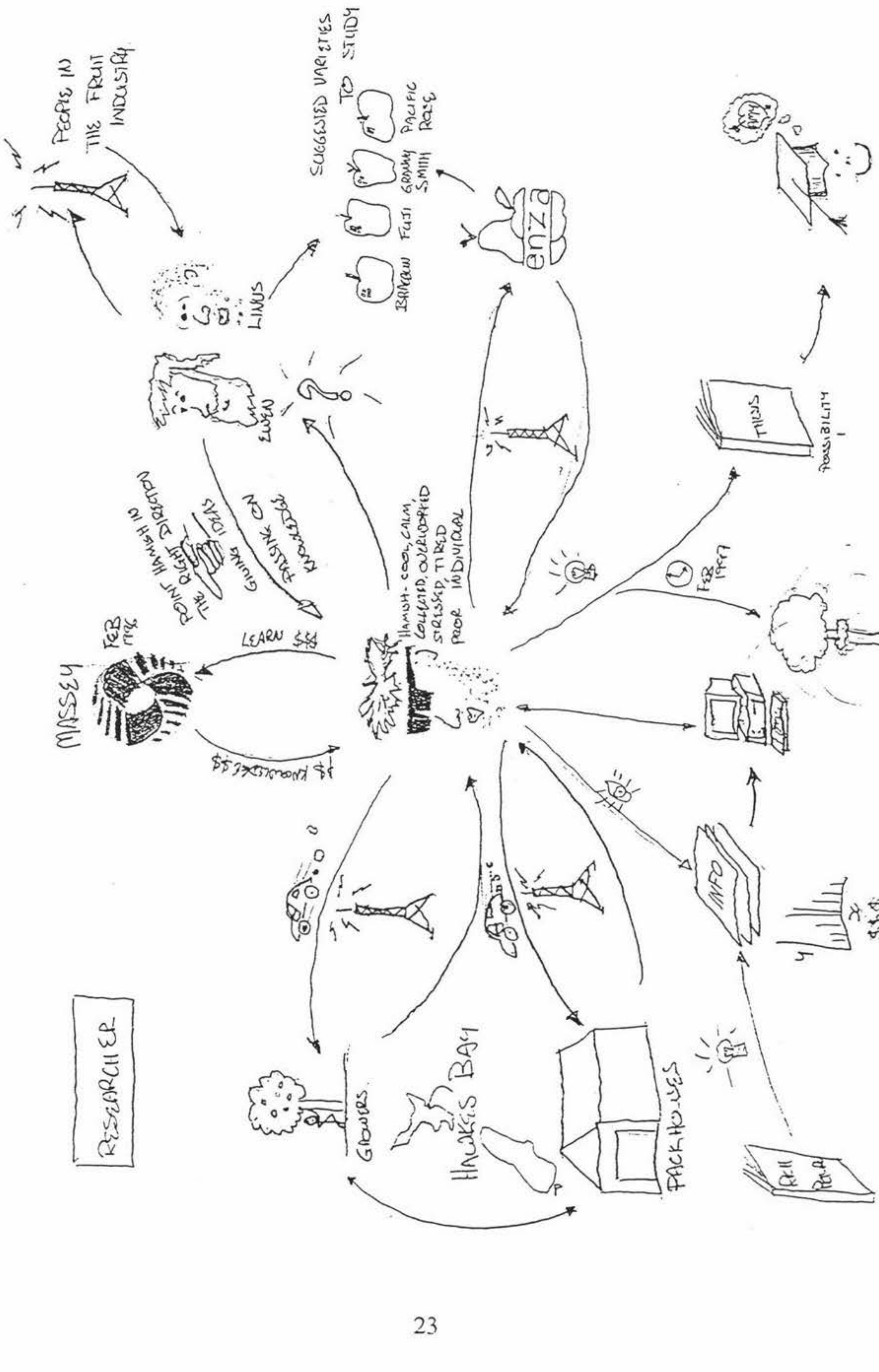
2.3.3 The Researcher (Figure 2.6)

The researcher is situated in the centre of this picture, as it is here that all information and communication is centered. The research is to focus around the understanding of the economic and management systems involved with the bruising of apples. At the beginning of the research, a head supervisor was identified, later, the inclusion of a second supervisor was necessary to assist with the physical side of bruise occurrence and relating properties. Through discussion with the two supervisors and ENZA New Zealand (International) staff, in Hastings, an initial research problem statement was derived. This was to investigate the cost of apple bruising to the New Zealand pipfruit industry. This problem was to be investigated from the orchard, through the apple handling system to the port of export.

The project needed information from direct sources to analyse. It was evident that the two most valuable sources were the packhouses, and the growers who supply them. The packhouses were identified as being important because they could identify suppliers of fruit with "high" and "low" levels of bruising, and hopefully provide contacts that could be interviewed. The different levels were hoped to provide a contrast in figures for the loss in value due to bruising.

To ensure that relevant data could be obtained, it was evident that the approach to take would be to follow fruit from a grower through the system to the packhouse. Hawke's Bay was chosen for this research as it was the most accessible place from Palmerston North, with a large well established pipfruit industry that contains a wide variety of growers and packhouses, for data collection.

Figure 2.6 Rich picture depicting the Researcher situation.



2.4 Problem Statement and Research Objectives

From the rich picture developed to represent this research, a more focused problem statement has been formed. This was further refined with a more extensive literature search until the following problem statement could be developed.

Although the number and percentage of fruit lost, or likely to be lost, because of bruise damage as it passes through the handling system is well documented (Brown *et al.* 1989; Banks *et al.* 1993; Pang 1993), the loss in value attributable to bruising, as it occurs, at the various stages of the apple handling system, from harvest through to loading at the port of export, is not well documented.

From the problem statement several hypothesis have been developed:

1. The loss of value in fruit, due to bruising, resulting from handling can be found.
2. The loss in value of fruit is considerably more at the market end of the system than it is at the beginning.
3. The onshore (in New Zealand) opportunity cost of bruising is considerably more to the supplier, than the value loss faced by the industry.

This work will focus on the issue of fruit bruising and the value of such damage, to the New Zealand pipfruit industry. An important outcome of this study is a description for the value of fruit as it progresses through the postharvest handling system and the quantification of the loss in value due to bruising.

From the literature, a valuable management tool used to appraise a firms resources and the cost involved was discovered. This was Porter's (1985) description of a value chain, which uses an approach to identify costs that occur at each stage within a firm, with the available resources, to turn an input product into the firms final output product. A series of value chains formed a value system. This approach was adopted as a framework to achieve the objectives of this thesis, which are to:

1. Develop methodology to evaluate the incremental value of fruit, as it passes through a value system as described by Porter (1985), for the apple handling chain in the Hawke's Bay district.
2. Present the increasing loss in value of fruit as it is bruised while passing through the apple handling system.
3. Determine the opportunity cost for bruising to the supplier, through the cost of production and the loss of potential returns.

This research is only concerned with operations on–shore in New Zealand, as the industry exerts more direct control over the handling of fruit during this phase than it does elsewhere. In order to solve these problems, data was collected from both the literature, and from growers and packhouse operators.

Chapter Three Literature Review

3.1 Introduction

"Farm management research is focused on management techniques, practices, and strategies for more efficient resource allocation and/or ways to market inputs and outputs which will maximise profits, minimise costs, and reduce risk in its many forms" (Howard and MacMillan 1991). In the case of this research report, the focus is on apple bruising and the loss in value it brings about in the New Zealand apple industry.

The research method involves data collection, collation, and analysis (Dryden 1995). The main classes of research tools available for the purpose of research may be distinguished as: secondary sources (literature); rapid rural appraisal (exploratory survey); surveys, both single and multiple visit; case studies; and experiments (Maxwell 1986). Yin (1994) sets out relevant situations for different research procedures (Table 3.2). These approaches vary in cost, coverage, accuracy, time, and statistical validity, therefore trade–offs between the variables must be calculated for each particular project (Maxwell 1986). To collect the required data, a combination or sequence of research methods will be needed. In general, case studies are preferred for research that have "how" or "why" questions being posed; when the investigator has little control over the events; and the focus is on some real–life problem (Yin 1994).

Table 3.2 Relevant situations that have to be considered for different research procedures.

Procedure	Form of research question	Requires control over behavioural events?	Focuses on contemporary events?
Experiment	how, why	yes	yes
Survey	who, what, where, how much, how many	no	yes
Archival analysis	how, why	no	yes/no
History	how, why	no	no
Case Study	how, why	no	yes

(Source: Yin 1994)

How and why questions are commonly used to clarify issues. These how and why questions seek more detailed information than could be obtained from who, what or where questions. Experiments, histories, and case studies are useful for answering how and why questions (Yin 1994).

The purpose of Chapter Three is to, review literature concerning the research data collection and compilation methods, used to complete this research project, and to review Porter's (1985) value chain concept, which is used as the analytical framework for this thesis. The last half of the Chapter is a review of literature concerning apple bruising and its occurrence within the handling system.

3.2 Cases Studies

Case studies have long been accepted as a useful educational tool in many branches of science (Maxwell 1986). Case studies have been traditionally used as a basis for teaching law and medicine, however they were not adopted for management teaching until the second decade of the 20th century (Ravenscroft and Wiggins 1990).

Yin (1994) gives the definition of a case study as;

> "*A case study is an empirical* (real word) *inquiry that:*
>
> - *investigates a contemporary phenomenon within its real–life context; when*
> - *the boundaries between phenomenon and context are not clearly evident; and in which*
> - *multiple sources of evidence are used.*"

The case study method combines theoretical knowledge with practical situations in order to develop analytical skills in identifying problems and determining feasible solutions to these problems. Case studies are used in that they "*allow the student to step figuratively into the shoes of the decision maker or problem solver*" (Erskine, Leenders, and Maufette–Leenders 1981). This means the student is able to view all that is occurring, and put their theoretical knowledge into practice to solve or improve the case that is being studied, without affecting the real life situation.

While knowledge is an important factor in undertaking case studies, it is only important to the extent that it provides the background information for the problem solving and decision making (Ravenscroft and Wiggins 1990). When applied to farm management, the case study method has an advantage of being able to draw together a number of disciplines, and to highlight different disciplines, within a single case (Ravenscroft and Wiggins 1990). Furthermore, Maxwell (1996) reports that the case study method is a useful and cost–effective addition to the range of research tools used in multidisciplinary farming systems research.

To investigate the cost of apple bruising in the industry, the researcher must draw upon knowledge of apple husbandry, research, financial, and market estimates. In addition, the range of possible case study material can be drawn from a diverse background and multiple sources. The evidence may be qualitative, quantitative, or both (Eisenhardt 1989).

Ravenscroft and Wiggins (1990), wrote that the starting point of a case study requires the researcher to define what the decision maker, or subject of the case, wishes to achieve. The next stage is to identify the potential courses of action that can lead to the achievement of the objectives, or the solution of the problem. It is then important to establish what assumptions have to be made, in determining which of the potential solutions is the most favourable to the decision maker. This is because a case study rarely has fully documented information on the case.

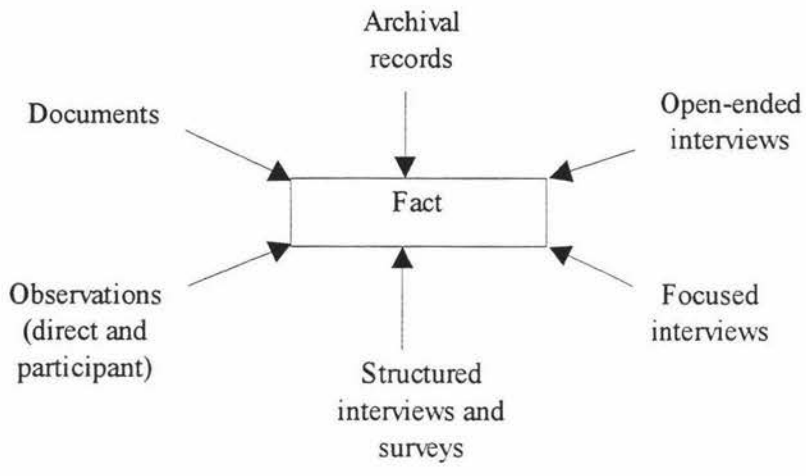
3.3 Data collection

Data collection for any research report will require the use of many sources of information to answer the research questions. Eisenhardt (1989) and Yin (1994) have identified six major sources of data, these are:

- documentation;
- archival records;
- interviews;
- direct observations;
- participant observation; and
- physical artifacts.

Yin does not rate any one of these sources any better than the other, but suggests using at least three or four. For this reason, this report is a single study, which draws on multiple sources of evidence to find answers to the stated objectives. Yin (1994) calls this "*...the convergence of multiple sources of evidence*", and supplies the following diagram (Figure 3.7) to represent a study and the sources of information it draws from.

Figure 3.7 Convergence of multiple sources of evidence to undertake a single study.



(Source: Yin 1994)

3.3.1 Documentation

Documentation, and systematic searches for relevant documents are an important part of data collection (Yin 1994). Documentation can include letters, memoranda, written reports of events, administrative documents, formal studies, newspaper clippings and other articles appearing in the mass media.

3.3.2 Interviews

Often the most important aspects of case study research is not the formal data collected, but the understanding of management practices derived from conversation with the interviewee (Maxwell 1986, Parker and Hughes 1989). An interview differs from a normal conversation, in that, it has a focus and a purpose. It may not be a good conversation, but good data should be the outcome (Gray *pers. comm.* 1996).

Interviews can take several forms, but the most common for case studies is one of an open–ended nature (Yin 1994). This is where the interviewer can ask selected people for facts of a matter as well as the person's opinions about events. The other option is a focused interview (Merton, Fiske, and Kendall 1990). This is where an interview lasts for a short period of time, which could be an hour, and the questions may still remain open–ended and assume a conversational manner, but the interviewer will be following a certain set of questions derived from the case study protocol (Yin 1994). Parker and Hughes (1989), state that an interview is more than likely to occur on the respondent's property, this may be the orchard or packhouse, as it allows the interviewer direct observation of the property. The observations can range from formal to casual data collection activities.

The interviewer may take written notes during the interview, or use a tape recorder, if the interviewee is prepared to be recorded (Tolich and Davidson 1996). Although a tape recorder is a help in recording data, it should not be totally relied upon (Tolich and Davidson 1996), as some settings are too noisy.

3.4 Models

In its simplest terms, a model is a representation of a real situation or object (Angus–Leppan 1984). A model uses data collected from the system to describe it, but it must be remembered that the model is not an exact replica of that system, meaning, it is an approximate (Daké *pers. comm.* 1996). Financial models describe activity in terms of money, in either a single period or over a number of periods.

Much of the value of modelling lies with the ability to quickly perform repetitive calculations, and these calculations are done through the use of spreadsheets. The key to modelling success is sensitivity analysis wherein the significant parameters or variables of the decision are identified and variously modified to "see what happens" (Buchanan 1987).

Daké (1996) suggests, that a good spreadsheet model should help answer:

1. 'what–if' questions for tactical and strategic planning;
2. 'what might have been' questions to examine past errors/weaknesses in these decisions;
3. 'what has been' questions, which act as a front-end decision support systems or information system when coupled to a database.

Financial applications of computer based simulation models can be used for three different types of planning used by management (operating, administrative, and strategic) (Angus–Leppan 1984). The aim of the model is to ensure that output generated meets the requirements of potential users. The quality of output depends to some extent on the data inputs, and is therefore important to ensure that the income and expenditure functions have been adequately specified (Angus–Leppan 1984). Bhaskar, Williams, Pope, and Morris (1984b) list five types of models:

1. Strategic models;
2. Impact models;
3. Budgeting models;
4. Planning models; and
5. Cash flow forecasting.

The different types of models are often combined. A particular model may of course fulfill more than one role, and it is common to link models together using a common database.

In the past, companies built their own tailor-made models using in–house operations, research personnel, and a general purpose language (Bhaskar, Williams, Pope, and Morris 1984a). The situation has changed in that non–specialists can now build their models on computers with the aid of modelling systems such as spreadsheets (Bhaskar *et al.* 1984a).

3.5 Spreadsheets

Spreadsheet software is ideally suited for constructing and running financial models. A spreadsheet program comprises a large matrix, which can be thought of as the computer equivalent of a large, multi–column sheet of analysis paper (Bhaskar *et al.* 1984b). Typically, only part of the array is shown on the display at any one time, making it possible to shift the spreadsheet so that a different segment of the statement can be examined by the operator (Bhaskar *et al.* 1984b).

Spreadsheets may be implemented to assist in many problem solving situations. For management decisions these tasks could be to:

1. assist managers in their decision process in semi–structured tasks;
2. support rather than replace management judgment; and
3. improve decision making.

From a survey in the Manawatu district, Coy (1986) divided the benefits of spreadsheets into three categories. With these the most common reasons for using spreadsheets were also given. The categories and reasons are:

1. The ability to manipulate numbers
   - it saves time on <u>calculations</u>
   - it enabled more <u>what–if</u> analysis to be done
2. Ease of translation from draft to final copy
   - it saved time on copy <u>typing</u>
   - it saved time on <u>proof reading</u> and corrections
   - it enabled easier <u>exchange of information</u> with colleagues
   - a more <u>timely</u> report was produced
3. Psychological benefits
   - individual was more <u>confident</u> of the accuracy of the final result
   - the job was done with less <u>strain</u> on the individual than formerly.

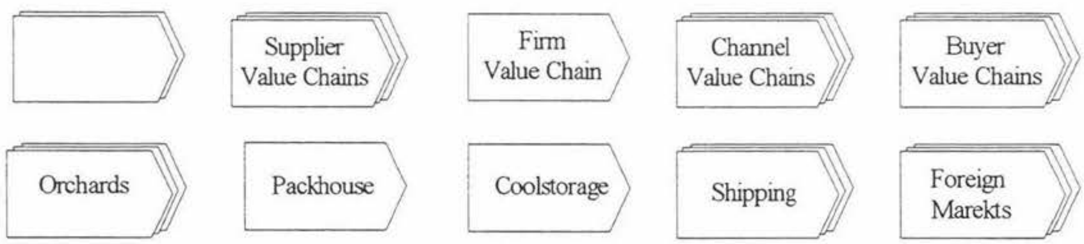
(Source: Coy 1986)

3.6 The Value Chain

An economic tool that has been used by firms to assess their competitive advantage in a systematic way is a value chain analysis (Partridge and Perren 1994). The concept of the value chain is that it divides a firm into its strategically relevant activities in order to understand the behaviour of costs and the existing and potential sources of differentiation (Porter 1985). The linking of such value chains leads to the development of a value system.

A value system can be created for the supplier (the apple grower), transportation (delivery to the packhouse), the firm (packhouse), etc., until the product reaches the buyer. A value chain is just one link in the value system (Figure 3.8), like a grower or packhouse is in the New Zealand apple value system, which is overseen by ENZA.

Figure 3.8 The Value System as described by Porter (top), and an adapted model representing the New Zealand pipfruit industry value system (bottom).

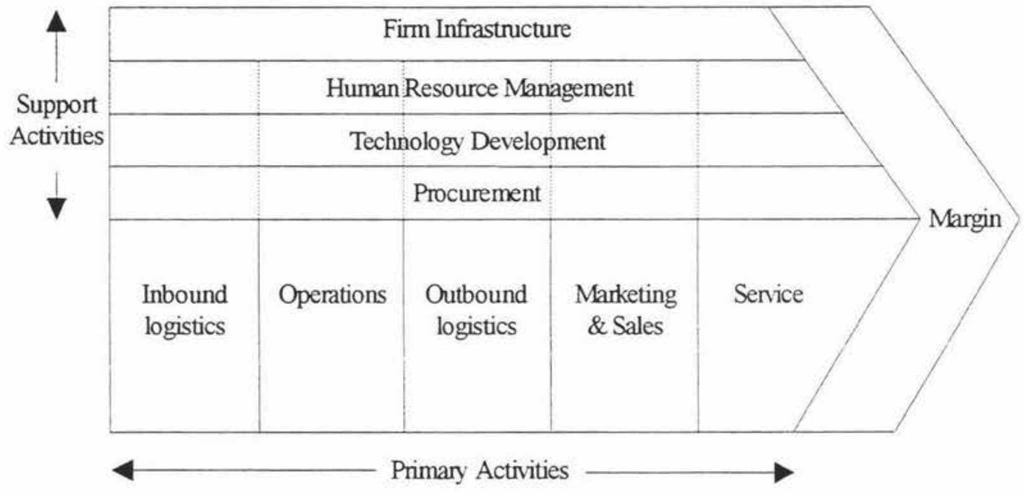


(Source: Porter 1985)

The above Figure represents a single–industry firm value system. Although it can not be seen in Figure 3.8, each segment is linked by transportation, with the only distribution channel being represented as shipping. Porter also describes a diversified firm value chain as being similar, but may be involved with other parts of the system through vertical integration, this means, the firm may have diversified so it supplies the raw products it uses to produce a higher level product. An example of this would be a group of growers who get together and construct a large packhouse to pack their, and maybe other grower's, fruit for export. As the business expands it may add a coolstore facility to the operation, and could also diversify to the point of providing its own fruit transport company. It is through this value system, that the added value for export fruit will be found.

Although not specifically designed as such, the value chain will provide a useful tool for describing the activities involved with the export of apples, from orchard to port, and the value added to the product. Porter's generic value chain is presented in Figure 3.9.

Figure 3.9 The generic value chain.



(Source: Porter 1985)

It can be seen that the value activities can be broken into two main types, support and primary. The support activities contribute to the infrastructure required for primary activities to function (Partridge and Perren 1994). The primary activities are those directly concerned with the provision of the product or service and its distribution to the customer (Porter 1985; Partridge and Perren 1994).

The support activities are segmented into four categories, and are defined as follows. Procurement is the function that acquires inputs needed by the firm's value chain, such as raw materials, supplies, machinery, and buildings (Partridge and Perren 1994; Dryden 1995).

Technology development is a range of developments that provide improvements in products or processes, for example, apple variety trails, or electronic colour sorters.

Human resource management encompasses, staff hiring, training, empowerment, etc. (Porter 1985; Preece, Fleisher, and Toccacelli 1995). Firm infrastructure plans, finances, and controls the firm's entire value chain (Partridge and Perren 1994),. These support activities are all associated with the primary activities.

The primary activities are segmented into five areas. Inbound logistics are activities that are associated with receiving, storing, and transferring inputs to the operation stage (Partridge and Perren 1994). An example of this is a packhouse receiving bins of fruit, storing them, then preparing the fruit for grading. Operations are the activities that change inputs into the final product form, for example, the grading of all fruit to get the best grade for export. Outbound logistics are associated with collecting, storing, and physically distributing the product to the customers. This could be seen as transporting palletised fruit to a coolstore contracted by ENZA. Marketing and sales are the activities that persuade customers to purchase the product (Partridge and Perren 1994). At present this is performed by ENZA New Zealand (International), for all pipfruit that is sold by NZAPMB, whereas companies that have special licenses from ENZA, have to undertake pipfruit sales themselves. Since the deregulation of the domestic market, this area is becoming increasingly important for orchards that sell the fruit independently. The final primary activity is service, which is not so much directed at orchards, but to ENZA who have export markets that expect a high quality product.

3.7 *What is a Bruise?*

Bruising is usually identified as brown discoloured flesh caused by the oxidation of the cell sap exposed to air (Ingle and Hyde 1968; Holt and Schoorl 1977). For handling and grading purposes, fruit are assessed in terms of the surface dimensions of detectable bruises, rather than bruise volume[6]. Hence, while bruise volume may be important to fruit processors, surface area or bruise diameter is of more commercial significance to the fresh fruit industry (Pang, Studman, and Banks 1992a). These visual imperfections are what the consumer judges against when purchasing the fruit. The larger the surface bruise area, the less appealing it is to the consumer (Opara, Studman, and Banks 1991). For this reason standards are enforced to reduce the amount of bruised fruit arriving at a market.

ENZA's export standards allow for the total bruise area on any one fruit to be no more than 1 cm^2. Fruit with either a single bruise, or a number of small bruises whose sum coverage exceeds 1 cm^2 is rejected (Figure 3.10). For the fresh fruit industry, bruise size with skin on the apple is used, whereas, in the processing industry flesh bruising would be used.

Figure 3.10 1 cm^2 for bruise area allowable on fruit.

[6] Bruise volume is the volume of bruised flesh beneath the surface of the skin. This bruised flesh is the cause of the brown discolouration that is identified as a bruise when an apple is dissected.

3.8 Bruising

Studman (1990) reported that bruising during handling is caused by either:

- impact (free fall); or
- compression; or
- vibration.

Field studies of handling systems have shown that most bruising occurs as a result of impact against a variety of surfaces. In particular, bruising occurs during apple harvesting, grading, handling, and transport when fruit impacts with other fruit (Bollen and Dela Rue 1990; Banks 1991). Compression bruising occurs due to forces experienced during bulk handling and package handling. Vibration bruising takes place when fruit vibrates due to the movement of its surroundings. For example, during transport of fruit from the orchard to the packhouse, both sides of the bins and the top layers of fruit vibrate due to road conditions (Schoorl and Holt 1985).

The deceleration of an apple when it strikes a surface is very important in determining the size of the bruise that will occur (Brown *et al.* 1989; Studman 1991; Pang, Studman, and Ward 1992b). If an apple strikes a soft surface the deceleration is slower, and the area that is in contact with the surface is larger, therefore decreasing the size of the bruise. If the apple strikes a hard surface the deceleration is great, and the contact surface is small, so the pressure is greater on the apple causing a larger bruise.

When an apple impacts upon another apple, generally one is more severely bruised than the other (Pang *et al.* 1992a; Pang *et al.* 1992b). Pang (1992b) mentioned that, while great care is taken to avoid fruit impacts on bare steel surfaces, apple–to–apple impacts are relatively common in the fruit handling system, and it was not surprising that they are responsible for significant quantities of bruising. Pang further found that when an apple impacts another apple which is unable to move, bruise areas on fruit are only 24% smaller than bruises caused from impacting a steel surface.

3.9 Bruise Susceptibility

The bruise susceptibility of an apple is defined as the change in measured bruise volume corresponding to the energy absorbed which resulted from a compression, impact, or vibration force on a given surface (Holt and Schoorl 1977; Garcia, Ruiz–Altisent, and Chen 1988; Brusewitz and Bartsch 1989; Pang 1993).

Bruise susceptibility is a good indicator of how susceptible an apple variety is to bruising. This information can be used to illustrate that certain varieties may have to be handled with more care than another, and greater measures will need to be taken to prevent bruising. There have been several varieties tested for their bruise susceptibility (Klein 1987; Pang *et al.* 1992a; Pang 1993), they have then been ranked in Table 3.3. Braeburn is the least susceptible, and Splendour, a parent of Pacific Rose™, the most.

Table 3.3 Bruise susceptibility of apple varieties.

Variety	Bruise Susceptibility	Bruise Susceptibility Rank
Braeburn	Low	1
Fuji	Medium	2
Gala	Medium/High	3
Granny Smith	High	4
Splendour	High	5

(Adapted from Pang *et al.* 1992)

Investigations of bruising incurred during harvesting, from the time fruit are placed into the field bins, have shown that highly bruise resistant varieties, on average, sustain less than half the amount of field bruises which occur with low resistance varieties (Banks, Studman, Hewett, Wood, Varela–Alvarez, and Creoge 1989).

3.10 Bruise Recovery

Many people within the industry have observed that, after initial development of colour, bruises subsequently fade, leading to a belief in the phenomenon of "bruise recovery'' (Samim and Banks 1993).

Thus, some flesh bruises on apples may not be visible to the sorters in the packhouse, and the fruit pass as acceptable. These fruit would then be sent to the markets as Class 1 fruit, and sold to the consumer as such. Even though the bruises have faded, and may not be visible to the consumer, the bruises could still have a marked effect on consumer satisfaction at the time of consumption (Samim and Banks 1993), because when the consumer has taken a bite from the fruit, it appears and tastes "floury".

3.11 Bruise Observations

Samim and Banks (1993) found that when they impacted opposite sides of apples with the same force, variations in bruise size resulted. Results from Brusewitz and Bartsch's (1989) experiment showed that bruise volume was 10.9% smaller on the red side and 4.5% larger on the greener side, than the average sizes of bruises for all sides of an apple, supporting property variations around an apple. These authors related this differentiation in bruising to the shaded side of the fruit having more immature tissue, which bruised more readily. These variations in bruise sizes could be the reason that some suppliers of fruit might have greater bruising levels than others.

Further tests carried out by Samim and Banks (1993) found that bruises on the blushed sides of red–skinned apple cultivars are generally more intensely discoloured than those on the green side of the same fruit. However, the red pigment in the skin masks this more intense discolouration quite effectively, so that red skinned cultivars are often perceived to be less bruise susceptible than green or yellow skinned fruit. These results indicate that in a packhouse situation on a sorting table, red skinned apple varieties are more likely to have a lower bruise rejection rate than green, because graders are less likely to identify the bruises on the red apple varieties. This would then increase the grading and sorting costs of green skin apple varieties over the red, due to the greater amount of fruit which will be identified with a bruise, which therefore has to be removed from a line. This could be countered though, by saying that the sorting table should be slowed to increase bruise identification in the red skinned varieties.

In tests undertaken by Pang *et al.* (1992a), bruise visibility was found to vary for different varieties. Meaning that, even though a variety might not show signs of visual bruising, there is bruising present below the skin, once that fruit is peeled. The results they reported were graded from the least visible to most visible bruising varieties, as shown in Table 3.4.

Table 3.4 Bruise visibility of five different apple varieties following standard treatment.

Variety	Visible Bruising (%)
Braeburn	0
Fuji	38
Gala	48
Granny Smith	50
Splendour	82

(Adapted from Pang *et al.* 1992a)

The order in which bruise visibility was found related very closely to the order of bruise susceptibility for the varieties.

The varieties Gala and Splendour have been included because they are the parents of Pacific Rose™. By displaying these two varieties, the bruise susceptibility for Pacific Rose™ may be indicated. The data shows that the bruises on Pacific Rose™ could be highly visible, although no published bruise susceptibility data was found concerning this variety.

3.12 The Handling System

Nel (1980) investigated the occurrence of bruising starting from the orchard, and continuing through to the end of packhouse handling. When talking to both the growers and the packhouse operators, Nel found each had definite ideas on where bruising occurred. Packhouse operators believed that most of the bruising occurred during the picking and transportation of fruit, both on the orchard and on the way to the packhouse. The growers had little doubt that most of "*our apples are bruised by those packhouse operators*".

Despite growers and packhouse operators blaming each other for bruising, some definite points at which bruising is more likely to occur have been identified. These are:

- in the field, between the tree and the field bin;
- and on grading equipment, between the sorting table and final size bins/tray fillers.

(Nel 1980; Banks *et al.* 1989; NZAPMB 1991).

Bruising in the field, can be influenced by the cultural practices used to raise the crop to a harvestable product. In other words, preharvest cultural practices can affect bruising (Klein 1987; Durand 1990; Banks et al. 1993).

3.12.1 Cultural Practices

Bruise susceptibility varies from fruit to fruit. Many factors affect bruise susceptibility, and these include: water status; exposure to sunlight; chill exposure during growth period; or position on the tree (Banks *et al.* 1993; Bollen 1993b).

Irrigation of trees close to harvest time has been found to increase the chances of fruit bruising (Durand 1990). A study undertaken by Banks *et al.* (1993) using Braeburn, found that in irrigated trees, bruise area and bruise depth increased by 7% to 9.7% above bruising levels in fruit from non–irrigated trees. To minimise this risk, Banks *et al.* (1993) suggested that irrigation close to harvest be reduced.

The time of day of harvest has been shown to have an effect on the bruise susceptibility of fruit. Klein 1987, Brown *et al.* 1989, and Banks *et al.* 1993, have all reported that warm fruit, is less susceptible to bruising than cold fruit. Banks *et al.* (1993) cites from Jones, Lakso, and Syvertsen (1985), that fruit growing on the tree, are known to go through a diurnal cycle in both water status and temperature. In the heat of the day, fruit loses water back into the tree and regains it at night. Fruit are then expected to have a lower bruise susceptibility in the afternoon than in the early morning because of warmer temperatures, reduced water status, or a combination of both. Banks *et al.* (1993) in trials using Golden Delicious trees, found the bruise area was 4% lower at mid–morning and 6.5% less in afternoon harvests than bruise areas of similar fruit picked in the early morning. If growers were aware of these variations in tree status which lower the bruising of fruit, they could take preventative measures to reduce the probability of bruising.

3.12.2 Harvesting

During harvesting of apples, damage by bruising is of major concern. In some cultivars, bruising may result in down–grading of up to 50% of the total crop picked (Pang, Studman, Banks, and Bass 1996).

Growers differ in their handling methods and attitudes towards maintaining low levels of bruising (Wennergren and Lee 1961; Nel 1980). Their attitudes may influence the methods, amount of supervision, etc., used in harvesting and handling apples. Bruising of varieties can vary between growers due to handling methods. Since growers may consider a variety less susceptible to bruising than another, they may handle one variety with less care than it deserves (Wennergren and Lee 1961). As a result, more damage occurs than might have. This is a management problem that can easily be rectified, by simply stating to the workers that all fruit bruises with little effort and increasing quality control, provided the growers are aware of variety differences.

Harvesting is the most stressful part of fruitgrowing (Wilton 1995). With good harvest management it is possible to minimize the rate at which rejects are created by the picker. Immature under–coloured, bruised, and stem punctured fruit can all be reduced with good staff management. Wilton (1995) writes, that in terms of fruit value, 5% picker created rejects costs over $10 per bin. With a 10% picker defect, approximately $20 equals the cost of harvesting the bin itself, this was close to $24 for the 1996 season.

Sykes *pers. comm.* (1996), mentioned that a grower may put in many hours, and take a lot of care with the production of their fruit, but may lose out with labour management during picking. This comment is supported by Funt and Cameron (1995). The small owner/operator, or family unit may not be able to cope with the sudden influxes of staff. If workers are not controlled adequately, bruising can occur.

Studies carried out by Wennergren and Lee (1961), and more recently Banks *et al.* (1993), showed that more bruising occurred when the pickers used canvas bags rather than rigid sided picking containers such as a picking bucket. The occurrence of bruising in apples picked into bags was found to depend upon the way the individual picker used the bag. Carelessness by pickers created large bruises in picked fruit when they bumped into objects such as the ladder or bin with their picking bag (Banks *et al.* 1989).

From a survey of seven properties in the Hawke's Bay region of New Zealand, Banks *et al.* (1993) found that impacts of fruit onto other fruit, or other surfaces, was a much greater problem than finger bruising (NZAPMB 1991). About 75% of field bruising occurred as fruit were released into the bin. Banks *et al.* (1993) suggested that this bruising can be reduced by about 30% using the "backward sweep technique" to release the fruit into the bin from the bag. A further reduction of between 30% and 60% in bruising could occur if padding of various sorts was placed into the bottom of the field bin. A recent development to reduce this type of bruising is the installation of hydraulic cushions in the bins. Trials conducted using field bins with the hydraulic cushions[7], showed a reduction of bruising of between 34% and 54% (Anon 1993).

A British report undertaken to study the occurrence of apple bruising in the field, found that 21% of harvested fruit was damaged (Anon 1985). For their top grade standards, bruising reduced 6% of the apples in picking bags to Class II status. By the time the apples were in the bin, 13% had been reduced to Class II, and 8% to Class III. The main problem was attributed to the way the picking bag was emptied into the bin (Anon 1985). The study showed that 32% of the pickers did

[7] Hydraulic cushions (plastic bags partially filled with water) that are made in various sizes that can be installed for the prevention of bruising in field bins, graders, etc. Water–filled cushions made by Borden Liquipac, who specialise in the production of durable, liquid–filled plastic bags.

not bruise the fruit at all, but importantly only 8% of the pickers did 50% of the damage. The training and monitoring of this small percentage of people, has been suggested by Schulte Pason, Timm, and Brown (1993), Wilton (1995), and Van Workum (*pers. comm.* 1996). By improving the small percent of below average pickers, less damage is likely to occur to the fruit. The other option is the dismissal of staff that do inflict the greater amounts of bruising and train new staff.

Pickers should be well trained to ensure field bruising is minimised. John Wilton (1995), a Horticultural Consultant, has run workshops using an experienced picker to demonstrate the finer points. As well as demonstrating picking techniques, pickers were shown how to remove several fruit in one hand without bruising them. Emptying the fruit from the picking bag to reduce bruising and stem puncture damage, was also demonstrated. Training sessions for pickers have often been suggested to show better picking techniques, this has shown to be beneficial, with a decrease in bruising (Schulte Pason *et al.* 1993). Schulte Pason *et al.* (1993) produced two videos to assist in communication of proper apple handling techniques for field and packhouse workers.

Motivating the pickers has been suggested as a way of avoiding bruising (Wennergren and Lee 1961; NZAPMB 1991). A payment system derived on the amount of bruising that a picker produces can be implemented. The lower the amount of bruising the greater the payment for the worker. Monitoring of fruit should be undertaken before any movement of field bins has taken place, so pickers are not penalised for bruising they were not responsible for. The adoption of such an incentive scheme however, requires a commitment by growers to developing a sound monitoring system. In one large Hawke's Bay orchard, pickers are monitored several times during the course of the day. The fruit is checked for bruising occurrence and pickers are then paid accordingly (Van Workum *pers. comm.* 1996).

Since ENZA sets the selling price by count size and other quality parameters, growers must optimise the size distribution and quality of their fruit to get the best returns. For growers to consider optimising their returns by minimising bruising, the benefits derived from this must exceed the costs (Wennergren and Lee 1961). That is, the costs of methods for reducing bruising such as: increased monitoring; modified equipment; improving tracks; etc., must be lower than the benefits from improved returns for fruit which has less bruising. Unless growers feel that there is such a gain, they will not reduce bruising.

3.12.3 Transportation

As described in Chapter One, fruit are regularly transported from one part of the handling system to another. While fruit is in transit they undergo bruising due to, the speed of the vehicle, the condition of the track or road, type of vehicle suspension, etc. The description of bruising during transport will be broken down into two parts. The first relates to bruising that occurs on orchard, and the second deals with road transportation.

Burton, Brown, Schulte Parson, and Timm (1989) undertook a study to investigate bruising related to picking and transportation in bins. Most of the bruising in the bin was found to occur due to excessive compression forces, these were then compounded by transportation on either short tyned forks, the rear of bin trailers, and also on heavy duty leaf–sprung trucks traveling on unsealed roads. From the field tests carried out, it was found that when fruit was placed in field bins then moved by tractor and forks, the bottom layer sustained significantly more bruises than other fruit in the bin. Bollen, Woodhead, and Dela Rue (1995), summarised the results (Table 3.5) and stated that the majority of bruising was below 1 cm^2, but also noted some of the sample fruit had bruises well exceeding 1 cm^2.

Table 3.5 Table of bruising percentages that Bollen *et al* (1995) summarised from Burton *et al.* (1989).

Mode of Transport	Position	Bruising of sampled fruit greater than 1 cm^2 (%)	Overall Bruising (%)
Tractor forks			22 – 31
Bin Trailer	Rear	11	50
	Front		12
Truck (11.3 km of rough road)			65
	Bottom layer of fruit in bin	13	
	Middle layer of fruit in bin	12	
	Fruit in contact with sides of bin	33	

Although results of Burton's experiment did not state the sizes of the bruises, individual fruit could have had an excessive amount of small bruising which when totalled could have exceeded 1 cm^2, thus making the fruit unacceptable for export from New Zealand.

A large pipfruit producer in the Hawke's Bay area has made similar observations concerning the bruise damage caused by tractor mounted tyne forks, and truck suspension (Van Workum *pers. comm.* 1996). In the field, tractors are now fitted with spring loaded forks to reduce the damage caused in the bins, due to transport on rough tracks. To reduce this movement around the orchard, "pick–up stations" are strategically located, this allows bins of fruit to be stacked together which are later loaded onto a truck for transportation to the packhouse This minimises tractor transport.

During transportation fruit bins are subjected to racking, swaying, and vertical movement, which causes continual load redistribution. The amount of bruising that occurs at the bin edge and bottom, is highly dependent on bin condition and/or transport duration (Maindonald and Finch 1986; Schulte Pason, Timm, Brown, Marshall, and Burton 1990; Bollen *et al.* 1995). Racking of bins, which causes excessive compression forces on the fruit, can be overcome by installing two opposing solid walls in bins, leaving the usual wooden slats for the other two walls, to allow air movement through the bin.

Using early harvested Granny Smith, Bollen *et al.*(1995) investigated the bruising that occurs in field bins when fruit is transported through the orchard and then to a packhouse. A "sound" bin (no loose boards), and an old bin (loose boards) were used to transport the fruit a short distance from the pickers to the loading area. Both bins were then trucked 10 km to a packhouse.

The results showed, the sound bin produced slightly fewer fruit defects than the old bin. The sound bin was estimated to have damaged, with bruises exceeding 1 cm^2, 0.4% of the apples in the bin. The fruit on the top side of the bin were the worst affected. It was suggested that the free motion of the top fruit caused this damage, since the rest of the fruit in the bin were constrained from movement by other fruit. For the old bin, there was considerably higher damage. Overall, 3.5% of fruit transported under these conditions had bruising over the industry tolerance level, that is greater than 1 cm^2. All bruising that exceeded 1 cm^2 was confined to the sides and the floor of the bin.

The results indicate, that the accumulated cost of losses due to bruising caused by racking, swaying, and vertical movement, could be significant to a grower. This means the grower, or bin supplier should either maintain, or insist that well maintained bins are used.

Maindonald and Finch (1986) estimated, that for each unstable bin of fruit trucked between Hastings and Henderson, a distance of approximately 430 km, 50 – 100 kg (12.5 – 25.0%) of fruit per bin[8] would be wasted because of bruising.

When fruit is to be transported from the orchard to the packhouse, field bins are loaded onto trucks, which may have either conventional leaf sprung suspension, or air cushion suspension. Air suspension has been shown to decrease fruit damage in the bins (Maindonald and Finch 1986; Burton *et al.* 1989).

Despite the introduction of air suspension on trucks, bruising of fruit, which had left the orchard in a reasonable state, has been on occasions high upon arrival to packhouses. Studies by Schoorl and Holt (1985), have found a number of variables that effect the amount of bruising to fruit when it is transported. These include: reported direct relationships between the speed of the carrier; and the condition of the road (Holt and Schoorl 1982; Schoorl and Holt 1985; Schulte Pason *et al.* 1990).

Maindonald and Finch (1986) found the use of air suspension in trucks used to transport fruit, reduced bruising by 1 – 2%. However, Van Workum (*pers. comm.* 1996), from personal observation, commented that grower's conventionally sprung trucks are still adequate for fruit transportation because these people are generally concerned for their fruit, and their trucks are usually quite old and heavily loaded, therefore, they do not attain speeds that would result in significant fruit damage. Commercial carriers, however, have larger more powerful trucks that are able to attain high speeds that can indirectly cause fruit damage, and these are individuals less concerned about fruit quality than growers.

[8] Bins used for the experiment held 380 - 400 kg of fruit, which is equivalent to approximately 21 TCEs.

3.12.4 The Packhouse

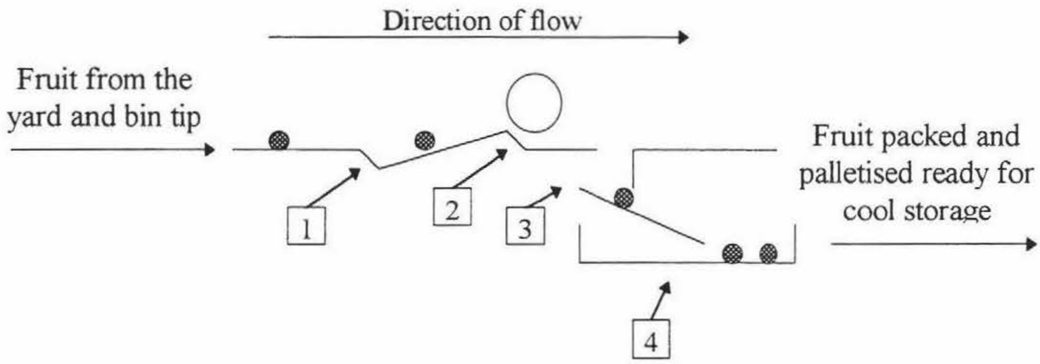
It is important that fruit enter the packhouse as bruise free as possible, because an indirect cost of bruising is the general slowing down of grading and the fruit sorting process (Wennergren and Lee 1961).

ENZA regulations require that fruit must be submitted to coolstorage within 48 hours of picking, to reduce ripening and water loss. Growers and researchers have observed that apples are most susceptible to bruising when the fruit have high turgor (Banks *et al.* 1993). Banks *et al.* (1993) suggested, that bruising might be reduced if weight loss was allowed in the fruit, for example, through water loss, which in a way conflicts with ENZA requirements. Banks *et al.* (1993) found, using Royal Gala, that compared to grading immediately, a reduction in bruise area of 20%, 28% and 48% could be obtained by holding fruit for 1,3, or 9 days at ambient temperatures before grading. They concluded that reductions in fruit bruising can be achieved by holding fruit at ambient temperatures for 1 day, before grading, and still comply with ENZA protocols.

In further trials, Banks *et al.*(1993) found that Gala apples graded immediately after removal from coolstorage, were damaged 40% more, than if they had been allowed to warm. This means, that fruit that is to be packed after removal from cold storage should be left to reach ambient temperature to reduce bruising.

As Appendix 1 shows, the bruising of fruit has been reported by various authors to occur at many points in the handling system, within the packhouse. Not all of the processes inflict enough damage to be of concern, but at some points damage may be more severe, and attempts need to be taken to reduce damage that occurs at these stages. Damage occurs at different places in the packhouse, mostly due to the condition of the grading equipment (Brown *et al.* 1989; Banks *et al.* 1993). The most important problem points identified in packhouses were the fruit transfer points (Figure 3.11), where a drop in height was required (Guyer, Schulte Pason, Timm, and Brown 1990; Banks *et al.* 1993). These points can contribute to about 80% of the damage in a packhouse operation (Bank *et al.* 1993).

Figure 3.11 Typical problem transfer points on a New Zealand apple packing line.



In Figure 3.11 the problem transfer points that the fruit move through are:

- 1 fall from sorting table to the conveyor;
- 2 passage under the foam transfer wheel from the singulator to the cup race;
- 3 first drop onto the chute following the cup race; and
- 4 passage of fruit all the way from the cup race until it came to rest in a final size bin or tray.

(Adapted from Banks *et al.* 1993)

Following a survey of 11 graders in the Hawke's Bay, Banks *et al.* (1993) found that the most serious bruising occurred when the fruit passed under the foam transfer wheel from the singulator to the cup race, and when the fruit was released from the cup to its final resting place in the size bin (Figure 3.11). These points were also identified as problem points by Nel (1980), Bollen (1993c), and Pang (1993).

The points of transfer on a grading machine include both, a drop, and a forward motion which create enough energy to bruise fruit. Bollen (1993c) noted, if apples were to impact a hard surface with the speed equivalent to a vertical drop of 15 – 25 mm, then there is a reasonable probability that some of the fruit will inflict a bruise equal to or greater than 1 cm^2. From simulations in a laboratory, Bollen (1993c) found that an impact velocity equivalent to a 30 mm drop, meant that 5% of the apples tested had a 1 cm^2 bruise, and if this was increased to 80 mm, almost half would sustain a commercially significant bruise. These drops were designed to simulate apples moving from the cup drop out–feed conveyors and the chutes, and the rotary bins. Guyer *et al.* (1990) noted that bruising for low resistance varieties, such as McIntosh, began at only 1.9 mm, and Pang *et al.* (1992a) found drop heights varying from 32.5 mm for Splendour, and 64.2 mm for Braeburn, would produce bruising of 1 cm^2. In a typical packhouse situation, drop heights are rarely over 40 mm (Pang 1993), therefore varieties with a bruise susceptibility similar to Splendour, are more than likely to sustain bruising while traveling over a grading machine.

To overcome the drop heights that do occur on the packing lines, minimal height differentials need to be included in machine design (Guyer *et al.* 1990; Banks *et al.* 1993). Other recommendations to reduce bruising on the grading equipment made by Guyer *et al.* (1990) and Banks *et al.* (1993) were:

- at the transfer wheel, have good padding of the hesitation bar and close synchronization of singulator and cup race;
- at the chute drop, pad all surfaces, reduce slopes of ramps to decrease fruit speed; and
- at the packing tables, cover the base with padding (for example, foam, water cushions), and do not allow fruit to build up, to avoid apple to apple impacts.

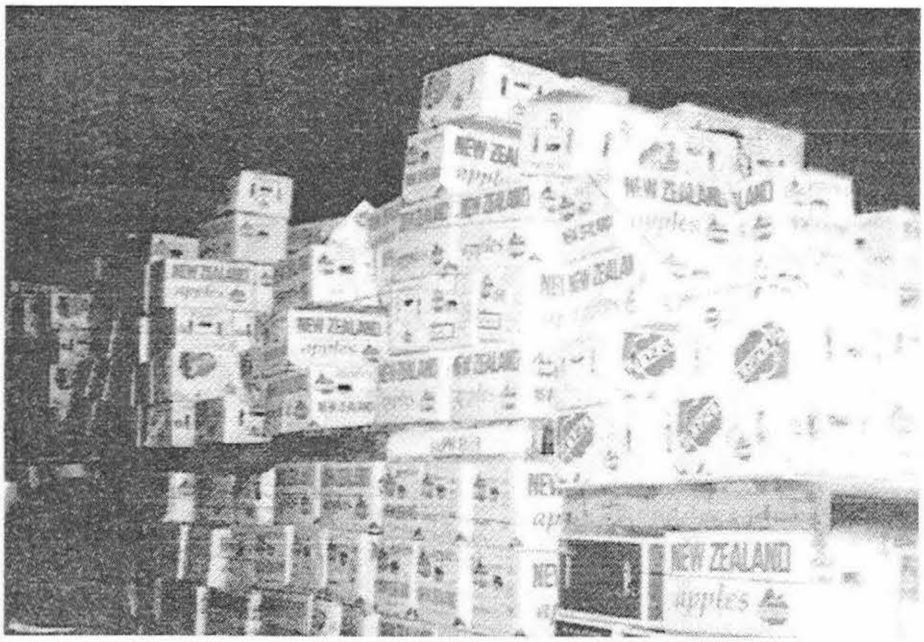
The economic importance of apple–to–apple impacts was shown by Banks (1991), who conducted a survey of export apple packhouses in New Zealand which indicated that the major cause of damage occurred from the cup drop into the packing bin. The majority of bruising at this point was a result of apple–to–apple impacts, or impacts from the cup drop onto the chute. Bollen (1993a) then removed the cup drop damage from Banks' data and found that 10% of the fruit sustained a bruise larger than 1 cm^2 due to apple–apple impacts.

Fruit once packed is considered "in grade". Little published work reports upon bruising that occurs from this stage onwards, in the packhouse. Newly introduced packaging is expected to decrease the probability of bruising, that has been occurring, however, data on the levels of bruising sustained have been extrapolated from other published "expert" information.

3.12.5 Packaging

Before palletisation was introduced, industry experts estimated 0.5% – 1.0% of cartons in ENZA coolstores collapsed. Cartons tended to collapse due to an excessive weight of fruit being stacked, and the loss in strength of cartons that had absorbed water, from the air. The top and bottom layers of fruit were mostly damaged (Perrett *pers. comm.* 1996). Palletisation, and cornerboards, have been introduced to overcome this problem (Anon 1995).

Figure 3.12 Bulk break cartons stacked on top of each other, illustrating the problem which occurs when a carton collapses under the weight of other cartons above.



The up–front cost of the new cartons and packaging should be off set by greater efficiencies (Anon 1995). With the RDT's being able to inter–lock, as well as being strapped to a pallet making them more stable, lower costs should be incurred from fruit damage (Anon 1995).

3.12.6 Storage

Little published data has been found reporting on the occurrence of bruising in coolstores, and during handling in coolstores.

Brusewitz and Bartsch (1989), reported that a change in bruise volume increased with storage time, depending on different varieties and the type of storage. Hyde and Ingle (1968) noted that the size of apple bruises tended to increase with advancing preharvest maturity, but tended to decrease with longer postharvest storage time prior to bruising on the sea trip to Europe.

3.12.7 Shipping

The majority of New Zealand apples are transported by ship to their markets. Up until 1996 this has been undertaken in break bulk stowage (Heap 1995). Heap (1995) cites a report by Crosby, Barr, and Cardell (1983), that the average amount of bruised fruit increased by 10% during transit, after leaving New Zealand. Heap (1995) also cites Crosby *et al.* (1983) who undertook packaging trials with palletised fruit which produced marginally less bruising, than the bulk break stowed cartons.

3.13 Additional Costs of Bruising

The relation between bruising and the incidence of decay in apples has been studied. Brown *et al.* (1989) states that blue mould caused by *Penicillium expansum* is the principle cause of postharvest decay of apples, accounting for 80 – 95% of apple decay in the U.S. markets (Wright and Billeter 1975; Cappellini, Ceponis, and Lightner 1987). From experiments and observations on fruit with bruise sizes exceeding 12.8 mm, Brown *et al.* (1989) believed that 4 – 8% of the tray packed apples may show signs of decay after arriving on the market.

Brown *et al.* (1989) from English, Ryall, and Smith (1946) wrote that, bruises need not be severe; all that is needed is a microscopic break in the epidermis or an injured lenticel to provide an avenue for fungus to enter the apples. The numerous bruises that do occur, happen for both the early and late harvested fruit.

3.14 Bruising Reported in the Literature

Many people have investigated the causes of apple bruising, and have published the resulting figures. The best way to interpret these figures, this author believes, is to class the varieties investigated as being of low, medium, and high susceptibility to bruising, as summarized in Table 3.6, and presented fully in Appendix 1.

Table 3.6 Table summarising the range of bruising that occurs at various points of the apple handling system.

Position of bruising in the handling system	Range of Bruising for differing susceptibilities (%)			
	High	Medium	Low	All Varieties
In the field	0.27 – 9.40			0.27 – 9.50
Combination of field and transportation	6.00			7.00 – 12.30
Transportation	1.24 – 6.00			1.24 – 6.00
Packhouse	3.00 – 39.75		2.40 – 30.50	2.40 – 39.75
Coolstore*				
Shipping				10

* Note – No data was located which reported upon bruise occurrence during handling and subsequent stacking and storage of fruit.

A concern with the published information, was that there appears to be no consistent scale used for reporting the degree of bruising. Some researchers indicated the number of bruises per apple but not the sizes, others reported percentage of bruises per population, while others report "commercially significant" bruising (greater than 1 cm^2).

3.15 Summary

Of the research methodologies available, case studies are the most appropriate for data collection which could be applied to Porter's value system approach of the New Zealand postharvest apple handling system. Through the use of spreadsheets, the data could be easily entered and modified for analytical reasons.

The characteristics of apple bruising have been well documented, as well as the levels of bruising that occur at specific points through the postharvest handling system. There are stages where there is a definite lack of information, from packaging until fruit arrive at the port of export, making it difficult to assess total bruising in the system. Although there is plenty of information concerning the bruising characteristics of individual apple varieties, costs relating to the amounts of bruising are very few. Since data inadequacies exist, a postharvest value system for apples cannot be developed.

Chapter Four Research Method

4.1 *Information Collection*

This project was carried out in four stages. The first was the collection of bruise information in relation to various stages through the apples handling, and the second, the use of a rich picture to help develop the problem statement, have already been described. The next stage, which was collecting the economic data for the development of the value system model using case studies, and the final stage which was to calculate the accumulated loss in value attributable to bruising, are described in this chapter.

To meet the need for "real world" economic and fruit loss data for this research project, a case study methodology (Yin 1994), as described in Section 3.2, was followed. Case studies were chosen as the most appropriate way for collecting data because they enable a detailed understanding of the system in question to be developed. In order to ensure that data triangulation (Yin 1994) could occur, corroboration for grower and packer claims was sought in the literature and from other industry experts. Another reason why case studies were used for this research, was that they allowed the researcher to interact with people in the pipfruit industry at different levels, and gain an understanding of how a large primary industry has developed into New Zealand's most successful horticultural industry.

Since ENZA deals with fruit supplied from packhouse operators and not necessarily directly from growers, and because fruit is paid for once it is packed, it was considered appropriate to build initial case studies around packhouses. From these packhouses, growers could be contacted to enable the value system to be investigated back to the orchard using additional case studies.

To ensure that some of the major differences that have developed in the industry with the advent of large, new, corporate styled packhouses and the loss of small operations, ENZA New Zealand (International) staff were asked to provide the names of a number of packhouses for each of the "large", "medium", and "small" sized operations[9]. From this list it was initially hoped that case studies could be developed for five packhouse operations (1 large, 2 medium, and 2 small). However, because of time and resource constraints only one large packhouse operation and one small packhouse operation were selected as case study properties.

Rather than consider all apple varieties handled by each packhouse, four commercially significant varieties were selected in this study. These varieties were:

- Braeburn;
- Fuji;
- Granny Smith; and
- Pacific Rose.

Braeburn, Fuji, and Pacific Rose were selected because they are high value crops which have differing bruise susceptibility, and could thus be used to model differing bruise management scenarios. Granny Smith, while not a "high value" crop was chosen because much of New Zealand's bruising research has been carried out using this variety. The volume of Granny Smith produced in New Zealand is still high even though the income is relatively low.

The interviews were undertaken using the approach recommended in "Starting Fieldwork" by Tolich and Davidson (1996), and their suggestions for semi–structured interviews, mentioned in Chapter 3.3.2, were used as a guide. The format for the semi–structured interviews, which was used with both packhouse operators and suppliers, was developed and tested with the assistance of

[9] ENZA lists packhouses into the following categories according to the amount of cartons packed in a season through the packhouse. "Large" > 350,000 TCEs, "medium" 100,000 – 350,000 TCEs, and "small" < 100,000 TCEs.

University staff, including the orchard manager. The aim was to collect data from each of the packhouses, and from selected grower suppliers; and from that to develop a model concerning actual returns in the 1995/96 season, the costs/charges incurred in handling that crop, and the levels of bruising sustained through the handling system. Porter's value system served as the framework for both the development of questions and for defining the way that the growing/packing/supply system was considered. To obtain the necessary data from each operation, the same questions were asked for both packhouses and suppliers. Slight variations to the questions were made, so they were appropriate for the individual who was being interviewed.

Interviewees were first contacted by telephone to establish that they were prepared to be involved. Those who agreed were provided with a written description of the project and were also asked to fill in a data sheet before the interview so that as much information as possible could be extracted during the interview. None of the participants completed this form, therefore many issues were not able to be resolved during the interviews and further information had to be derived either by telephone or fax at a later date.

The manager of the large packhouse was asked if he could provide the name of two suppliers growing the selected varieties. One was to be a supplier who had been identified as having some problems with bruising the previous season, and another who had not encountered bruise problems. As the operator of the smaller packhouse supplied his own fruit, the same individual was interviewed as both a packhouse operator and grower.

The two suppliers named by the large packhouse manager were contacted to determine if they were willing to participate in the study. Following confirmation that these suppliers would participate, meetings for semi–structured interviews were arranged. All interviews took approximately two hours to complete.

The interviews were conducted using a tape recorder and hand written notes. The written notes were used to highlight points which assisted the researcher in recalling the interview during tape transcription. Notes were also made to prompt further questions during the interview. Later, after the interview, the main points of interest and important figures were transcribed and presented in summary form. This information was carefully studied, and gaps were identified. Subsequent telephone calls and faxes were made to clarify the information and to develop a more complete data set.

Microsoft® Excel spreadsheets, prepared using Porter's value system as a framework, were used for both data entry and the analysis of information desired. Data analysis is described in the next section.

4.2 Data Analysis

In order to find the value of fruit as it progressed through the handling system, the costs incurred for each stage which add value to the fruit needed to be identified. Data from the case studies and the information derived from the literature were then combined to model the loss in value, caused by bruising, of the fruit through the handling system. By doing this, and expressing the value of the losses attributable to bruising in terms of the value of fruit at each stage through the system, rather than as a percentage of fruit picked or packed as is commonly reported in literature (Nel 1980; Barton *et al.* 1983; Banks *et al.* 1993), the objectives of this research were achieved.

For fruit to be produced, significant amounts of resources are required. In monetary terms this includes labour, machinery, administration, and most importantly equity. For the purpose of this research, the value of apples on the tree was calculated by making allowance for all these costs. Therefore, both operating and funding costs make up the "Growing" costs.

Having calculated the value of the fruit on the tree using this method, the incremental value of fruit on a TCE basis has been modelled with a spreadsheet where either the calculated values of a particular operation, or the actual commercial rate charged for that operation, have been added. For the purpose of this project the identifiable stages in the value system are:

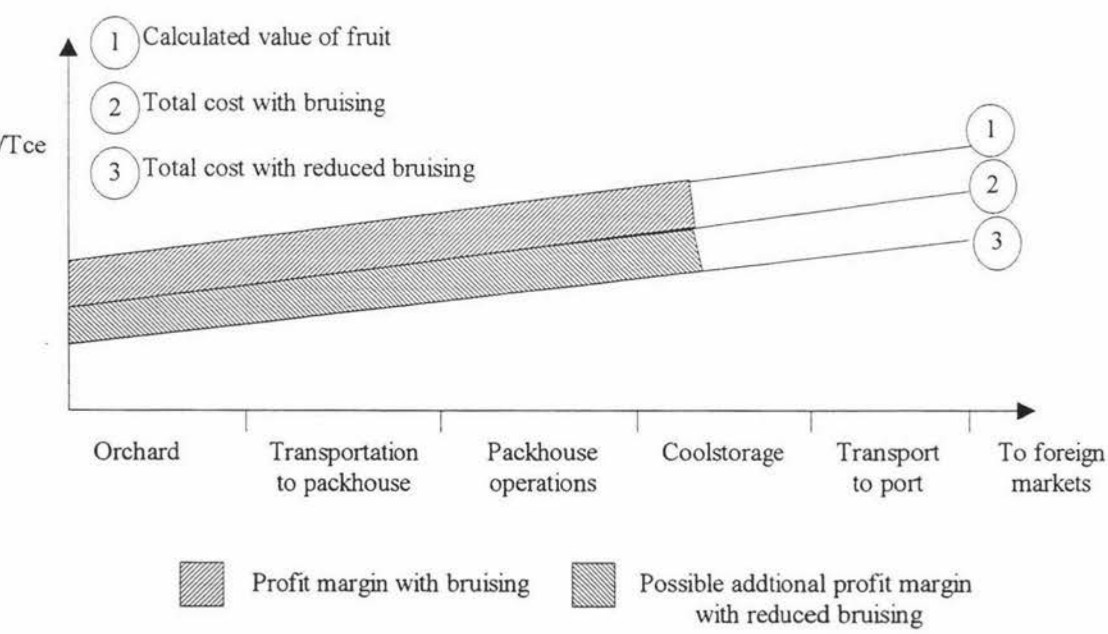
- picking, which includes quality monitoring and field bin movement;
- trucking, both from the orchard to the packhouse, and trucking involved with the movement of fruit once packed;
- packing, all operations at the packhouse which include drenching, sorting, sizing, packing, and palletisation;
- coolstorage of fruit once packed for export.

In the real world, ENZA pay for fruit based on market returns after packaging. Grower returns do not necessarily equal or exceed the costs to produce the fruit. For poor paying varieties it is possible for growers to receive less than the costs of growing the fruit. For this reason, rather than using the calculated value of fruit at the orchard and adding values on to the orchard value to determine the value at the packhouse, costs that were incurred prior to packing were removed from the value paid by ENZA, to calculate the actual value of fruit on the tree. This average payout for each variety was obtained from the MAF Farm Monitoring Report (1997). Costs incurred after packing were then added to this value. By using this method, the value of fruit could be estimated through the value system. For the purpose of this report, the value system begins with fruit on the tree prior to harvest, and ends ship-side at the port prior to export.

For a number of reasons, data collection during interviews was inadequate. In order to get sufficient information to construct models, regional averages from MAF Farm Monitoring Reports were used. One of the most important pieces of data missing from two of the three orchardists interviewed was the enterprise equity, and asset value for the case study orchards. The valuation data obtained from one interview was used to estimate the value of each case study property. Other stages in the value system charged a commercial rate that included operational and funding costs. It was further assumed that the orchardists would require a 20% return on their equity.

For each orchard in this project, the total cost of bruising has been identified as the cost of getting fruit to a particular stage plus the opportunity cost of not selling reject fruit at "export prices". Since fruit are only removed at the sorting table, money must be spent picking, handling, etc., until the fruit reach that stage. The relationship between total costs and the difference of the loss in value that is removed from the fruit is presented in Figure 4.13. The lower total cost is the predicted model if bruising can be reduced. The lines are parallel to one another because it is assumed that the value of the fruit increases at the same rate as the opportunity cost of fruit moving through the value system. The straight lines represent the costs in the handling system, even though the costs of each stage would vary.

Figure 4.13 The differences between the value of the fruit, the total cost including bruising, and the total cost with reduced bruising.



Although the models of the value systems do not contain complete information, for example, the true costs of the small orchard, the models can still be run, and when the information is available the model can be re-run. This would then increase the accuracy for the loss in value of fruit in the value system due to bruising.

4.3 *Presentation of Results*

For the purpose of discussion, data from the case study packhouses has been kept separate, that is one model describes the situation for the "large" packhouse system, while another describes the situation for a "small" packhouse system. The model for the "large" system has been prepared using data from Orchard One, Orchard Two, and Packhouse One, while the model for a "small" system has been derived from Orchard Three and Packhouse Two only.

The results are organised so the case study descriptions which describe the two large orchards that packed fruit through Packhouse One are presented first. The description of the "small" packhouse and its supplying orchard is described next. These descriptions provide some background information from which the value system models were developed.

There were some discrepancies between the reports of bruising found in the literature, and those reported by the interviewees from the case studies. It was necessary to standardise the bruising levels. A description of this presented in Chapter 5.3 describes the relationship with the comparisons between the total amount of bruising for a variety, as used by many researchers, and the amount of bruising reported from the rejects, as used by growers and packers.

The results then present the individual production costs at each stage in the postharvest handling system for both the "large" and "small" packhouse systems for each of the four varieties investigated. For the purpose of presenting the total cost for a TCE to pass through the two different handling systems, these costs are then accumulated by variety.

From the costs at each stage, and, using ENZA grower payments as a base value at the end of the packing stage, it is then possible to calculate the real value of fruit as it passes through the system. The value system is divided into two Tables. The first Table works back from the packed fruit to the value of fruit as it hangs on the tree prior to harvest. The first section of the value chain is directly related to the supplier, because they own the fruit during these stages, and are paying for the movement of the fruit. The second Table illustrates the value of the fruit once it leaves the packhouse to the port of export. This section of the system is directly related to ENZA, since they have paid the supplier for the fruit, and control the movement of the fruit.

Once the value of fruit was found, the loss in value attributable to bruising was then calculated and presented for the two value systems. Since the loss in value was minimal for low occurrences of bruising, the loss in value was presented for increasing levels of bruise occurrence for each stage in the value system for each variety used in this study.

Finally, rather than simply presenting the actual value losses attributable to bruising, the total costs of bruising have been calculated (Appendix 2 and Appendix 3). The opportunity cost, which is the income not earned because fruit is not exported but is rejected, illustrates where the most significant loss in value in the system occurs.

Chapter Five   Results and Discussion

5.1 Introduction

The first section of this Chapter contains information, from the case study interviews, about the large packhouse and the two orchards supplying it, and the small packhouse and orchard supplying it. For this research, the information from the case study properties and the literature have been used to construct various models concerning the postharvest apple value system. From these models, the loss in apple value attributable to bruising in the postharvest handling system was calculated. From Section 5.3 onwards, the results derived from the use of these models are presented and discussed.

5.2 Case Study Descriptions

The five case study interviews have been grouped into two case studies. The first case study involves the two large orchards that supply a large packhouse, and require road transportation for their fruit to reach the packhouse. The second case study involves a small orchard that supplies a small packhouse situated on the same property. The packhouses are presented before the orchards for each case study, since they are the primary source of bruising data

5.2.1 Case Study One: Two Large Orchards Supplying One large Packhouse

Packhouse One

Packhouse One is a corporately owned packhouse which has a throughput of more than 350,000 TCEs, which means that it is considered to be a large packhouse by ENZA staff. Of the four varieties of interest in this research, the packout percentages are presented in Table 5.7.

The packhouse has 13,000 bins ready for use by its suppliers. The packhouse charges for packing on a flat rate per kilogram of fruit submitted. This means, that regardless of the level of bruising in a line, the charge per bin is the same. The packhouse operates with one 8 hour day shift and one 8 hour night shift throughout the harvest season.

The packhouse uses a Compaq computerised grader, and has recently incorporated an optical colour sorter. The packhouse submits tenders to ENZA to undertake value added processes on the fruit, including CA storage, colour grading, and waxing.

Approximately 20% of the varieties handled by the packhouse need to be drenched due to low levels of calcium in the fruit. This is recognised by the packhouse management as an operation that tends to bruise fruit, therefore they try to minimise this process.

As bins arrive at the packhouse, they are placed into storage under shade. If fruit can not be packed within the ENZA coolchain specifications, fruit is placed into coolstorage, and later removed when it is ready to be packed. After fruit has been packed it is placed into third party coolstorage, until it is taken to the port of export. Rather than packing all fruit at harvest time, some fruit is placed into CA storage, and at the end of the picking season it is withdrawn and packed for local market.

The following two case study orchards supplied their apple crops to Packhouse One.

Orchard One

Orchard One is located North East of Hastings, in the Hawke's Bay region. The total area planted in apples is 48.31 ha, but 34% of this is under redevelopment and younger than 3rd leaf[10], leaving 31.79 ha in production for export (Table 5.7). Three of the four varieties investigated in this research are in full production (Table 5.7). A large area of Pacific Rose™ has been planted, but it is still younger than 3rd leaf. As well as these four, eight other varieties are in production on the orchard. The orchard is run by a manager, and employs a number of permanent staff. Casual staff are employed for pruning, thinning, and picking.

Each year the majority of staff who carried out fruit thinning between November and December are retained to carry out harvesting between February and April. Retaining the same staff, allows the workers to become familiar with the orchard and its management. At peak harvesting, 20 pickers are employed on a contractual basis, and work 5½ days a week. All pickers are given training, even if they are experienced. The 20 pickers are grouped into 2 gangs of 10 people, and each of these gangs has a quality controller (QC) overseeing the quality of their work. Rather than mechanical aids, such as cherry pickers, ladders are used for fruit that is out of reach from the ground. Fruit is picked in the rain if the packhouse requires fruit, even though the managers believe that this fruit is more likely to bruise than fruit harvested when it is dry.

Each gang is provided with a tractor and driver to shift bins of fruit. Tractors used to move bins of fruit are equipped with floating rear forks. Tracks in the orchard have an all weather gravel surface to keep the ride as smooth as possible. Full bins of fruit are moved to loading bays, loaded onto trucks by forklift, then carted to the packhouse, some distance away by road. There are two shadehouses on the property used to store the fruit away from the direct sunlight

[10] Fruit from trees younger than 3rd leaf are deemed unacceptable for export by ENZA, because of their poor storage quality.

prior to pickup by the trucks. All bins are provided and delivered, at a cost, by Packhouse One.

Orchard Two

This Hastings orchard is of similar size to Orchard One with a total area of 41.55 ha planted in apples (Table 5.7), and an additional 12 ha in peaches. At present, only 3% of the orchard is under redevelopment (less than 3rd leaf), leaving 40.31 ha in production. Three of the four varieties that are being investigated in this research are in full production (Table 5.7). As well as the existing producing area of Pacific Rose™, a further 0.5 ha are established at the site, but are not included as the trees are less than 3 years old. Granny Smith has been grown on the orchard, but has been removed during redevelopment. Another 11 varieties are grown on the orchard. The orchard is run by a manager, with additional permanent staff.

The same contract staff are employed for pruning, thinning and harvesting operations which enable them to become familiar with the orchard and its management. To recruit the extra staff necessary when contractors cannot pick all the fruit, adverts are placed in national newspapers. All pickers are required to take a colour perception test, to check for colour blindness, before they are trained to undertake harvesting operations.

During the harvest period there are usually 4 gangs working. One gang comprises 8 pickers, who are assisted with bin moving by a tractor and driver. Two QCs are employed, each QC checks the quality of the fruit picked by two gangs for defects and blemishes attributable to the picking operation. All pickers use a ladder to reach fruit too high to be picked from the ground. For the first pick[11], 2 metre ladders are used, then for varieties that need a 2nd, 3rd, or 4th pick, 3 metre ladders are used. No cherry pickers are used for picking. The gangs work 5½

[11] Often more than one selective pick is undertaken on a variety due to maturity variations within a crop.

days a week, and pick in the rain if required. All bins are provided and delivered, at a cost, by Packhouse One.

Once fruit has been harvested, bins are either placed in one of two shade houses on the property, or double stacked with a reflective cover drawn over the top of the stack. Bins are taken to the packhouse when a full truck load has been harvested. When possible, the shade houses are emptied at the end of the day, while fruit that has to be left over night is loaded on the first full truck load the following morning.

Table 5.7 Some packhouse and orchard characteristics in Case Study One.

Variety	Orchard One	Orchard Two	Packhouse One
	Variety areas (ha)		Season Packout (%)
Braeburn	7.85	9.76	36
Fuji	4.40	4.69	20
Granny Smith	5.84	–	9
Pacific Rose™	–	3.78	1
Total Planted area in apples (ha)	48.31	41.55	Throughput greater than 350,000 TCE
Total area in apple production, including other varieties (ha)	31.79	40.31	

5.2.2 Case Study Two: One Small Orchard Supplying a Small Packhouse

Packhouse Two

This packhouse is located on case study Orchard Three's site, which is described next. The packhouse is considered by ENZA staff to be a small packhouse as fewer than 100,000 TCEs are packed each season. In addition to packing for Orchard Three, Packhouse Two packs for six other orchards on a commercial basis. The owner of Packhouse Two and Orchard Three manages the packhouse operation during the fruit harvest season.

The packhouse charges for packing according to the packout per kilogram of fruit supplied input. The lower the packout, the higher the cost of packing.

The packhouse uses a 1985 MacDonald's electronic cup type grader. All fruit is packed upon arrival, or as soon as possible because there is no coolstore on site. During harvesting, 20 staff are employed in the packhouse to work one 10 hour shift each day. If required, staff will work a nightshift. Once all fruit is packed it is then carted, with the packhouse truck, to ENZA Coolstores in Whakatu.

Orchard Three

Orchard Three is located to the South of Hastings, and has plantings covering close to 11 ha. Of the area in production there is 2.2 ha of Braeburn, 1.2 ha of Fuji, 1.8 ha of Granny Smith, and 1 ha of Pacific Rose™. There are four other varieties grown on the orchard. Pacific Rose™ is the youngest of the varieties grown, although not in full production yet, they are older than 3rd leaf. The orchard is an owner/operator business.

Unlike the previous two case study orchards, harvesting is undertaken by staff who are paid an hourly wage, instead of a contract rate. The owner/manager does not like to train "experienced" pickers, as he believes this upsets them, however he does train inexperienced pickers. Most staff are friends of the owner, and tend to be "older" people. Some additional help is recruited if assistance is needed. Staff are shared between Orchard Three and one other orchard. Fruit is very rarely picked in the rain, as the owner believes that doing so tends to upset the pickers.

During harvest, 20 people are employed for picking and two additional staff are employed to drive tractors. The tractors are equipped with rear mounted forks for use when bins are being moved. The tractor drivers also monitor the quality of fruit being picked, and inform the owner of the property, about progress, as fruit enters the packhouse. All fruit out of reach from the ground is harvested from a ladder.

The orchard owns its own bins, which range from 10 to 15 years old. All fruit is packed at the on–orchard packhouse, Packhouse Two.

5.3 Bruising Percentages in Real Terms

Before presenting the results of the analyses performed on the postharvest apple value system, there exists one area of possible confusion between researcher derived data and grower/packer provided data. This confusion may arise because although researchers (Maindonald and Finch 1986; Brown *et al.* 1989; Schulte Pason *et al.* 1990; Pang *et al.* 1996) usually report losses attributable to bruising as a percentage of the whole crop, growers and packhouse operators do not. Growers and packers report on bruising (or any reject) as a proportion of the total fruit rejected.

As illustrated in Table 5.8, as the percentage packout increases, a given rate of bruising (expressed as "% of rejects") will become a smaller proportion of the crop. For instance, a grower who reports 5% crop loss attributable to bruising, that is 5% of rejects, is losing 3% of the whole crop at a 40% packout. At an 80% packout 5% of rejects is equivalent to 1% of the whole crop (Table 5.8). The relationship between the reported reject levels of bruising and the total crop bruising were very linear. Data which at first suggested that orchardists and packhouse operator's crops had suffered high bruising, on further analysis, revealed that bruising as a proportion of the total crop was much less of a problem.

Table 5.8 Percentage of total crop bruised based on 5% of packhouse reject rate, at packouts from 40% to 80%.

Packout Rate (%)	Reject Rate (%)	Total Crop Loss (%)
40	60	3.0
50	50	2.5
60	40	2.0
70	30	1.5
80	20	1.0

Table 5.9 shows the overall percentage of bruising as it was detected at the sorting table in the packhouse for each variety in the two case studies, and the bruising as a percentage of the reject rate.

Table 5.9 Percentage of rejects attributable and the corresponding percentage of total crop rejected because of bruising for each of the three Case Study Orchards.

Variety	Orchard One		Orchard Two		Orchard Three	
	Reject Rate (% of rejects)	Whole Variety (%)	Reject Rate (% of rejects)	Whole Variety (%)	Reject Rate (% of rejects)	Whole Variety (%)
Braeburn	12.0	3.9	13.0	4.4	4.0	1.2
Fuji	12.0	5.4	11.0	3.7	3.0	0.8
Granny Smith	16.0	8.7	–	–	10.0	4.0
Pacific Rose™	–	–	12.0	4.8	2.0	1.0

Note – Bruising levels are an average of the whole variety for the 1995/96 season.

The results from Orchard One concur with the overall bruise susceptibility, reported in the literature and summarised in Table 3.3 of this thesis. The data derived from Orchard Two and Orchard Three, although more variable, still in general support the research data. For Orchards Two and Three, Fuji suffered a marginally lower rate of rejection due to bruising than Braeburn. However, Granny Smith suffered considerably more bruising than the other three varieties, perhaps because growers did not perceive it to be worth handling with a lot of care, as it was a low value crop. The managers did comment that the first one or two weeks of harvest for Granny Smith resulted in low bruise occurrence, but very high levels were reported for the late harvested fruit. The high rates of bruising were a direct result of the fruit being more mature in the late harvests.

For Pacific Rose™, the data used to generate the information was limited (only 3,061 TCEs were packed for Orchard Two, and 500 TCEs for Orchard Three), therefore the results may be misleading. The parents of Pacific Rose™, Splendour and Gala, were reported by Pang *et al.* (1992) to be highly susceptible to bruising, therefore Pacific Rose™ was expected to have a high bruise occurrence in the case studies. The bruise levels of 4.8% for Orchard Two, and 1.0% for Orchard Three, are lower than expected. These low rates of bruising could have occurred because the orchardists realised that the variety earned high returns and that the fruit needed to be handled very carefully to ensure these returns were achieved.

Orchard Three had lower levels of bruising for all varieties than either Orchard One or Orchard Two. There could have been several reasons why this occurred. The first possible reason could be due to the labour management at harvest on this small orchard. Orchard Three used workers paid on an hourly rate, the other two orchards used contract staff. Orchard Two's manager mentioned that he occasionally "had trouble with people who rushed through picking to make more money for the higher paying varieties". This means that workers were not taking proper care of the fruit but were trying to get as much picked as possible in order to maximise their pay. These pickers would be warned that if they did not slow down, and reduce the damage of the fruit, they would be moved to pick another variety that had a lower contract pay rate. If the bruising levels reported by Orchard Three are a true indication of bruising at harvest, it would appear that workers paid on an hourly rate, if this is the reason for bruise reduction, would be more appropriate for bruise reduction. Larger orchards use contract labour because of the maturity time–frames within which varieties must be picked. As large orchards have a considerable area to harvest, the priorities are firstly to ensure that fruit are picked, and secondly bruise reduction.

The second reason for possible lower bruise levels reported for Orchard Three is, Orchard One and Orchard Two used a different postharvest handling system to Orchard Three. The extra stages that were included in their system, which Orchard Three did not have, could have added bruise damage to the crop. The extra stages, for Orchard One and Orchard Two were, the fruit being moved to a loading station after harvest and stacked, the loading of bins onto a truck, and then the road trip to the packhouse, unloading the bins and stacking before packing, all of which could have increased the amount of bruising in fruit. Since Packhouse Two is located on Orchard Three, the fruit is transported directly from the orchard to the packhouse. This removed the extra stages of stacking, loading and unloading onto a truck, and additional transportation of bins.

On more possibility of reduced bruising levels for Orchard Three could have been the policy of harvesting wet fruit. It was reviewed and presented in Chapter 3.12.1, that fruit that had been harvested after periods of irrigation had a higher bruise susceptibility. Rain can also produce the same effects. Therefore, since Orchard Three's fruit was rarely harvested wet, and Orchards Two and Three did so more often, the rates of bruising were reduced.

5.4 Production Costs

To make the analysis of results consistent, the case study properties have been grouped into two categories, those related to the large packhouse and those related to the small packhouse. The production costs of Braeburn and Fuji for Orchard One and Orchard Two are an average of the two, while Granny Smith and Pacific Rose™ are derived from a single orchard (Appendix 4).

A summary of the cost information, derived from the models prepared for this research, is presented in Table 5.10.

The owner of Packhouse Two and Orchard Three had few precise figures of costs and provided much of the information from guestimates. The cost estimates for harvesting varied greatly, for this reason the data from Orchard Three and Packhouse Two is questionable. For example, Orchard Two reported a total harvest cost of $1.56 per TCE ("Harvesting" and "Harvesting support" costs combined), whereas Orchard Three reported a total "Harvesting" cost of $6.67 per TCE (Table 5.10). Furthermore, the MAF Farm Monitoring Report reports the average cost of harvesting to be $1.23 per TCE (MAF 1997). Further comment on this issue is made in the next chapter, Conclusions.

Table 5.10 Calculated costs per TCE for each of the four varieties to be produced, harvested, etc., through the value system for the large and small packhouse systems.

Operation	Braeburn ($/TCE)		Fuji ($/TCE)		Granny Smith ($/TCE)		Pacific Rose™ ($/TCE)	
	Large[a]	Small[d]	Large[a]	Small[d]	Large[b]	Small[d]	Large[c]	Small[d]
1. Growing	6.92	10.32	6.92	10.32	6.84	10.32	7.00	10.32
2. Harvesting	1.16	2.07	1.18	4.13	1.00	1.12	1.27	6.67
3. Harvesting support	0.27	–	0.27	–	0.23	–	0.29	–
4. Transport to packhouse	0.16	–	0.16	–	0.16	–	0.16	–
5. Drenching	0.03	0.18	–	–	–	–	–	–
6. Packing[e]	2.98	2.33	2.98	2.33	2.98	2.45	2.98	2.57
7. ENZA levy	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
8. Transport to coolstore	0.12	–	0.12	–	0.12	–	0.12	–
9. Coolstorage	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63
10. Transport to port	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total	13.60	16.87	13.60	18.75	13.30	15.85	13.78	21.52

[a] Costs are based on average data associated with Orchard One and Orchard Two.
[b] Costs are based on data associated with Orchard One.
[c] Costs are based on data associated with Orchard Two.
[d] Costs are based on data associated with Orchard Three.
[e] Growers are paid for fruit at this point of the handling system.

If the system is viewed as starting on–orchard and proceeding in the direction of fruit flow; that is, towards the port, the initial costs in the model are the on–orchard production costs, which appear in the Tables as "Growing" and include production, a share of fixed costs, and a share of equity return. As expected, these costs were the greatest in the handling system, they were almost half of the total costs incurred in the handling system (Table 5.10). For simplicity "Growing" costs have been presumed to be constant for all varieties on each orchard, and these have been averaged for Braeburn and Fuji between Orchard One and Orchard Two. "Growing" varied between $6.84 per TCE for Orchard One and $7.00 per TCE for Orchard Two in the large packhouse model, to $10.32 per TCE for the owner operator orchard/packhouse model. This is acceptable for this research because, although there are differences in the costs to produce each variety on an orchard, the differences were a small proportion of the production costs. The lower costs for the large orchards can probably be attributed to the economies of scale derived by these large operations. In all cases the next greatest cost in the handling system was "Packing".

For the orchards supplying Packhouse One, the packing prices of their fruit were constant, because of the packhouse's approach to charging. Orchard Three's packing costs increased as packout decreased. For the three orchards, packing costs were an average of the whole variety over the season. The packing cost would vary greatly if calculated on a weekly basis, because as the fruit matures on the tree, it is more susceptible to bruising. Orchard Three's owner commented that after the second week of harvest the bruising rate increases to approximately 40% of the crop, therefore costs would be much greater than they would have been for the first few weeks of harvest. This would apply to all varieties, but is more obvious in Granny Smith as it is a high bruising variety.

As Orchard Three has an on–site packhouse, and used its own bins, there were no direct transport and bin hiring costs inflicted on the orchard. These costs have been bundled in the "Growing" costs of the orchard. This bundling of costs, and the effect of economies of scale, appears to have increased the "Growing" costs for Orchard Three by approximately $3.00 per TCE above the "Growing" costs of Orchard One and Orchard Two. A similar effect was found for Orchard Three's transportation costs as they are bundled into Packhouse Two's packing charges.

Costs incurred from "Coolstorage" onwards are constant to all orchards as they are set by ENZA. These rates could also be lower or higher than the actual values, because it is not known to what extent ENZA smoothes the real costs to suppliers to simplify management. Suppliers were charged the ENZA levy based on the number of TCEs they produce for export, because of this the levy has been included as a production cost for export fruit.

It can be seen that although the small packhouse and its supplier have fewer components in their value system, than the large orchards and packhouse, they still appear to have high accumulated costs through the system (Table 5.11). This is due to the costs being bundled, and because of the economies of scale of the large packhouse system.

Table 5.11 Calculated accumulated costs per TCE for each of the four varieties to be produced, harvested, etc., through the value system for the large and small packhouse systems.

Operation	Braeburn ($/TCE)		Fuji ($/TCE)		Granny Smith ($/TCE)		Pacific Rose™ ($/TCE)	
	Large[a]	Small[d]	Large[a]	Small[d]	Large[b]	Small[d]	Large[c]	Small[d]
1. Growing	6.92	10.32	6.92	10.32	6.84	10.32	7.00	10.32
2. Harvesting	8.08	12.39	8.10	14.45	7.84	11.44	8.27	16.99
3. Harvesting support	8.35	–	8.37	–	8.07	–	8.56	–
4. Transport to packhouse	8.51	–	8.53	–	8.23	–	8.71	–
5. Drenching	8.54	12.57	–	–	–	–	–	–
6. Packing[e]	11.52	14.90	11.51	16.79	11.21	13.89	11.69	19.56
7. ENZA levy	11.72	15.10	11.71	16.99	11.41	14.09	11.89	19.76
8. Transport to coolstore	11.84	–	11.83	–	11.53	–	12.01	–
9. Coolstorage	13.47	16.73	13.46	18.62	13.16	15.72	13.64	21.39
10. Transport to port	13.60	16.86	13.59	18.75	13.29	15.85	13.77	21.52

[a] Costs are based on average data associated with Orchard One and Orchard Two.
[b] Costs are based on data associated with Orchard One.
[c] Costs are based on data associated with Orchard Two.
[d] Costs are based on data associated with Orchard Three.
[e] Growers are paid for fruit at this point of the handling system.

Since the suppliers were paid for fruit once it had been packed, to receive a 20% return on equity from growing and handling fruit, the returns had to match the cost accumulated through the whole handling system. If this did not occur the supplier did not cover costs: they then either had to reduce costs somewhere in the system, or expect a lower return on equity. Therefore, the growers bore the greatest share of the risk. This is because all other stages in the handling system were paid in full either by the grower or by ENZA for the handling of fruit.

5.4 Actual Value of Fruit Passing Through the Handling System

In the 1995/96 season, the average export returns on a dollar per TCE basis for Braeburn, Fuji, Granny Smith, and Pacific Rose™are presented in Table 5.12.

The average grower returns vary due to the market demand of the variety. Pacific Rose™ had a much higher return compared to the other three varieties as it was a new variety with a high demand.

Table 5.12 Average grower return for export fruit for the 1995/96 season.

Variety	Average Grower Return ($/TCE)
Braeburn	11.80
Fuji	13.80
Granny Smith	9.80
Pacific Rose™	20.00

(Source: MAF 1997)

Since ENZA pays growers for packed fruit, at stage "1" in Table 5.13, that is at "Packing", it was necessary to consider the value system described in Table 5.10 and Table 5.11 in "reverse", so that the returns to the grower could be calculated "back" from the average ENZA payout. Using this approach, the return per TCE for "Growing" has been derived, and is shown in Table 5.13 as row "6".

The real value of fruit at "Growing" is different to the calculated "Growing" costs for all orchards. The "Growing" cost for Braeburn on the large orchards is $6.92 per TCE (Table 5.11), compared to the real value of $7.20 per TCE. This indicates that the large orchards are able to produce a TCE of Braeburn for less than the real value and that given reasonable levels of management, growers can expect at least a 20% return on equity. This also applies to Fuji and Pacific Rose™. However, assuming the "Growing" costs are the same for all varieties, the "Growing" cost for Granny Smith is $7.20 per TCE on the large orchard, but the real value is $5.03 per TCE. Granny Smith is already being produced for more than it is worth, therefore the added costs are decreasing the return on equity for the orchard. Presumably even though Granny Smith may be the one variety that can be produced more cheaply than others, this is why growers are reducing their Granny Smith plantings.

Table 5.13 The real value of fruit per TCE for the four varieties as they progress through the value system. The value starts with the ENZA payment, then moves back to the calculated value of the fruit as it hangs on the tree prior to harvest.

Operation adding value	Braeburn ($/TCE)		Fuji ($/TCE)		Granny Smith ($/TCE)		Pacific Rose™ ($/TCE)	
	Large[a]	Small[d]	Large[a]	Small[d]	Large[b]	Small[d]	Large[c]	Small[d]
1. Packing[e]	11.80	11.80	13.80	13.80	9.40	9.40	20.00	20.00
2. Drenching	8.82	9.47	–	–	–	–	–	–
3. Transport to packhouse	8.79	–	10.82	–	6.42	–	17.02	–
4. Harvesting support	8.63	–	10.66	–	6.26	–	16.87	–
5. Harvesting	8.37	9.29	10.39	11.47	6.03	6.95	16.57	17.43
6. Growing	7.20	7.22	9.21	7.33	5.03	5.83	15.31	10.76

[a] Values are based on average data associated with Orchard One and Orchard Two.
[b] Values are based on data associated with Orchard One.
[c] Values are based on data associated with Orchard Two.
[d] Values are based on data associated with Orchard Three.
[e] Growers are paid for fruit at this point of the handling system.

The small orchard has a "Growing" cost of $10.32 per TCE for the four varieties. This exceeds the real value per TCE for Braeburn, Fuji, and Granny Smith. For Pacific Rose™ the "Growing" cost is slightly lower than the real value of $10.76 per TCE (Table 5.13). The operators of such orchards will be under pressure to save costs on their system or else face financial difficulties.

By modelling the fruit value after packing, the value of bruising to ship–side can be estimated (Table 5.14). As ENZA pays the suppliers at "Packing", and ENZA charges growers a levy, the real value for fruit is the same for both value systems at this point. The difference that develops between the large and small packhouse systems relate to the inability of this researcher to unbundle the costs at the small packhouse. This means that although the small packhouse system has transportation to the coolstore, the actual cost can not be identified as it has been bundled into the "Packing" costs.

Table 5.14 The real value of fruit per TCE for the four varieties while they progress through the value system. The value starts with the ENZA payment, then moves forward to the value of the fruit as it sits at the port of export.

Operation adding value	Braeburn ($/TCE)		Fuji ($/TCE)		Granny Smith ($/TCE)		Pacific Rose™ ($/TCE)	
	Large[a]	Small[d]	Large[a]	Small[d]	Large[b]	Small[d]	Large[c]	Small[d]
1. Packing[e]	11.80	11.80	13.80	13.80	9.40	9.40	20.00	20.00
2. ENZA levy	12.00	12.00	14.00	14.00	9.60	9.60	20.20	20.20
3. Transport to coolstore	12.12	–	14.12	–	9.72	–	20.32	–
4. Coolstorage	13.75	13.63	15.85	15.63	11.35	11.23	21.95	21.83
5. Transport to port	13.88	13.76	15.98	15.76	11.48	11.36	22.08	21.96

[a] Values are based on average data associated with Orchard One and Orchard Two.
[b] Values are based on data associated with Orchard One.
[c] Values are based on data associated with Orchard Two.
[d] Values are based on data associated with Orchard Three.
[e] Growers are paid for fruit at this point of the handling system.

Even though the real value of fruit at the port is very similar for both value systems (Table 5.14), the calculated values for the accumulated costs of production at the port are very different. These are best presented in Table 5.15 which follows. The real value of a TCE is greater for the large packhouse system than it is for the small packhouse system. This is reversed for the calculated value of a TCE, with the small packhouse system having the higher values. The differences between the real value and the calculated value are closer for the large packhouse system, and for three of the four varieties the real value is greater than the calculated value. This is the opposite for the small packhouse system, with the calculated value of Pacific Rose™ being only slightly lower than the real value.

Table 5.15 Table illustrating the difference between the accumulated real value of a TCE, and the accumulated calculated value of a TCE, when fruit arrives ship side at the port of export.

	Braeburn ($/TCE)		Fuji ($/TCE)		Granny Smith ($/TCE)		Pacific Rose™ ($/TCE)	
	Large[a]	Small[d]	Large[a]	Small[d]	Large[b]	Small[d]	Large[c]	Small[d]
Real value	13.88	13.76	15.98	15.76	11.48	11.36	22.08	21.96
Calculated value	13.60	16.86	13.59	18.75	13.29	15.85	13.77	21.52

[a] Values are based on average data associated with Orchard One and Orchard Two.
[b] Values are based on data associated with Orchard One.
[c] Values are based on data associated with Orchard Two.
[d] Values are based on data associated with Orchard Three.

5.5 Loss in Value Attributable to Bruising Calculated for the Value System

The cost of fruit bruising is a percentage of the real industry value of each TCE exported. Table 5.16 shows that, as value is added to each fruit as it progresses through the handling system, the loss in value attributable to bruising increases at the same time. Therefore, from data derived from the spreadsheets presented in Appendix 6, 1% bruising suffered in a carton at the port, can be seen to be worth considerably more than if incurred during harvesting. This is the result of several variables. One being, that the production costs early in the handling system are distributed over a large number of fruit prior to sorting in the packhouse. The other being, that fruit have not passed through the value adding processes, thus the value of fruit is lower at the beginning than further along the handling system. For example, the loss in value of 5% bruising to Braeburn caused during coolstorage is worth $0.68 per TCE, this is equivalent in cost to 9.4% bruising at harvest, or 10% bruising at packing is worth $1.18 per TCE which is equivalent in value to 14% bruising at harvest.

The loss in value can be expressed in another way, which is, the value lost (or cost) for 5% bruising at harvest for Braeburn is determined to be $0.36 per TCE, whereas the value lost (or cost) of 5% bruising of fruit packed in a carton at the port is $0.68 per TCE (nearly twice the value).

Table 5.16 The loss in value attributable to bruising for Braeburn, for the large packhouse and its suppliers, for different levels of bruising as fruit passes through the value system.

Operation	Loss in value attributable to bruising ($/TCE)	
	Bruise occurrence over total crop	
	5%	10%
1. Growing	0.36	0.72
2. Harvesting	0.42	0.84
3. Harvesting support	0.43	0.86
4. Transport to packhouse	0.44	0.88
5. Drenching	0.44	0.88
6. Packing[a]	0.59	1.18
8. Transport to coolstore	0.60	1.19
9. Coolstorage	0.68	1.36
10. Transport to port	0.68	1.37

[a] Stage at which bruised fruit is removed, therefore a decrease in the amount of fruit in a line.

Table 5.17 The loss in value attributable to bruising for Fuji, for the large packhouse and its suppliers, for different levels of bruising as fruit passes through the value system.

Operation	Loss in value attributable to bruising ($/TCE)	
	Bruise occurrence over total crop	
	5%	10%
1. Growing	0.46	0.92
2. Harvesting	0.52	1.04
3. Harvesting support	0.53	1.07
4. Transport to packhouse	0.54	1.08
5. Drenching	–	–
6. Packing[a]	0.69	1.38
8. Transport to coolstore	0.70	1.39
9. Coolstorage	0.78	1.56
10. Transport to port	0.78	1.57

[a] Stage at which bruised fruit is removed, therefore a decrease in the amount of fruit in a line.

Wennergren and Lee (1961) reported that for bruise occurrence larger than 1 cm^2, it was possible for 9.5% of apples to be bruised (Appendix 1). If this bruising was to happen in the harvesting of Fuji, the loss in value attributable to bruising would be $0.87 per TCE. Wennergren and Lee (1996) then report that the bruising level of fruit received at the packhouse is 12.3% which is greater than 1 cm^2 (Appendix 1). With Fuji arriving at a packhouse with this level of bruising, the loss in value due to bruising would have increased to $1.33 per Tce.

Table 5.18 The loss in value attributable to bruising for Granny Smith, for the large packhouse and its suppliers, for different levels of bruising as fruit passes through the value system.

Operation	Loss in value attributable to bruising ($/TCE)	
	Bruise occurrence over total crop	
	5%	10%
1. Growing	0.25	0.50
2. Harvesting	0.30	0.60
3. Harvesting support	0.31	0.63
4. Transport to packhouse	0.32	0.64
5. Drenching	–	–
6. Packing[a]	0.47	0.94
8. Transport to coolstore	0.48	0.95
9. Coolstorage	0.56	1.12
10. Transport to port	0.56	1.13

[a] Stage at which bruised fruit is removed, therefore a decrease in the amount of fruit in a line.

From the literature reviewed in Chapter Three, it was reported that varying levels of bruising occur through the system. Granny Smith was reported to have a high bruise susceptibility (Pang *et al.* 1992) also in Chapter Three. If the bruising level was reported to be 9.4%[12] (Nel 1980), at the orchard just prior to transportation (Appendix 1), the loss in value would be $0.47 per TCE. Bollen *et al.* (1995)

[12] Although Nel (1980) reported this level of 9.4% bruising for Golden Delicious, it has been applied to this example because, Granny Smith and Golden Delicious have similar bruise susceptibilities.

reported that for Granny Smith during transportation from the orchard to the packhouse, 3.5% of the fruit incurred bruising greater than 1 cm^2 (Appendix 1). This additional 3.5% bruising for transportation would increase the loss in value to $0.64 per TCE.

Table 5.19 The loss in value attributable to bruising for Pacific Rose, for the large packhouse and its suppliers, for different levels of bruising as fruit passes through the value system.

Operation	Loss in value attributable to bruising ($/TCE)	
	Bruise occurrence over total crop	
	5%	10%
1. Growing	0.77	1.53
2. Harvesting	0.83	1.66
3. Harvesting support	0.84	1.69
4. Transport to packhouse	0.85	1.70
5. Drenching	–	–
6. Packing[a]	1.00	2.00
8. Transport to coolstore	1.01	2.01
9. Coolstorage	1.09	2.18
10. Transport to port	1.09	2.19

[a] Stage at which bruised fruit is removed, therefore a decrease in the amount of fruit in a line.

The value of the bruise increases with the movement through the value system. The bruise at the end of the value system, at the port, is almost worth twice as much as it is at the beginning, on the orchard. On the large orchard, for Pacific Rose™, every 1% bruising at harvesting decreases the value by $0.15 per TCE while at the port, for every 1% increase of bruising the value drops $0.22 per TCE (Table 5.19).

The value of bruising is different for each variety because of the different real values. The greater the real value of the variety, the higher the loss in value attributable to bruising. From the previous four Tables it can be seen that the bruising of Granny Smith has the lowest value while Pacific Rose™ has the highest.

As the orchard has to pay for all processes prior to packing, orchardists have to bear all losses in value to this stage. As fruit moves through the early stages of the handling system it has been noted, in the literature, that differing amounts of bruising occur at each stage (Appendix 1). Therefore, as the bruising accumulates, so does the loss in value attributable to bruising for the orchard. After packing an orchard's fruit, the value of bruising within each carton should have been decreased, as bruised fruit has been removed during sorting. Since the fruit is now considered the property of ENZA, bruising that occurs from this point on is an indirect loss of value for the orchard, because ENZA suffers extra costs, which are debited from income. In the long run grower returns will suffer.

5.6 Losses in Value Attributable to Bruising Calculated using Bruising Levels Reported in the Literature

In Chapter Three, Table 3.6, summaries of bruising levels were presented that were collected from reviewed literature. The minimum, mean, and maximum values were then applied to the loss in value attributable to bruising for each variety. Although the three different levels of bruising were for differing varietal bruise susceptibilities, the same levels were used for the four investigated varieties of this research, because it is possible for these levels to be experienced for all the varieties.

The losses in value for Braeburn and Fuji were the same through the system for the different values (Table 5.7), since it was found in Section 5.4 of this Chapter that the real value of the fruit passing through the large packhouse value system was the same. Using the reported bruise susceptibilities by Pang *et al.* (1992) that were reviewed and presented in Chapter Three, Table 3.3, the following interpretations of the losses in value attributable to bruising can be made for the large packhouse system.

The mean and minimum values are the most probable for Braeburn and Fuji because of their reported bruise susceptibilities. For example, the loss in value attributable to bruising for a TCE arriving at the packhouse could be $0.76 per TCE to $1.04 per TCE for both Braeburn and Fuji (Table 5.20). The mean and maximum loss in values would be most applicable for Granny Smith, because it had a high bruise susceptibility reported. Values for the loss in value attributable to bruising after fruit have passed through the packhouse for Granny Smith could range from $1.33 per TCE to $3.76 per TCE (Table 5.20). Although no reports on the bruise susceptibility of Pacific Rose were found in the literature, only its parents, it is believed that it is a medium to high bruising variety, therefore the mean and maximum losses in value could be used. Examples of losses for Pacific Rose™, using bruising values from the literature, could range from $2.83 per TCE to $8.00 per TCE once passed through the packhouse (Table 5.20).

Table 5.20 Using values reported in the literature: the losses in value attributable to bruising for three different bruise levels occurring on the orchard until fruit has passed through the packhouse, in the large packhouse system.

Operation	Bruise Level	Braeburn ($/TCE)	Fuji ($/TCE)	Granny Smith ($/TCE)	Pacific Rose™ ($/TCE)
Orchard	Minimum	0.09	0.09	0.05	0.15
	Mean	0.62	0.62	0.37	0.99
	Maximum	1.01	1.01	0.59	1.59
Field to Packhouse	Minimum	0.76	0.76	0.45	1.19
	Mean	1.04	1.04	0.62	1.64
	Maximum	1.33	1.33	0.79	2.09
Packhouse	Minimum	0.35	0.35	0.25	0.50
	Mean	1.95	1.95	1.33	2.83
	Maximum	5.52	5.52	3.76	8.00

Fruit maturity is greater near the end of the harvest season, therefore bruise susceptibility increases (Klein 1987; Brown *et al.* 1989; Banks *et al.* 1993). As fruit become more susceptible, all the varieties would suffer the maximum losses in value due to bruising. This agrees with the comment made during the interviews, which was that bruising levels increased with the late harvested fruit. The growers from Orchard One and Orchard Three noticed this mostly with the variety Granny Smith in the last weeks of harvest.

Although the results for loss in value attributable to bruising were not presented for the small packhouse system, the losses in value at the orchard level were slightly higher because of the higher value of the fruit (Table 5.13). No values can be presented for the transportation of fruit from the field to the packhouse because this operation could not be unbundled from the "Harvesting" costs. Since ENZA payments to growers were used to assess the value of fruit after packing, the loss in values at this stage are the same as the large packhouse system, presented in Table 5.20.

5.7 Cost of Bruising on a per Carton Basis to the Supplier

The cost of bruising to a supplier affects them in two ways, one as a direct cost, that is being charged for handling damaged fruit, and the other as an opportunity cost. In other words, the supplier suffers a loss of income because down graded fruit do not receive the premium export payout. Therefore, to derive the total cost of bruising for the supplier, both the direct cost of handling bruised fruit and the loss of income suffered because that fruit is not sold need to be added together (Table 5.21). At packing, bruised fruit are a loss to orchardists because they have spent money getting these fruit to this point and then these fruit are rejected. For example, in Table 5.21, it can be seen that for Braeburn, the large packhouse system incurs a total cost of $23.32 per TCE of bruised fruit produced, the small packhouse system $26.70 per TCE. Fruit which is bruised after the point of sorting is assumed to be taken into account by ENZA, and subsequently reflected in supplier payouts, but no data from ENZA was available for analysis. As data to evaluate the final market returns for the varieties considered in this study was unavailable, the opportunity cost of bruising after fruit was packed, was not able to be calculated for ENZA.

Table 5.21 The accumulated total cost of a bruised TCE of fruit to the supplier as it progresses through the handling system to the point of packing for each of the four varieties.

Operation	Braeburn ($/TCE)		Fuji ($/TCE)		Granny Smith ($/TCE)		Pacific Rose™ ($/TCE)	
	Large[a]	Small[d]	Large[a]	Small[d]	Large[b]	Small[d]	Large[c]	Small[d]
1. Growing	18.72	22.12	20.72	24.12	11.87	19.72	27.00	30.32
2. Harvesting	19.88	24.19	21.90	28.25	12.87	20.84	28.27	36.99
3. Harvesting support	20.15	–	22.17	–	13.10	–	28.56	–
4. Transport to packhouse	20.31	–	22.33	–	13.26	–	28.71	–
5. Drenching	20.34	24.37	–	–	–	–	–	–
6. Packing[e]	23.32	26.70	25.31	30.59	16.24	23.29	31.69	39.56

[a] Costs are based on average data associated with Orchard One and Orchard Two.
[b] Costs are based on data associated with Orchard One.
[c] Costs are based on data associated with Orchard Two.
[d] Costs are based on data associated with Orchard Three.
[e] Growers are paid for fruit at this point of the handling system.

Since the production costs on the small orchard were higher than the large orchards, the total cost of bruising is considerably more. This means that the small orchard needs to keep bruising at a minimum to help save costs, and improve export returns.

Table 5.22 presents the total cost of export income lost for the four varieties investigated over the three case study orchards for a 1% level of fruit bruising. The average total cost is just above 3% of export earnings for three of the four varieties. Since the production costs are the same, and the bruising levels and returns were similar, the total cost for Fuji and Braeburn were expected to be similar. For every 1% of bruising occurring, the orchard loses the equivalent to 3% of its export earnings.

Table 5.22 Equivalent percentage of export income lost due to the total cost of bruising, opportunity cost and production costs from "Orchard" up until and including "Packing", for the three case study orchards.

Orchards	Braeburn (%)	Fuji (%)	Granny Smith (%)	Pacific Rose™ (%)
Large	3.0[a]	3.0[a]	4.8[b]	2.6[c]
Small[d]	3.2	3.0	4.1	4.0

[a] Average of Orchard One and Orchard Two.
[b] Orchard One.
[c] Orchard Two.
[d] Orchard Three.

As seen in Table 5.22, for Granny Smith, the percentage of export income lost due to bruising was 4.8% for the large orchard, and 4.1% for the small orchard, which was a little higher than the other varieties. This is for several reason, these being: the production costs are similar to the other varieties, yet the returns are low; and it is a highly bruise susceptible variety, which means a high percentage of fruit is rejected due to bruising. The literature suggested that up to 50% of a crop may be lost due to bruising (Pang *et al.* 1996). If a variety, such as Granny Smith experienced such a high level of bruising for the small orchard, the total cost would be in excess of 205% ($19.27 per TCE) more than the export returns to the supplier, if paid $9.40 per TCE by ENZA.

For other varieties with a high bruise susceptibility, and a higher return than Granny Smith, the total cost would be expected to be greater. Pacific Rose™ has a higher total cost than Braeburn and Fuji for the small orchard (Table 5.22), because of its higher harvesting costs, and it has a very high export return. The results for Pacific Rose™ are lower than expected at 2.8% for the large orchard. Overall, it was expected that Pacific Rose™ would have a higher total cost than the other three varieties. Once Orchard Two and Orchard Three reach full production, more income is earned, therefore the total cost will rise.

5.8 *Summary*

Economies of scale have been an important factor in the production costs of the orchards. The small orchard incurred greater "Growing" and "Harvesting" costs than the large packhouse suppliers. For this reason, the small packhouse system's fruit was of a lower value than the large system. The costs also appeared higher because unlike the large packhouse, the small packhouse did not breakdown its value system into small increments, and therefore bundled some of the costs in the different stages. The loss in value attributable to bruising was slightly lower for the small packhouse system, because of the lower value of its fruit compared to the large packhouse system. In all cases, the loss in value due to bruising was worth approximately twice the amount at the port than it was on the orchard prior to harvesting. The high value varieties have a higher loss attributable to bruising. This was found with Pacific Rose™ having the greatest losses and Granny Smith the least.

The total costs of bruising, opportunity cost and production costs, were greater on the small orchard than the large orchards. The reason for the high total costs on the small orchard was due to the high costs involved moving fruit through the postharvest handling system.

The loss in value, due to bruising through the value system beyond the packhouse, is considerably less than the cost of bruising which affects the supplier from the point of "Growing" to "Packing". This is because the opportunity cost of loss in income is not taken into consideration by the value system, only production costs. This means, that in the early stages of the handling chain, the value system recognises the loss in value as primarily a loss of value in fruit caused by bruising, without including loss of potential export income. After fruit has been packed, the loss in value is the same for the value system and the supplier, as the supplier has been paid for fruit that will continue to be bruised through the handling chain, and as mentioned earlier, the final supplier payout has already taken this bruising into account. Because the final returns for a TCE at market were not known, the opportunity cost of fruit bruising could not be calculated after "Packing".

Chapter Six Conclusion

6.1 Introduction

This Chapter is divided into five sections. The first three sections relate to the results of Chapter Five and the objectives that were put forward in Chapter Two. The first of these sections covers the value system and its use in the postharvest handling system of apples. A section that explains how the value system was then used to derive the value of bruising follows, and the last section covers the total cost of bruising to the growers.

The fourth section covers recommendations and opportunities for further research. This section also explains the problems encountered undertaking this research, and suggestions to avoid these situations.

6.2 The Apple Value System

The value system, as described by Porter (1985), and reviewed in Chapter 3.6, was found to be an appropriate method to evaluate the problem of bruise value. The value system offered the opportunity to find the real value of fruit, by using the costs that were involved with the movement of fruit through the handling system, using ENZA grower payments as a base fruit value.

Two value systems for apples in the Hawke's Bay district were developed using the value system as a framework and implementing a case study approach to derive data. One value system was derived for a postharvest apple handling chain which involved orchards that supply fruit to a large commercial packhouse that packed more than 350,000 TCEs per season. This fruit required road transportation from the orchard to the packhouse as the packhouse was some distance from the orchards. A second value system was developed for a postharvest apple handling chain that went from orchard to packhouse on one site, consequently the fruit did not pass through as many handling stages as fruit handled in the first system, that is the large packhouse system. This smaller packhouse packed less than 100,000 TCEs per season.

The development of the two value systems based on packhouse size was considered important, because packhouses have different management and cost structures resulting in different value systems. This was obvious when a small packhouse and orchard were supplied and owned by the same individual, since costs were at times bundled into a different stage in the value system, compared to a corporate structured operation. Although costs were bundled in the small packhouse system, the real difference between the two value systems was a result of economies of scale. This would have occurred with the small orchard and packhouse from Case Study Two being over capitalised, compared to the large orchards and packhouse of Case Study One.

Because ENZA pays growers when fruit is packed, the value systems were derived with fruit being of equal value at this point. Using this approach, it was possible to determine the "real" value of fruit as it passed through the system to packing then to ship side.

The value system approach enabled the profitability of each system to be evaluated, but mainly, it enabled the "real" value of fruit at each stage, from picking to ship side, to be calculated. The "real" value per TCE, calculated from real returns, was often different to the calculated value per TCE for the orchards. The "Growing" costs, including production and fixed costs, were in all cases, except for Granny Smith, calculated to be less than the real value of the fruit for the large orchards.

For the large orchards, the calculated value of Granny Smith was much higher than the real value, and was likely not to cover a return on equity, whereas Braeburn, Fuji, and Pacific Rose™ calculated fruit values were lower than the real values for the large packhouse system. Varieties whose real value exceeds the calculated value, would be profitable for growers to grow. When the calculated value exceeds the real return the converse applies, that is growers make less than a 20% return on equity and may even incur a loss from producing that variety.

The small orchard's "Growing" costs for three of the four varieties were more than the "real" value of the fruit, thus they had a lower calculated value than the "real" value. Pacific Rose™ had an initial calculated value more than the "real" value, but as it passed through the value system its value became less than the "real" value. For all varieties produced on the small orchard, the real returns were less than the calculated returns. These results bring to attention some questions concerning whether the data supplied was accurate, or is it profitable for small growers to produce apples? If the data supplied was accurate, this research indicates that small orchards are at a definite disadvantage for producing apples, compared to large orchards, as their returns are low and they are not receiving the high returns their owners might expect.

The models that were developed, using Porter's value system approach, did meet and achieve the first objective that was proposed in Chapter 2.4. The methodology helped to evaluate the incremental value of apples as they passed through the postharvest handling system in the Hawke's Bay District. By completing the first objective, the other two objectives could be achieved, and therefore provide a means in which the hypotheses stated in Chapter 2.4 could either be accepted or rejected.

6.3 The Loss in Value Attributable to Bruising

The loss in value prior to "Packing" has a direct impact on the supplier and not as much on the industry, since it is the supplier who shoulders all the costs incurred up until and including this stage. The loss in value after "Packing" is an indirect cost to growers and a more direct cost to ENZA, because the payment growers receive from ENZA has taken into account the loss in value attributable to bruising by removing it from the total payments.

From the value of fruit found at each stage in the postharvest handling system, the value of bruising was established. As expected, fruit that passed through the system, increased in value, therefore the loss in value attributable to bruising also increased. The first hypothesis, which was that the loss of value of fruit due to bruising resulting from handling can be found, could be accepted. The second hypothesis, which was the loss in value of fruit attributable to bruising is considerably more at the market end of the system than it is at the beginning, is also accepted as the loss in value of fruit increases as fruit passes through the system, although the value as a proportion of sale price was not investigated.

Since the cost of "Growing" was a high cost at the start of the value system, the initial loss in value due to bruising is relatively expensive. As the stages in the system between "Growing" and "Packing" were lower in cost, in comparison to "Growing", the value of fruit bruising does not increase appreciably through the system. "Packing" is the next greatest cost after "Growing", so depending on the way packing is charged for, when the percentage of bruising begins to increase, the loss in value becomes more noticeable. The "Packing" stage appears high as it includes all activities undertaken at the packhouse. If this stage had been broken down into its separate components such as yard work, drenching, fruit dumping, sorting, etc., the increase in value would not have been as apparent. This would also apply to the breaking down of the "Growing" stage.

The loss in value attributable to bruising is greater to the large packhouse system, than the small packhouse system, because of the higher real value of the apples. Since bruised fruit is not removed from the time it is harvested, until it is sorted in the packhouse, all bruising is accumulated. Once fruit have left the packhouse, the bruising level should drop below the specified level ENZA has set for export standards, because the sorters at the packhouse should have removed bruised fruit. This decrease in bruising allows the loss in value to decrease before it increases again, due to excessive forces during handling later in the system. It is predicted that with the new packaging types, this bruising will be reduced. Because of the high fruit value at the market end of the value system, bruising that occurs is of high value in comparison to the bruise value at the orchard end.

6.4 Loss in Value using Bruise Levels Reported in Literature

Using bruise levels reported in the literature, losses in value attributable to bruising were able to be presented, in Chapter Five, for the four investigated varieties. Using the susceptibility rankings reported for the varieties, it was possible to calculate likely ranges of loss in value attributable to bruising per TCE.

The values for Braeburn and Fuji were the same as they were found to have the same real value per TCE as each variety passed through the value system. Even though Granny Smith had a higher bruise susceptibility, the loss in value for Braeburn and Fuji was slightly greater than Granny Smith because of the higher value of their fruit. The loss in value attributable to bruising was greatest for Granny Smith at the packhouse because of the increase in value of fruit, and that a high level of bruising had been reported at this stage. The loss in value attributable to bruising was considerably higher for Pacific Rose™ than the other varieties, because of its high value and expected high bruise susceptibility.

The range in values found for the loss in value for each of the varieties could be readily increased. The ranges at present, best illustrate bruising for early and late harvested fruit in a season. Excessive handling forces, or unfortunate climatic factors could increase the levels of bruising, therefore increasing the loss in value per TCE.

Losses in values for the small packhouse system were not presented. The loss in value of fruit would be the same at the small packhouse because the fruit is the same value at this point for both packhouse value systems. The losses in value incurred by the small packhouse system are much greater than the large packhouse system because of, the high costs it took to move fruit through the system, and also the loss of income when fruit did not make export returns.

6.5 Total Cost of Bruising to the Supplier

For fruit to move from the orchard to the end of packing, the costs of movement through the handling system are paid by the supplier. The literature review (Chapter Three) revealed that high amounts of bruising can occur between the fruit being harvested and packed. All bruising is accumulated through these stages until it is removed on the sorting table. Therefore, the bruised fruit have accumulated the same costs that were involved getting it to the point of sorting as export fruit, but do not receive the expected income.

The total costs were higher for the small orchard than the large orchards, due to the higher accumulated costs involved with the movement of fruit through the handling system. The total cost for fruit, after packing, was not presented as the final market price was not known.

From the results presented in Chapter Five, it is considered that the total cost, opportunity cost and accumulated production costs, of bruising to the grower is of considerable concern. The total cost is more of an issue for the low returning variety Granny Smith, than the other varieties. For every 1.0% bruising occurring in the large packhouse system, the grower's total cost of producing this variety was equivalent to losing 4.8% of their export income. The total cost of bruising appears to have the potential to become a major concern for the production of Pacific Rose™. This is because for every 1.0% bruising occurring in the small packhouse system, it was equivalent to 4.0% lost export returns. The total cost calculated for the large packhouse system was of a much lower value. The figures of Pacific Rose™ are questionable, as the case studies used for this research had low production levels, which produced varied results. Although Braeburn and

Fuji had lower total costs for bruising to the grower than the other two varieties, the problem of bruising should still be of concern. For both the small and large packhouse system, the total cost of 1.0% bruising was equivalent to losing 3.0% of the export returns.

Due to limited data, the results for Pacific Rose™ varied greatly, and it was difficult to determine an accurate total cost for the suppliers. Since the parents of Pacific Rose™ are considered to be highly bruise susceptible varieties, and Pacific Rose™ is a high value variety, it is expected to have a high total cost to the supplier, for the resulting bruised TCEs. This would indicate that if more data could be collected for Pacific Rose™ using additional case studies, the total cost would be expected to be higher than the value found in this research.

Since the opportunity cost to the suppliers of the two systems was found in this research, the third and final objective stated in Chapter 2.4 has been achieved. This objective was achieved mainly because the first objective was achieved. As the opportunity cost to the suppliers was considerably more than the loss in value attributable to bruising, the third hypothesis can be accepted.

The onshore total costs of bruising are considerably more to the supplier, than the loss in value faced by the industry. These losses are best presented at the "Packing" stage of the value system. For example, the total loss faced by the grower in the large packhouse system was $16.24 per Tce, and the total loss was even greater for the grower of the small packhouse system at $23.29 per TCE, while the loss in value faced by the industry is only $9.40 per TCE.

6.6 Recommendations and Opportunities for Further Research

A number of problems were encountered in the execution of this research project. The primary problem was that in the Hawke's Bay region, the value loss due to bruising was overshadowed by the greater problem of hail damage. The region had suffered three hail storms just prior to interviews being conducted: the interviewees were more focused on the problem at hand, than on fruit bruising.

Another problem encountered was the lack of information from some individuals interviewed. During the year some unforeseen setbacks occurred, resulting in time becoming a limiting resource. The time for when interviews could be undertaken by the researcher were pushed back until late in the research which meant fewer growers and packhouse operators being interviewed than preferred. With the interviews being undertaken late in the research this meant that they were taking place at the beginning of the apple harvesting season. This then meant that the interviewees had limited time to participate in the interviews, and provide the required data.

The development of a model is reliant on accurate data. Of the growers and packhouse operators participating, some were not able to provide the necessary data. This was due to the individuals either not having the appropriate varieties on their property or did not have the detail required for the model development. The lack of the interviewer's experience was also considered as a factor for incomplete data collection. Poor data collection resulted through a poor interviewing method.

Some of the problems mentioned previously could have been avoided with a more structured research plan. It would have been more appropriate to have organised more packhouses and growers to interview. If individuals were found who could not provide all the information that was required of them, they should have been thanked for their help, and removed from the study. A more careful investigation of the varieties grown on the orchards should have been undertaken. For the purpose of comparing results, it would have been more beneficial to have investigated orchards with the same varietal mix.

The interviewer's method could only have been improved with more interviews. With more practice interviews performed before the actual fieldwork was undertaken, data collection would have improved with more grower and packhouse interviews actually being undertaken. It was noticed by the researcher that data collection was more complete with each interview carried out.

Although the unforeseen time delays in this research could not have been avoided, future work should aim to be completed by early summer. Completing interviews by this time, data collection is not a hindrance to the interviewee's timetable, and it allows time for follow–up information to be collected and reviewed.

Another excellent opportunity to implement a value system is for the investigation of the value of fruit as it hangs on the tree. This would be useful in assessing a crop if it is damaged prior to harvest, for example hail, where insurance claims must be made. The value system also allows for the calculation of the loss in value due to bruising, which was investigated in this report.

The total cost that was derived in this research has a range of uses, and should not be restricted to the occurrence of bruising. The total cost could be used to assess the value of any damage that occurred to fruit at any point in the value system from growing to packing and final sale, provided data is available. It can be readily applied because it is taking into account all fruit that is passing through these stages in the handling system. This approach could easily be adopted to access the costs of hail damage.

A problem found when presenting the value system was that the costs of the packhouse were not broken down into the smaller increments. Except for "Growing", because it was considered preharvest, all postharvest stages were presented in small increments, and provided a constant increase in value through the value system. If the packhouse operations could have been broken down, the fruit value, and the loss in value attributable to bruising would not have appeared to increase at a sudden rate.

Using Porter's value chain as a framework, further studies could target an individual stage in the handling system and develop a value chain for that particular operation. For example, a value chain could be developed for a packhouse which would provide valuable information concerning the different stages within the packhouse. The packhouse has many identifiable operations, such as, yard work, drencher, fruit dumper, sorting table, etc., that have been identified in the literature as points where bruising occur (Nel 1980; Brown *et al.* 1989; Pang 1993). With the development of a value chain, information could be provided on where the greater losses in value attributable to bruising actually occur. For a small operator, it is expected to be a more difficult task to develop a value chain for the packhouse, because management does not usually have to have the sophisticated reporting system necessary in corporate packhouses.

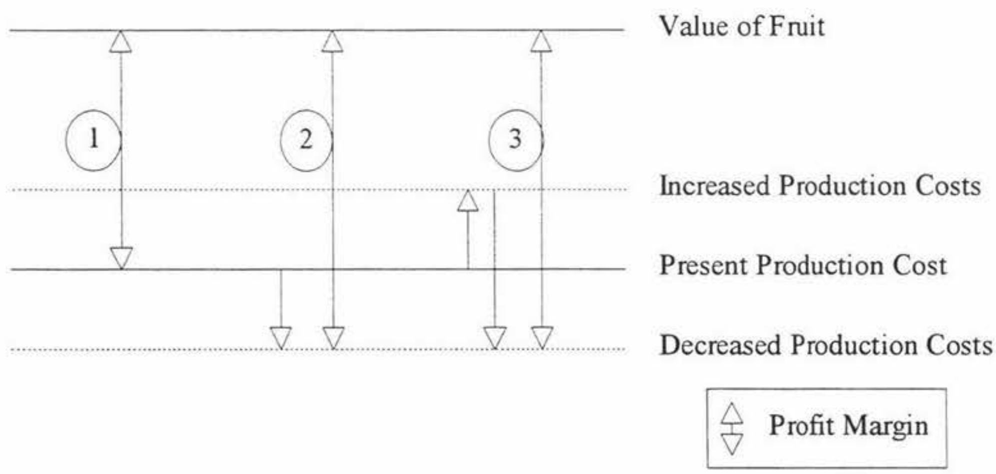
If a series of value chains could be developed for the postharvest apple handling chain, an accurate model of the value system could be developed, to provide valuable information to the industry. It could be used to investigate value adding processes, or subsequently, value losing actions attributable to some problem in the fruit industry. If these value chains were to be developed it would be advisable, from this researcher's experience, to investigate an operation where the operator maintains accurate records. A value chain investigation would definitely require multiple visits and an excellent rapport between the researcher and the individual used to obtain the data needed. A steady flow of communication would enable the researcher to obtain information when they are away from the property.

6.7 Different Orchard Management Structure for Fruit Flow

From the model developed, using the case studies in this report, a fruit value has been determined for each of the four varieties investigated. The case study orchards at present are considered to be operating under management strategy "1", which is operating with a profit margin between the present production costs, fruit value, and bruise occurrence (Figure 6.14). This is where the fruit value was found using the present production costs and ENZA payment to suppliers. If an orchard was to implement management strategy "2", it would be attempting to increase the profit margin by decreasing "Growing" costs (Figure 6.14). This could be achieved through reducing fixed costs, keeping low capital costs, increase efficiency of staff, equipment use, etc. As most orchardists try to minimise costs this strategy is liable to return minimal dividends.

The third management strategy, "3", is to increase the present production costs in order to save in the long run by reducing bruising (Figure 6.14). By reducing the overall bruising, more TCEs are able to receive export returns. This might be undertaken by increasing field monitoring of pickers, or possibly paying workers more, in order to improve work quality by ensuring more care is taken with the fruit.

Figure 6.14 The effect of differing management practices on the possible profit margin for the supplier.



In this research project it was interesting to find that most people assume that growers could expect a 20% return on equity. Growers in many cases had to accept a lower return on equity because, after they had paid all charges, their returns simply did not provide enough for a 20% return on equity. This could indicate greater industry problems in the future, since growers who do not receive a good return on equity, might not be willing to invest in equipment that could later improve the quality of their crop. Another issue, previously discussed, is that growers may have already identified some problem that does need rectifying, but because the returns do not surpass the costs of the changes needed, growers are not willing to alter their management practices.

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Appendix 1 List of authors, the year they published, and the bruising they reported.

Author	*Published Date*	*Position in Handling Chain*	*Incidence of Bruising (%)*	*Size of bruise*	*Variety of apple (if known)*	*Bruise Susceptiblity*[1]
			Field/Grower			
Nel	1980	Grower	7.05	< 1 cm^2	Golden Delicious	High
Nel	1980	Grower	0.86	< 1 cm^2	Golden Delicious	High
Nel	1980	Grower	9.4	< 1 cm^2	Golden Delicious	High
Nel	1980	Picker into bag	0.27	< 1 cm^2	Golden Delicious	High
Nel	1980	Emptying into bin	2.46	< 1 cm^2	Golden Delicious	High
Nel	1980	Transport on trailer to loading zone	1.68	< 1 cm^2	Golden Delicious	High
Nel	1980	Total Grower	5.65	< 1 cm^2	Golden Delicious	High
Barker	1996	Total Grower	5	< 1 cm^2	All apples	
Wennergen and Lee	1961	Picking bag	9.5	< 1 cm^2	All apples	
Wennergen and Lee	1961	Field create	5.9	< 1 cm^2	All apples	
Banks, Mowatt *et al.*	1993	Field bruising into bin	75	all bruises	All apples	
Banks *et al.*	1993	Orchard	40		All apples	
Anon	1985	Field	21		All apples	
Anon	1985	Field	6	< 1 cm^2	All apples	
			Field/packhouse			
Wennergen and Lee	1961	Received at packhouse	12.3	< 1 cm^2	All apples	
Sargent *et al.*	1987	Harvest - packhouse	93	all bruises	All apples	
Brown *et al.*	1989	From field bin to floatation	6	12.8 to 19	Golden Delicious/early	High
Guyer *et at.*	1990	Pick and haul	4.5 bruises/fruit	< 6.1	All apples	
Pipmark anon		At packhouse	7	< 1 cm^2	All apples	
			Transportation			
Nel	1980	Loading zone to packhouse	1.24	< 1 cm^2	Golden Delicious	High
Schulte-Pason	1990	Road transport	100km = 6	< 1 cm^2	Golden Delicious	High
Barker	1996	Transport	5	< 1 cm^2	All apples	
Bollen *et al.*	1995	Road transport	3.5	< 1 cm^2	Granny Smith	High
Maindonald & Finch	1986	Road transport	18.5	< 1 cm^2	All apples	

[1] Bruise susceptibility ranking determined by author

Appendix 1 (continued)

Author	*Published Date*	*Position in Handling Chain*	*Incidence of Bruising (%)*	*Size of bruise*	*Variety of apple (if known)*	*Bruise Susceptibility*[1]
			Packhouse			
Nel	1980	Bin Tip (Dry)	12.24	< 1 cm^2	Golden Delicious	High
Nel	1980	Bin Tip (Dry)	5.94	< 1 cm^2	Golden Delicious	High
Nel	1980	Bin Tip (Wet)	0	< 1 cm^2	Golden Delicious	High
Brown *et al.*	1989	Washer to inspection table	1.4 bruises/fruit		Golden Delicious	High
Brown *et al.*	1989	From field bin to floatation	8	12.8 to 19	Golden Delicious/late	High
Nel	1980	Brushes	9.87	< 1 cm^2	Golden Delicious	High
Nel	1980	Sorting Table (dry)	39.75	< 1 cm^2	Golden Delicious	High
Nel	1980	Sorting Table (dry)	53	< 1 cm^2	Golden Delicious	High
Nel	1980	Sorting table (wet)	11.1	< 1 cm^2	Golden Delicious	High
NZAPMB	1991	Sorting table/singulator	5.3	< 1 cm^2	Gala	Medium/High
Brown *et al.*	1989	Table to singulator	2 bruises/fruit		Golden Delicious	High
Nel	1980	Singulator (dry)	25.34	< 1 cm^2	Golden Delicious	High
Nel	1980	Singulator (dry)	11.7	< 1 cm2	Golden Delicious	High
Nel	1980	Singulator (wet)	5.7	< 1 cm^2	Golden Delicious	High
NZAPMB	1991	Singulator/grader	19	< 1 cm^2	Gala	Medium/High
Brown *et al.*	1989	Singulator to chute drop	1.8 bruises/fruit		Golden Delicious	High
Banks et al.	1993	Sorting to packing bin	36	< 1 cm^2	Splendour	High
Brown *et al.*	1989	Tray pack table	14.7	< 1 cm^2	Golden Delicious	High
NZAPMB	1991	Grader/chute drop	2.4	< 1 cm^2	Gala	Medium/High
NZAPMB	1991	Size bin	26.6	< 1 cm^2	Gala	Medium/High
Brown *et al.*	1989	Packing table	1 bruise/fruit		Golden Delicious	High
Nel	1980	Packing bin - palletisation	4.3	< 1 cm^2	Golden Delicious	High
Nel	1980	Packing bin - palletisation	4.51	< 1 cm^2	Golden Delicious	High
Nel	1980	Packing bin - palletisation	3.4	< 1 cm^2	Golden Delicious	High
Nel	1980	Glue machine	1.18	< 1 cm^2	Golden Delicious	High
Nel	1980	Palletisation	3.06	< 1 cm^2	Golden Delicious	High
Bartram *et al.*	1983	Total packing line	14	< 1 cm^2	Golden Delicious	High
Brown *et al.*	1989	Floating tank to end of line	9 to 13	< 1 cm^2	Golden Delicious	High
NZAPMB	1991	Total packing line	30.5	< 1 cm^2	Gala	Medium/High
Brown *et al.*	1989	Packing line	3	12.8 to 19	Golden Delicious/early	High
Brown *et al.*	1989	Packing line	5	12.8 to 19	Golden Delicious/late	High
Guyer *et at.*	1990	Grading line	5.5 bruises/fruit	< 6.1	All apples	
Banks *et al.*	1993	Grading operation	40		All apples	
Barker	1996	All operations	2.5	< 1 cm^2	All apples	

[1] Bruise susceptibility ranking determined by author

Appendix 1 (continued)

Author	*Published Date*	*Position in Handling Chain*	*Incidence of Bruising (%)*	*Size of bruise*	*Variety of apple (if known)*	*Bruise Susceptibility*[1]
			Shipping			
Guyer *et at.*	1990	Shipping	.5 bruises/fruit	< 6.1	All apples	
Cosby *et al.*	1983	Shipped to markets in Europe	10		All apples	
			Industry Costs and other			
Bollen cites Banks	1993	New Zealand industry	$16 million		All apples	
Banks *et al.*	1993	Industry bruising	$25 million			
Orchardist Anon	1991	Industry bruising	$6-10 million		Granny Smith	High
Orchardist Anon	1991	Hawkes Bay	12.5		All apples	
Banks *et al.*	1993	Other causes	20		All apples	

[1] Bruise susceptibility ranking determined by author

Appendix 2 Calculation of the total cost of bruising.

Total cost of producing the bruised TCEs in the case studies was found by;

1. [Bruised Rate (%) x Reject Rate (%)] x Total Production (TCE)
   ⇒ Bruised Fruit (TCE)
   where
   [Bruised Rate (%) x Reject Rate (%)] = Total Percentage of Crop Bruising (%)

2. Bruised Fruit (TCE) x Accumulated Production Cost at Packing ($/TCE)
   ⇒ Production cost of Bruised Fruit ($)

3. Bruised Fruit (TCE) x ENZA Payment for Variety ($/TCE)
   ⇒Opportunity cost ($)

4. Production Cost of Bruised Fruit ($) + Opportunity Cost ($)
   ⇒ Total of Bruised Fruit ($)

5. Net Packout (TCE) x ENZA Payment for Variety ($/TCE)
   ⇒ Export Income for Variety ($)

6. (Total Cost of Bruised Fruit ($) ÷ Export Income for Variety) x 100
   ⇒ Total percentage of Total Cost of Bruised Fruit to Export Income (%)

7. Total percentage of Total Cost of Bruised Fruit to Export Income (%) ÷ Total Percentage of Crop Bruising (%)
   ⇒ Percentage of Total Cost per 1% of Bruising (%)

Appendix 3 Hypothetical Orchard example for total cost where fruit is transported off the orchard to a commercial packhouse.

Assumptions

Variety	Braeburn	Production per ha	3500 TCE
Packout rate	64%	Reject rate	36%
Payout per TCE	$11.80	Crop bruising	10%
Accelerated cost of production from Growing to Packing			$11.52/TCE

1. Bruised Fruit:

   [10% x 36%] x 3500 TCE = 126 TCE

   where Total Crop Bruising is 10% x 36% = 3.6%

2. Production Cost of Bruised Fruit:

   126 TCE x $11.52/TCE =$1451.52

3. Opportunity Cost:

   126 TCE x $11.80 = $1486.80

4. Total Cost of Bruised Fruit:

   $1451.52 + $1486.80 = $2938.32

5. Export Income:

   [64% x 3500 TCE] x $11.80 = $26,432.00

6. Total percentage of Total Cost of Bruised Fruit to Export Income:

   [$2938.32 ÷ $26,432.00] x 100 = 11.16%

7. Percentage of Total Cost per 1% of Bruising:

11.16% ÷ 3.60% = 3.10%

Table 1 - Accumulated production costs per TCE as meet by each orchard.

Operation	Braeburn				Fuji				Granny Smith		Pacific Rose^{TM}	
	Orchard One	Orchard Two	Average of One & Two	Orchard Three	Orchard One	Orchard Two	Average of One & Two	Orchard Three	Orchard One	Orchard Three	Orchard Two	Orchard Three
Growing	6.84	7.00	6.92	10.32	6.84	7.00	6.92	10.32	6.84	10.32	7.00	10.32
Harvesting	8.04	8.13	8.08	12.39	7.94	8.27	8.10	14.45	7.84	11.44	8.27	16.99
Harvesting support	8.32	8.39	8.35	-	8.19	8.56	8.37	-	8.07	-	8.56	-
Transport bins to packhouse	8.47	8.55	8.51	-	8.35	8.71	8.53	-	8.23	-	8.71	-
Drenching	8.50	8.57	8.54	12.57	-	-	-	-	-	-	-	-
Packing	11.48	11.55	11.52	14.90	11.33	11.69	11.51	16.79	11.21	13.89	11.69	19.56
Transport to coolstore	11.60	11.67	11.64	-	11.45	11.81	11.63	-	11.33	-	11.81	-
Coolstorage	13.23	13.31	13.27	16.53	13.08	13.45	13.27	18.42	12.96	15.52	13.45	21.19
Transport to port	13.37	13.44	13.40	16.67	13.22	13.58	13.40	18.55	13.10	15.65	13.58	21.32
ENZA levy	13.57	13.64	13.60	16.87	13.42	13.78	13.60	18.75	13.30	15.85	13.78	21.52

Table 2 - Individual production costs for the various stages in the apple handling system for each orchard.

Operation	Braeburn				Fuji				Granny Smith		Pacific Rose^{TM}	
	Orchard One	Orchard Two	Average of One & Two	Orchard Three	Orchard One	Orchard Two	Average of One & Two	Orchard Three	Orchard One	Orchard Three	Orchard Two	Orchard Three
Growing	6.84	7.00	6.92	10.32	6.84	7.00	6.92	10.32	6.84	10.32	7.00	10.32
Harvesting	1.20	1.13	1.16	2.07	1.10	1.27	1.18	4.13	1.00	1.12	1.27	6.67
Harvesting support	0.28	0.26	0.27	-	0.25	0.29	0.27	-	0.23	-	0.29	-
Transport bins to packhouse	0.16	0.16	0.16	-	0.16	0.16	0.16	-	0.16	-	0.16	-
Drenching	0.03	0.03	0.03	0.18	-	-	-	-	-	-	-	-
Packing	2.98	2.98	2.98	2.33	2.98	2.98	2.98	2.33	2.98	2.45	2.98	2.57
Transport to coolstore	0.12	0.12	0.12	-	0.12	0.12	0.12	-	0.12	-	0.12	-
Coolstorage	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63
Transport to port	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
ENZA levy	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Total	13.57	13.64	13.60	16.87	13.42	13.78	13.60	18.75	13.30	15.85	13.78	21.52

Appendix 5 Calculated value of fruit as it passes through the value system per TCE.

Operation	Braeburn			Fuji			Granny Smith		Pacific Rose™	
	Orchard One	Orchard Two	Orchard Three	Orchard One	Orchard Two	Orchard Three	Orchard One	Orchard Three	Orchard Two	Orchard Three
Growing	7.16	7.25	7.22	9.31	9.11	7.33	5.03	5.83	15.31	10.76
Harvesting	8.36	8.37	9.29	10.41	10.37	11.47	6.03	6.95	16.57	17.43
Harvesting support	8.63	8.63		10.66	10.66		6.26		16.86	
Transport bins to packhouse	8.79	8.79		10.82	10.82		6.42		17.02	
Drenching	8.82	8.82	9.47							
Packing	11.80	11.80	11.80	13.80	13.80	13.80	9.40	9.40	20.00	20.00
Transport to coolstore	11.92	11.92		13.92	13.92		9.52		20.12	
Coolstorage	13.55	13.55	13.43	15.55	15.55	15.43	11.15	11.03	21.75	21.63
Transport to port	13.69	13.69	13.56	15.69	15.69	15.56	11.29	11.16	21.89	21.76
ENZA levy	13.89	13.89	13.76	15.89	15.89	15.76	11.49	11.36	22.09	21.96

Appendix 6a The total cost of bruising per TCE ($/TCE) for Orchard One and Orchard Two at a particular point in the handling system.

Orchard One and Orchard Two

Braeburn

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing
1%	0.19	0.20	0.20	0.20	0.20	0.23
2%	0.37	0.40	0.40	0.41	0.41	0.47
3%	0.56	0.60	0.60	0.61	0.61	0.70
4%	0.75	0.80	0.81	0.81	0.81	0.93
5%	0.94	0.99	1.01	1.02	1.02	1.17
10%	1.87	1.99	2.02	2.03	2.03	2.33
15%	2.81	2.98	3.02	3.05	3.05	3.50
20%	3.74	3.98	4.03	4.06	4.07	4.66
25%	4.68	4.97	5.04	5.08	5.08	5.83
30%	5.62	5.97	6.05	6.09	6.10	7.00
35%	6.55	6.96	7.05	7.11	7.12	8.16
40%	7.49	7.95	8.06	8.12	8.14	9.33

Orchard One and Orchard Two

Fuji

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing
1%	0.21	0.22	0.22	0.22		0.25
2%	0.41	0.44	0.44	0.45		0.51
3%	0.62	0.66	0.67	0.67		0.76
4%	0.83	0.88	0.89	0.89		1.01
5%	1.04	1.10	1.11	1.12		1.27
10%	2.07	2.19	2.22	2.23		2.53
15%	3.11	3.29	3.33	3.35		3.80
20%	4.14	4.38	4.43	4.47		5.06
25%	5.18	5.48	5.54	5.58		6.33
30%	6.22	6.57	6.65	6.70		7.59
35%	7.25	7.67	7.76	7.82		8.86
40%	8.29	8.76	8.87	8.93		10.13

Orchard One

Granny Smith

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing
1%	0.16	0.17	0.17	0.18		0.21
2%	0.32	0.34	0.35	0.35		0.41
3%	0.49	0.52	0.52	0.53		0.62
4%	0.65	0.69	0.70	0.71		0.82
5%	0.81	0.86	0.87	0.88		1.03
10%	1.62	1.72	1.75	1.76		2.06
15%	2.44	2.59	2.62	2.64		3.09
20%	3.25	3.45	3.49	3.53		4.12
25%	4.06	4.31	4.37	4.41		5.15
30%	4.87	5.17	5.24	5.29		6.18
35%	5.68	6.03	6.11	6.17		7.21
40%	6.50	6.90	6.99	7.05		8.24

Orchard Two

Pacific Rose™

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing
1%	0.27	0.28	0.29	0.29		0.32
2%	0.54	0.57	0.57	0.57		0.63
3%	0.81	0.85	0.86	0.86		0.95
4%	1.08	1.13	1.14	1.15		1.27
5%	1.35	1.41	1.43	1.44		1.58
10%	2.70	2.83	2.86	2.87		3.17
15%	4.05	4.24	4.28	4.31		4.75
20%	5.40	5.65	5.71	5.74		6.34
25%	6.75	7.07	7.14	7.18		7.92
30%	8.10	8.48	8.57	8.61		9.51
35%	9.45	9.89	9.99	10.05		11.09
40%	10.80	11.31	11.42	11.49		12.68

Appendix 6b The total cost of bruising per TCE ($/TCE) for Orchard Three at a particular point in the handling system.

Orchard Three

Braeburn						
Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing
1%	0.22	0.24			0.24	0.27
2%	0.44	0.48			0.49	0.53
3%	0.66	0.73			0.73	0.80
4%	0.88	0.97			0.97	1.07
5%	1.11	1.21			1.22	1.34
10%	2.21	2.42			2.44	2.67
15%	3.32	3.63			3.66	4.01
20%	4.42	4.84			4.87	5.34
25%	5.53	6.05			6.09	6.68
30%	6.64	7.26			7.31	8.01
35%	7.74	8.47			8.53	9.35
40%	8.85	9.68			9.75	10.68

Orchard Three

Fuji						
Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing
1%	0.24	0.28				0.31
2%	0.48	0.57				0.61
3%	0.72	0.85				0.92
4%	0.96	1.13				1.22
5%	1.21	1.41				1.53
10%	2.41	2.83				3.06
15%	3.62	4.24				4.59
20%	4.82	5.65				6.12
25%	6.03	7.06				7.65
30%	7.24	8.48				9.18
35%	8.44	9.89				10.71
40%	9.65	11.30				12.23

Orchard Three

Granny Smith						
Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing
1%	0.20	0.21				0.23
2%	0.39	0.42				0.47
3%	0.59	0.63				0.70
4%	0.79	0.83				0.93
5%	0.99	1.04				1.16
10%	1.97	2.08				2.33
15%	2.96	3.13				3.49
20%	3.94	4.17				4.66
25%	4.93	5.21				5.82
30%	5.92	6.25				6.99
35%	6.90	7.29				8.15
40%	7.89	8.34				9.32

Orchard Three

Pacific Rose™						
Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing
1%	0.30	0.37				0.40
2%	0.61	0.74				0.79
3%	0.91	1.11				1.19
4%	1.21	1.48				1.58
5%	1.52	1.85				1.98
10%	3.03	3.70				3.96
15%	4.55	5.55				5.93
20%	6.06	7.40				7.91
25%	7.58	9.25				9.89
30%	9.10	11.10				11.87
35%	10.61	12.95				13.85
40%	12.13	14.80				15.82

Appendix 7a The loss in value attributable to bruising for Braeburn per TCE, as it passes through the value system, for varying bruise percentages.

Orchard One

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.07	0.08	0.09	0.09	0.09	0.12	0.12	0.14	0.14
2%	0.14	0.17	0.17	0.18	0.18	0.24	0.24	0.27	0.27
3%	0.21	0.25	0.26	0.26	0.26	0.35	0.36	0.41	0.41
4%	0.29	0.33	0.35	0.35	0.35	0.47	0.48	0.54	0.55
5%	0.36	0.42	0.43	0.44	0.44	0.59	0.60	0.68	0.68
10%	0.72	0.84	0.86	0.88	0.88	1.18	1.19	1.36	1.37
15%	1.07	1.25	1.30	1.32	1.32	1.77	1.79	2.03	2.05
20%	1.43	1.67	1.73	1.76	1.76	2.36	2.38	2.71	2.74
25%	1.79	2.09	2.16	2.20	2.21	2.95	2.98	3.39	3.42
30%	2.15	2.51	2.59	2.64	2.65	3.54	3.58	4.07	4.11
35%	2.51	2.93	3.02	3.08	3.09	4.13	4.17	4.74	4.79
40%	2.86	3.34	3.45	3.52	3.53	4.72	4.77	5.42	5.47

Orchard Two

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.07	0.08	0.09	0.09	0.09	0.12	0.12	0.14	0.14
2%	0.14	0.17	0.17	0.18	0.18	0.24	0.24	0.27	0.27
3%	0.22	0.25	0.26	0.26	0.26	0.35	0.36	0.41	0.41
4%	0.29	0.33	0.35	0.35	0.35	0.47	0.48	0.54	0.55
5%	0.36	0.42	0.43	0.44	0.44	0.59	0.60	0.68	0.68
10%	0.72	0.84	0.86	0.88	0.88	1.18	1.19	1.36	1.37
15%	1.09	1.26	1.30	1.32	1.32	1.77	1.79	2.03	2.05
20%	1.45	1.67	1.73	1.76	1.76	2.36	2.38	2.71	2.74
25%	1.81	2.09	2.16	2.20	2.21	2.95	2.98	3.39	3.42
30%	2.17	2.51	2.59	2.64	2.65	3.54	3.58	4.07	4.11
35%	2.54	2.93	3.02	3.08	3.09	4.13	4.17	4.74	4.79
40%	2.90	3.35	3.45	3.52	3.53	4.72	4.77	5.42	5.47

Average of Orchard One and Orchard Two

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.07	0.08	0.09	0.09	0.09	0.12	0.12	0.14	0.14
2%	0.14	0.17	0.17	0.18	0.18	0.24	0.24	0.27	0.27
3%	0.22	0.25	0.26	0.26	0.26	0.35	0.36	0.41	0.41
4%	0.29	0.33	0.35	0.35	0.35	0.47	0.48	0.54	0.55
5%	0.36	0.42	0.43	0.44	0.44	0.59	0.60	0.68	0.68
10%	0.72	0.84	0.86	0.88	0.88	1.18	1.19	1.36	1.37
15%	1.08	1.26	1.30	1.32	1.32	1.77	1.79	2.03	2.05
20%	1.44	1.67	1.73	1.76	1.76	2.36	2.38	2.71	2.74
25%	1.80	2.09	2.16	2.20	2.21	2.95	2.98	3.39	3.42
30%	2.16	2.51	2.59	2.64	2.65	3.54	3.58	4.07	4.11
35%	2.52	2.93	3.02	3.08	3.09	4.13	4.17	4.74	4.79
40%	2.88	3.35	3.45	3.52	3.53	4.72	4.77	5.42	5.47

Orchard Three

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.07	0.09			0.09	0.12		0.13	0.14
2%	0.14	0.19			0.19	0.24		0.27	0.27
3%	0.22	0.28			0.28	0.35		0.40	0.41
4%	0.29	0.37			0.38	0.47		0.54	0.54
5%	0.36	0.46			0.47	0.59		0.67	0.68
10%	0.72	0.93			0.95	1.18		1.34	1.36
15%	1.08	1.39			1.42	1.77		2.01	2.03
20%	1.44	1.86			1.89	2.36		2.69	2.71
25%	1.80	2.32			2.37	2.95		3.36	3.39
30%	2.16	2.79			2.84	3.54		4.03	4.07
35%	2.53	3.25			3.31	4.13		4.70	4.75
40%	2.89	3.71			3.79	4.72		5.37	5.43

Appendix 7b The loss in value attributable to bruising for Fuji per TCE, as it passes through the value system, for varying bruise percentages.

Orchard One

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport Bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.09	0.10	0.11	0.11		0.14	0.14	0.16	0.16
2%	0.19	0.21	0.21	0.22		0.28	0.28	0.31	0.31
3%	0.28	0.31	0.32	0.32		0.41	0.42	0.47	0.47
4%	0.37	0.42	0.43	0.43		0.55	0.56	0.62	0.63
5%	0.47	0.52	0.53	0.54		0.69	0.70	0.78	0.78
10%	0.93	1.04	1.07	1.08		1.38	1.39	1.56	1.57
15%	1.40	1.56	1.60	1.62		2.07	2.09	2.33	2.35
20%	1.86	2.08	2.13	2.16		2.76	2.78	3.11	3.14
25%	2.33	2.60	2.67	2.71		3.45	3.48	3.89	3.92
30%	2.79	3.12	3.20	3.25		4.14	4.18	4.67	4.71
35%	3.26	3.64	3.73	3.79		4.83	4.87	5.44	5.49
40%	3.72	4.16	4.26	4.33		5.52	5.57	6.22	6.27

Orchard Two

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport Bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.09	0.10	0.11	0.11		0.14	0.14	0.16	0.16
2%	0.18	0.21	0.21	0.22		0.28	0.28	0.31	0.31
3%	0.27	0.31	0.32	0.32		0.41	0.42	0.47	0.47
4%	0.36	0.41	0.43	0.43		0.55	0.56	0.62	0.63
5%	0.46	0.52	0.53	0.54		0.69	0.70	0.78	0.78
10%	0.91	1.04	1.07	1.08		1.38	1.39	1.56	1.57
15%	1.37	1.56	1.60	1.62		2.07	2.09	2.33	2.35
20%	1.82	2.07	2.13	2.16		2.76	2.78	3.11	3.14
25%	2.28	2.59	2.67	2.71		3.45	3.48	3.89	3.92
30%	2.73	3.11	3.20	3.25		4.14	4.18	4.67	4.71
35%	3.19	3.63	3.73	3.79		4.83	4.87	5.44	5.49
40%	3.64	4.15	4.26	4.33		5.52	5.57	6.22	6.27

Average of Orchard One and Two

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport Bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.09	0.10	0.11	0.11		0.14	0.14	0.16	0.16
2%	0.18	0.21	0.21	0.22		0.28	0.28	0.31	0.31
3%	0.28	0.31	0.32	0.32		0.41	0.42	0.47	0.47
4%	0.37	0.42	0.43	0.43		0.55	0.56	0.62	0.63
5%	0.46	0.52	0.53	0.54		0.69	0.70	0.78	0.78
10%	0.92	1.04	1.07	1.08		1.38	1.39	1.56	1.57
15%	1.38	1.56	1.60	1.62		2.07	2.09	2.33	2.35
20%	1.84	2.08	2.13	2.16		2.76	2.78	3.11	3.14
25%	2.30	2.60	2.67	2.71		3.45	3.48	3.89	3.92
30%	2.76	3.12	3.20	3.25		4.14	4.18	4.67	4.71
35%	3.22	3.64	3.73	3.79		4.83	4.87	5.44	5.49
40%	3.68	4.16	4.26	4.33		5.52	5.57	6.22	6.27

Orchard Three

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport Bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.07	0.11				0.14		0.15	0.16
2%	0.15	0.23				0.28		0.31	0.31
3%	0.22	0.34				0.41		0.46	0.47
4%	0.29	0.46				0.55		0.62	0.62
5%	0.37	0.57				0.69		0.77	0.78
10%	0.73	1.15				1.38		1.54	1.56
15%	1.10	1.72				2.07		2.31	2.33
20%	1.47	2.29				2.76		3.09	3.11
25%	1.83	2.87				3.45		3.86	3.89
30%	2.20	3.44				4.14		4.63	4.67
35%	2.57	4.01				4.83		5.40	5.45
40%	2.93	4.59				5.52		6.17	6.23

Appendix 7c The loss in value attributable to bruising for Granny Smith per TCE, as it passes through the value system, for varying bruise percentages.

Orchard One

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.05	0.06	0.06	0.06		0.09	0.10	0.11	0.11
2%	0.10	0.12	0.13	0.13		0.19	0.19	0.22	0.23
3%	0.15	0.18	0.19	0.19		0.28	0.29	0.33	0.34
4%	0.20	0.24	0.25	0.26		0.38	0.38	0.45	0.45
5%	0.25	0.30	0.31	0.32		0.47	0.48	0.56	0.56
10%	0.50	0.60	0.63	0.64		0.94	0.95	1.12	1.13
15%	0.75	0.90	0.94	0.96		1.41	1.43	1.67	1.69
20%	1.01	1.21	1.25	1.28		1.88	1.90	2.23	2.26
25%	1.26	1.51	1.57	1.61		2.35	2.38	2.79	2.82
30%	1.51	1.81	1.88	1.93		2.82	2.86	3.35	3.39
35%	1.76	2.11	2.19	2.25		3.29	3.33	3.90	3.95
40%	2.01	2.41	2.50	2.57		3.76	3.81	4.46	4.51

Orchard Three

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.06	0.07				0.09		0.11	0.11
2%	0.12	0.14				0.19		0.22	0.22
3%	0.17	0.21				0.28		0.33	0.33
4%	0.23	0.28				0.38		0.44	0.45
5%	0.29	0.35				0.47		0.55	0.56
10%	0.58	0.70				0.94		1.10	1.12
15%	0.87	1.04				1.41		1.65	1.67
20%	1.17	1.39				1.88		2.21	2.23
25%	1.46	1.74				2.35		2.76	2.79
30%	1.75	2.09				2.82		3.31	3.35
35%	2.04	2.43				3.29		3.86	3.91
40%	2.33	2.78				3.76		4.41	4.47

Appendix 7d The loss in value attributable to bruising for Pacific Rose™ per TCE, as it passes through the value system, for varying bruise percentages.

Orchard Two

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.15	0.17	0.17	0.17		0.20	0.20	0.22	0.22
2%	0.31	0.33	0.34	0.34		0.40	0.40	0.44	0.44
3%	0.46	0.50	0.51	0.51		0.60	0.60	0.65	0.66
4%	0.61	0.66	0.67	0.68		0.80	0.80	0.87	0.88
5%	0.77	0.83	0.84	0.85		1.00	1.01	1.09	1.09
10%	1.53	1.66	1.69	1.70		2.00	2.01	2.18	2.19
15%	2.30	2.49	2.53	2.55		3.00	3.02	3.26	3.28
20%	3.06	3.31	3.37	3.40		4.00	4.02	4.35	4.38
25%	3.83	4.14	4.22	4.26		5.00	5.03	5.44	5.47
30%	4.59	4.97	5.06	5.11		6.00	6.04	6.53	6.57
35%	5.36	5.80	5.90	5.96		7.00	7.04	7.61	7.66
40%	6.12	6.63	6.74	6.81		8.00	8.05	8.70	8.75

Orchard Three

Bruising Percentage	Growing	Harvesting	Harvesting support	Transport bins to packhouse	Drenching	Packing	Transport to coolstore	Coolstorage	Transport to port
1%	0.11	0.17				0.20		0.22	0.22
2%	0.22	0.35				0.40		0.43	0.44
3%	0.32	0.52				0.60		0.65	0.65
4%	0.43	0.70				0.80		0.87	0.87
5%	0.54	0.87				1.00		1.08	1.09
10%	1.08	1.74				2.00		2.16	2.18
15%	1.61	2.61				3.00		3.24	3.26
20%	2.15	3.49				4.00		4.33	4.35
25%	2.69	4.36				5.00		5.41	5.44
30%	3.23	5.23				6.00		6.49	6.53
35%	3.77	6.10				7.00		7.57	7.62
40%	4.30	6.97				8.00		8.65	8.71